No.

FINAL REPORT

ON

PREPARATORY SURVEY

ON

THE PHOTOVOLTAIC POWER PLANT PROJECT

IN

THE ARAB REPUBLIC OF EGYPT

DECEMBER, 2012

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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Abbreviations and Acronyms

Organization

AFD	Agence Francaise de Developpment
AfDB	Africa Development bank
CDM EB	CDM Executive Board
CEDC	Canal Electricity Distribution Company
DAC	Development Assistance Committee
DANIDA	Danish International Development Agency
DNA	Designated National Authority
EC	European Community
ECX	European Climate Exchange
EDC	Electric Distribution Company
EEA	Egyptian Electric Authority
EEAA	Egyptian Environmental Affairs Agency
EEHC	Egyptian Electricity Holding Company
EETC	Egyptian Electricity Transmission Company
EgyptERA	Egyptian Electric Utility and Consumer Protection Regulatory Agency
EIB	European Investment Bank
EMA	Egyptian Meteorological Authority
ENAA	Engineering Advancement Association of Japan
EU	Europe Union
FIDIC	Federation International des Ingenieurs-Conseils
GEF	Global Environment Facility
GoE	Government of Egypt
GoJ	Government of Japan
HMO	Hurghada Meteorological Observatory
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IEC	International Electrotechnical Commission
IPCC	Intergovernmental Panel on Climate Change
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
KfW	Kreditanstalt für Wiederaufbau, meaning Reconstruction Credit Institute
KSA	Kingdom of Saudi-Arabia
METI	Ministry of Economy, Trade and Industry
MOEE	Ministry of Electricity and Energy
MOIC	Ministry of International Cooperation
MSEA	Ministry of State for Environmental Affairs
NASA	National Aeronautics and Space Administration
NECC	National Energy Control Center
NEDO	New Energy and Industrial Technology Development Organization
NGO	Non-Governmental Organization
NREA	New and Renewable Energy authority

OECD	Organisation for Economic Co-operation and Development
RCC	Regeional Control Center
REA	Rural Electrification Authority
UNFCCC	United Nations Framework Convention on Climate Change
USA	The United States of America
WB	World Bank

Others

AAT	Accelerating Aging Test
AC	Alternating Current
AEG	Annual Electricity Generation
B/C	Benefit and Cost
BE	Baseline Emission
BM	Build Margin
BOO	Built-Operation-Own
BOOT	Built-Operation-Own-Transfer
CB	Circuit Breaker
CC	Combined Cycle
CCL	Climate Change Japanese ODA Loan
CDM	Clean Development Mechanism
CdTe	Cadmium telluride
CEO	Chief Executive Officer
CERs	Certified Emission Reductions
CIF	Cost Insurance and Freight
CI(G)S	Copper Indium (Gallium) DiSelenide
CM	Combined Margin
CO	Carbon monoxide
CO2	Carbon dioxide
CSP	Concentrate Solar Power
CT	Current Transformer
CTF	Clean Technology Fund
DC	Direct Current
DfR	Draft Final Report
DL	Distribution Line
DOE	Department of Energy
DP	Distribution Point
EB	Executive Board
EHV	Extra High Voltage (220kV and 500kV)
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
E/N	Exchange of Note
EPC	Engineering, Procurement and Construction
ES	Earthing Switch

ESIA	Environmental and Social Impact Assessment
ETS	Emission trading System
FAC	Final Acceptance Certificate
FAPA	Fund for African Private-Sector Assistance
F/C	Foreign Currency
FIRR	Financial Internal Rate of Return
FIT	Feed in Tariff
FR	Final Report
F/S	Feasibility Study
FS	Factor of Safety
GDP	Gross Domestic Product
GHG	Green House Gas
GPRS	General Packet Radio Service
GPS	Global Positioning System
GT	Gas Turbine
GTO	Gate Turn-Off
Hp	Homepage
HV	High Voltage (132kV, 66kV and 33kV)
ICB	International Competitive Bidding
ICR	Inception Report
IDC	Interest During Construction
IGBT	Insulated Gate Bipolar Transistor
IPP	Independent Power Producer
IRR	Internal Rate of Return
ITR	Interim Report
JIS	Japanese Industrial Standards
JPY	Japanese Yen
L/A	Loan Agreement
LA	Lightning Arrester
LBS	Load Break Switch
L/C	Local Currency
LE	Egyptian Pound
LL	Load Leveling
LFO	Light Fuel Oil
LOLE	Loss of Load Expectation
LV	Low Voltage (220V,380V)
MDB	Main Distribution Board
MLTF	Multi-Layer Thin Film
MPPT	Maximum Power Point Tracking
MV	Medium Voltage（11kV,22kV）
M/M	Man/Month
NAS	Sodium-sulfur
NC	Normal Close
NCV	Net Calorific Value

NG	Natural Gas
NIF	Neighborhood Investment Funds
NO	Normal Open
NPV	Net Present Values
O&M	Operation and Maintenance
ODA	Official Development Assistance
OJT	On the Job Training
OM	Operating Margin
PC	Personal Computer
PCS	Power Conditioning System
PDD	Project Design Document
PDP	Power Development Plan
PIN	Project Idea Note
PIU	Project Implementation Unit
PLC	Programmable Logic Controller
PMU	Project Management Unit
POA	Program of Activities
PPA	Power Purchase Agreement
ppm	parts per million
PQ	Pre-Qualification
P.U.	Per Unit
PV	Photovoltaic
R&D	Research and Development
RoHS	Restriction of Hazardous Substances
S/S	Substation
SAPROF	Special Assistance for Project Formation
SCADA	Supervisory Control And Data Acquisition
SCF	Standard Conversion Factors
ST	Steam Turbine
STEP	Special Terms for Economic Partnership
SWGR	Switchgear
TDP	Transmission Development Plan
3G	3rd Generation
TOAC	Taking Over and Acceptance Certificate
TOR	Terms of Reference
Tr	Transformer
T/L	Transmission Line
UG	Under Ground
UPS	Unified Power System
UPS	Uninterrupted Power Supply
USD	US Dollar
VAT	Value Added Tax
VCB	Vacuum Circuit Breaker

VHV	Very High Voltage (220kV)
VT	Voltage Transformer
XLPE	Cross-Linked Poly-Ethylene
ZCT	Zero phase Current Transformer

Currency Equivalents

Currency unit = Egyptian Pound (LE)

1 LE = 100 piasters (pt)

Exchange rate : US$1.00 = LE 6.03 (Apr. 2012) provided by JICA

Fiscal year： July 1 to June 30

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1. Executive Summary

1) General

This study has been carried out from December 2010 to December 2012 in order to formulate Japanese ODA (Official Development Assistance) Yen Loan project for 20MW Photovoltaic (PV) Power Plant Project in Hurghada along with conducting solar radiation measurement in conjunction with identifying the situation of Egyptian power sector and the policy of renewable energy development, etc.

Owing to Egyptian Authorities such as NREA(New and Renewable Energy Authority), EEHC(Egyptian Electricity Holding Company), EETC(Egyptian Electricity Transmission Company), CEDC (Canal Electricity Distribution Company), EgyptERA(Egyptian Electric Utility and Consumer Protection Regulatory Agency) and EEAA(Egyptian Environmental Affairs Authority) with Egyptian consulting firms (Egyptrol and Environics) as well as specialists' tremendous support to the Study Team, the Study Report was prepared with mutually agreeable contents for both Egyptian side and Japanese side.

Accordingly, the Study Team believed that this Study Report is useful and contributing to enhance the relationship between Japan and Egypt for providing ODA Yen Loan.

The content for each topic is summarized as below.

2) Power Sector in Egypt

- Egyptian electricity power sector has been unbundled to generation, transmission and distribution sectors. NREA is established as the authority entrusted by promoting & developing new and renewable energy under Ministry of Electricity and Energy (MoEE).
- Peak Demand in Egyptian electricity power sector has been increased and reached approx. 25,700 MW in 2011/12 with average annual growth rate of approx. 7% for the last decade. In line with the power demand, generation facilities have been developed and reached approx. 27,000 MW installed capacity in total in 2011/12 in association with transmission and distribution network expansion.
- Since about 80% of the generation facilities are thermal power plants and they need to use lots of fuel for generation, the Supreme Council of Energy in Egypt has adopted a resolution to cover 20% of electricity generation with renewable energy by 2020, assuming a 12% contribution from wind energy, 5% from hydro and remaining are from solar which is consisting of solar thermal power plants and PV (photovoltaic)

power plants.

- NREA has developed CSP (Concentrated Solar Power) type of power plant integration with combined cycle gas turbine in Kuraymat which capacity is 140MW in total and is struggling to expand other CSP type and PV power plant projects.
- This 20MW PV power plant project in Hurghada is planned to be the first largest PV power plant project in Egypt, then GoE (Government of Egypt) and NREA is expecting to have sophisticated and advanced technical and financial support in order to implement/realize this project very soon.

3) Outline of the Project

- This project site is located in the existing Hurghada Wind Farm site (this implies no problem for land procurement) in northern part of Hurghada city along Hurghada – Ras Gharib road. There are several wind turbines and observatory facilities in the site but vacant space is enough for providing 20MW or more PV power plant. Since the existing wind farm is still in operation, electricity facilities called D/P (Distribution Point) is available at the site and it can be used for evacuating the generated power from the wind farm as well as expected PV power plant.
- Annual average Global Solar Radiation at Hurghada (data obtained from Methodological Authority in Egypt) is approx. 6.20 kWh/m2/day which is very high comparing with some PV power plants in Japan whose average radiation is approx. 3.84 kWh/m2/day. In order to obtain the solar radiation data at the site, which shall be compared with the data from Methodological Authority and other available data such NASA, Egypt Solar Atlas as well as analyzing dust effect to the PV modules at the site, the measurement system has been installed by JICA and one year measurement has been done by the Study Team. After one year measurement, the measurement facilities have been transferred from JICA to NREA. From the measurement, the following unique results were obtained:
  - ✓ The temperature gap between air temperature and that of PV module surface is relatively lower than expected one due to wind effect since the site is relatively high wind area and almost all the time wind is blowing.
  - ✓ From the measurements and comparison of two panels for a year; one for remaining as it is (without cleaning), and the other is with periodical cleaning (cleaning), and dust effect can be found as shown in Fig. EX-2 and table EX-1 below where around 7 % generation reduction was observed for 1 month, thus the Study Team recommended at least one month interval for the PV module cleaning. Further, from the measurement, it is found that during spring season, sand storms create high level of sand accumulation (dust effect) on the PV module. Then special treatment (cleaning) after the sand storms are also recommended.

- ✓ For solar radiation, it is found that data of the Methodological Authority and the measured one is very similar.

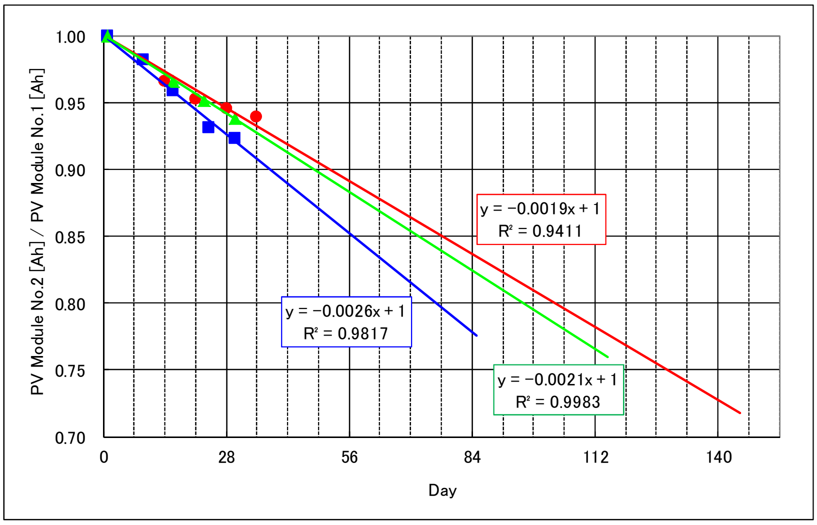


Fig. EX-1 Dust Effect
Red line: from Oct/2011 - Feb/2012
Blue-line: from Mar/2012 - May/2012
Green-line: from Jun/2012 - Sep/2012

Table EX-1 Dust Effect

Interval	From Oct./2011 to Feb./2012	From Mar./2012 to May/2012	From Jun./2012 to Sep./2012	Average
2 weeks	−3.2%	−3.8%	−2.9%	−3.3%
1 month	−5.7%	−7.8%	−6.3%	−6.6%

- Since several types of PV modules such as Crystal type, Thin Film type and Compound type, etc. are available in the market; suitable type of PV module for this project has been selected taking into account cost, efficiency, temperature characteristic, life type (deterioration ratio), environmental aspect, etc. Thus, the following 3 types of PV module were selected for comparison purpose:
  - ✓ Poly Crystalline type
  - ✓ MLTF (Multi-Layer Thin Film) type
  - ✓ CIS (Copper-Indium-Selenium) type
- Comparison between sun tracking type and fixed type was made, and then cost wisely, fixed type was selected.
- In order to estimate annual energy production of each type of PV module, the following factors were examined and considered:
  - ✓ PV module temperature and its correction coefficient (see Table EX-2)
  - ✓ Dust effect of PV module surface (see Table EX-1)
  - ✓ Deterioration ratio (see Table EX-3)
  - ✓ Other factors such as Inverter efficiency, array matching correction, etc.

Table EX-2 PV module temperature and its correction coefficient

Month		Jun	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Maximum Temperature Coefficient (AP max) %/℃
PV module temperature ℃		30.0	32.4	33.0	39.8	42.5	44.9	45.6	46.8	43.2	38.3	34.6	31.5	
Temperature Correction Coefficient	Poly Crystalline	0.977	0.966	0.963	0.932	0.920	0.908	0.905	0.900	0.916	0.939	0.956	0.970	-0.46
	CIS	0.985	0.977	0.975	0.954	0.946	0.938	0.936	0.932	0.944	0.959	0.970	0.980	-0.31
	MLTF	0.988	0.982	0.981	0.964	0.958	0.952	0.951	0.948	0.956	0.968	0.977	0.984	-0.24

Table EX-3 Deterioration Ratio

Type	Time deterioration
Poly Crystalline	1.0% /year
CIS	0.5% /year
MLTF	1.5% /year (～10years)
	0.0% /year (11～20years)

■ Taking into account the above factors to the measured solar radiation, expected energy production of each PV type for the 1st year and for 20 years is shown in Table EX-4 and Table EX-5 respectively.

Table EX-4 expected energy production of each PV type for 1st year

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Anuual total
Monthly Energy Production (MWh)	Poly Crystalline	2,593	2,629	3,188	3,079	3,121	3,091	3,097	3,084	2,974	2,798	2,638	2,468	34,760
	CIS	2,573	2,620	3,180	3,105	3,162	3,145	3,154	3,148	3,017	2,815	2,638	2,455	35,013
	MLTF	2,622	2,674	3,247	3,187	3,252	3,240	3,252	3,248	3,104	2,885	2,696	2,504	35,910

Table EX-5 expected energy production of each PV type for 20 years

year	Poly Crystalline [MWh/year]	CIS [MWh/year]	Multi Layer (Tandem) [MWh/year]
1	34,760	35,013	35,910
2	34,412	34,838	35,371
3	34,064	34,663	34,832
4	33,716	34,488	34,293
5	33,368	34,313	33,754
6	33,020	34,138	33,215
7	32,672	33,963	32,676
8	32,324	33,788	32,137
9	31,976	33,613	31,598
10	31,628	33,438	31,059
11	31,280	33,263	31,059
12	30,932	33,088	31,059
13	30,584	32,913	31,059
14	30,236	32,738	31,059
15	29,888	32,563	31,059
16	29,540	32,388	31,059
17	29,192	32,213	31,059
18	28,844	32,038	31,059
19	28,496	31,863	31,059
20	28,148	31,688	31,059
Total	629,080	667,010	645,435
Average	31,454	33,351	32,272

- Considering the existing transmission and distribution network systems around the site, the Study Team found several options to connect produced energy from the PV power plant to the network. Among these options, the Study Team selected the connection to the existing D/P at the site due to the following:
  - ✓ Each connection option can be satisfied with required connection regulation such as voltage fluctuation and available transmission power capacity
  - ✓ Cost wise, the selected option is the lowest one
- High performance battery is recommended to be applied to this project due to the following reasons:
  - ✓ Supply generated power from the PV power plant during day time to peak demand at evening and/or any time required.
  - ✓ Reduce voltage fluctuation caused by PV power output fluctuation (increasing and decreasing).
  - ✓ Compensate lack of reactive power.
  - ✓ Ease sharp variance of PV power output / precipitous change of load.
  - ✓ Avoid reverse power flow from the D/P to EETC's substation in Hurghada.

  Considering required capacity (2MW, 12MWh) and availability in the market, the following two types were recommended:
  - ✓ Sodium-Sulfur battery (NAS battery)
  - ✓ Lead battery for Load Leveling (LL battery)

4) Project Scope

- Type of PV module to be used

  Referring to the selected 3 types of PV modules and those energy production, required land area as well as expected project cost, Table EX-6 was made for comparison.

  From the Table EX-6, the Study Team recommended the followings:
  - ✓ Available land is enough for any type of the 3 considered types (approx. 500,000 m^2 or more can be allocated).
  - ✓ Even though the project cost mentioned in the Table is just a reference (the Study Team's expectation based on collected information), the followings are found:
    - MLTF is the lowest in the project cost.
    - CIS is the least in the generation cost.
  - ✓ Cost wise, either MLTF or CIS can be recommended to be selected.

  It should be noted that since large scale commercial use for both MLTF and CIS has stared recently, e.g., 2011-2012, it would be great help to assist in selecting the final type of PV modules during tendering stage, to have more information and data about the performance of these types, particularly data and information about deterioration rate across the life time which might be an issue of concern. Consequently, the three types considered in this study; Poly Crystalline, MLTF and CIS shall be eligible alternatives of selections during tendering stage.

In consideration of the above and in order to determine one certain type of PV module under this study for concrete and clear recommendation, the Study Team assumed that 20 MW for Multi-Layer Thin Film (MLTF) type is suitable for PV modules to be used under this project as a temporary solution. However, this assumption is only for this study and should not be binding to tender requirements to be defined in actual procurement stage later.

Table EX-6 Summary of comparison results among 3 PV types

Type of module	Poly Crystalline	MLTF	CIS
Required land area for 20MW (m2)	330,000	480,000	380,000
Annual energy production for 1st year (MWh)	34,760	35,910	35,013
Average annual energy production for 20 years considering deterioration (a) (MWh)	31,454	32,272	33,351
Project Cost (b) (nominal part only)	74.96Million US$	65.29 Million US$	65.95 Million US$
Generation Cost [(b)/(a)*20]	11.9UScents/kWh	10.1UScents/kWh	9.89UScents/kWh

■ Summary of Project Scope

The Contract for this project is one package for 20MW PV power plant construction project in Hurghada with the followings:

- ✓ Procurement and installation of the following main items:
  - 20 MW PV modules and accessories
  - Electrical equipment such as Inverters (500kVA * 40 units), step-up transformers (400V/22kV, 2MVA, 10 units), switchgears, etc.
  - Electrical equipment for existing D/P
  - High performance battery (2MW, 12MWh)
  - Monitoring systems
  - Exhibition system including sophisticated 3 D and/or 2D screens, etc.
- ✓ Services to be performed during warranty period (for 2 years)
  - Power plant performance verification
  - Verification of deterioration ratio of the installed PV modules
  - End of warranty inspections

- ✓ Services to be performed during O&M period
  - Operation of the PV power plant including monitoring and recording of the performance, faults if any, etc.
  - Maintenance of the PV power plant including cleaning of the PV modules, periodical maintenance for electrical equipment, fixing any problems, etc.
  - Verification of deterioration ratio of the installed PV modules
  - Technology transfer to NREA staffs for O&M techniques
  - Training to NREA staffs for O&M and other aspects
- ✓ Consulting Services

- Project cost is estimated as approx. 112 million USD for the total project cost including project cost, consulting services, owner's administration and others with contingency (5%) and escalations. Among the cost, approx. 68 million USD is expected to be covered by Japanese ODA Yen Loan (This covering amount is depending on discussion between NREA and JICA. If STEP scheme is applied and NREA has no objection to the STEP, the covering amount of JICA portion will be expanded to approx. 99 million USD as maximum except Owner's administration cost.
- The required power selling price from the PV power plant to distribution company (consumers) is approx. 27 US-cent /kWh considering all the above costs. But since this is the first large scale PV power plant project in Egypt, several optional items which shall be excluded from unit power selling cost comparison with other alternatives were considered such as exhibition system, training cost to NREA, battery, etc. Accordingly, based on the nominal cost, the selling PV power price became 18 US-cent / kWh which can be an acceptable and reasonable level.
- Project schedule is estimated as 67 months in total from selection of consultant to the end of warranty period of the project in case this project is STEP (Special Terms for Economic Partnership; kind of soft tied loan from Japan). The breakdown is as follows:
  - ✓ Selection of consultant: 4 months by JICA and 12 months by NREA
  - ✓ Selection of contractors including design: 23 months
  - ✓ Manufacturing and installation including testing & commissioning: 19 months
  - ✓ Warranty period: 24 months
- The procurement is carried out by International Competitive Bidding system in accordance with JICA rules and guidelines. The packaging number is one as described in the project scope above.
- NREA will establish Project Implementation Unit (PIU) for this project in timely manner.

5) Environmental

- Draft ESIA report is prepared in line with "Guideline of Principles and Procedures for Environmental Impact Assessment 2nd Edition" prepared by EEAA.

- Public Consultation for this project as part of ESIA process was held twice in Hurghada, in February 2012 and October 2012.
- From the above process, essentially, it is found that there is no significant factor to affect environmental impact from this project. But the following issues are to be taken into consideration in the tender process:
  - ✓ Recycling or disposal method of PV modules after using.
  - ✓ Method of disposal in Egypt or bringing back to the providing country at which the battery was manufactured, after using

6) Other issues

- Since this is the first large scale PV power plant project in Egypt, training to NREA is indispensable such as PV power plant design, method of construction supervision, O&M, etc., this training cost is considered in this study.
- NREA expressed its preference that CDM (Clean Development Mechanism) will be applied to this project as NREA did before for the wind projects, if CDM scheme is still available. Based on the methodological tool "ACM0002: Consolidated baseline and methodology for grid connected electricity generation from renewable sources", the emission factors, CER (Certified Emission Reduction) of this project can be estimated as approx. 321 thousand ton in total 20 years.
- IRR (Internal Rate of Return) is calculated in economically and financially considering the suggested power sales price (27 US-cent / kWh) which is accepted by EgyptERA as the first largest PV power plant project in Egypt. The result is as follows:
  - ✓ EIRR (Economic Internal Rate of Return): 6.55%
  - ✓ FIRR (Financial Internal Rate of Return): 4.39%

2. Suggestions

The Study Team would like to express its comments and suggestions to this project as follows:

1) General issues

- It is better to realize this project as soon as possible in order to meet Egyptian renewable energy policy and to grant the first large scale PV power plant project in Egypt. The following issues might be some obstacles to proceed this project unless appropriate adjustments are treated:
  - ✓ Official request from GoE to GoJ (Government of Japan)
  - ✓ Get permission for STEP scheme to this project from OECD-DAC (Organization for Economic Co-operation and Development-Development Assistance Committee).
  - ✓ Selection of two kinds consultant, one will be selected by JICA as grant support; the other will be selected by NREA. NREA's selection of consultant shall be completed in line with JICA's consultant work time frame in order to have seamless project implementation.
- Japanese government will support Egyptian policy for renewable development which is in line with direction of low GHG (Green House Gasses) emission. Accordingly, going forward of this project without delay is fostering both countries friendship.
- It is suggested that NREA and JICA shall have mutual agreement in advance, especially for the following matters:
  - ✓ Make clear boundary and responsibility between the first consultant to be selected by JICA and the second consultant to be selected by NREA.
  - ✓ The above two consulting works shall be continuously kept without delay and especially from taking over the works from former to the later when the first and the second Consultants are different.
  - ✓ Project Management Plan describing roles and functions of related entities such as JICA, NREA, CEDC, (EETC), Consultant, Contractors and other participant such as study team dispatched from JICA should be developed.
- PIU (Project Implementation Unit) or PMU (Project Management Unit) is recommended to be established and its members being maintained as much as possible in order to secure consistent philosophy to this project from selection of consultant, through PQ (Pre-Qualification) and Tendering till completion of the project.

2) Technical issues

- Though MLTF was selected in this study as assumption, actual selection shall be done in tendering stage with the latest information and conditions considering the followings:

- ✓ Proposed cost shall be evaluated by generation cost (= expected total generated power (kWh) for whole life period / project cost).
- ✓ Expected total generated power taking into account deterioration of PV modules shall be considered. And the deterioration of PV modules shall be verified some time later during or at the time of warranty period (or maintenance period in case maintenance contract is included under this project).
- ✓ Past performance record such as experience for similar nature and complexity project (20MW or more or less, in Middle East, Africa, South East Asia, etc.) with operation certificate (minimum 3 years) from the project Client shall be examined.
- ✓ Annual production capacity for the proposed PV module shall be checked.
- ✓ Deterioration of the proposed PV module with its certificate or record shall be checked.
- ✓ Certificate for the proposed PV module from International Accredited Organization shall be checked.
- ✓ Warranty to the proposed PV module from the tenderer shall be checked.
- ✓ Training menu of operation and maintenance to be proposed from tenderers shall be checked.

3) Environmental issues

- ■ Clear requirements to the Contractor for recycling system and/or disposal method for PV module and batteries after using shall be described in tender documents.

(end)

Chapter 1: Introduction

Chapter 1 Introduction

Section 1 Background

(1) Power demand in Egypt has been growing rapidly, e.g., 7% in last fifteen years.

(2) Power generation needs to be developed in line with the demand. According to 6th five year development plan (2007/8-2011/12), the generation will be increased by 9.1% p.a.

(3) In consideration to the above, GoE (Government of Egypt) established "Supreme Council of Energy" in 2006 and has adopted a resolution to cover 12% of the generation capacity development plan of up to 2011, and by 2020 to cover 20% of the total generation capacity with renewable energy.

(4) Climate in Egypt has an excellent condition of strong solar radiation for solar power generation. GoE requested to GoJ (Government of Japan) to carry out Feasibility Study (F/S) of photovoltaic power plant in Egypt.

Section 2 Outline of the Project

(1) Objectives

Investigate solar radiation, social infrastructure and environmental and social considerations. Carry out F/S of photovoltaic power plant project based on results of the investigation.

Collect economical and financial information assuming the project formation of Japanese ODA yen loan in the near future.

(2) Scope of the Project

The project consists of four (4) major components as summarized below:

1) Engineering, procurement & construction of photovoltaic power plant facilities including the following:
   - ✓ Photovoltaic modules with its related equipment
   - ✓ Remote monitoring and control system
   - ✓ Electrical works
   - ✓ Civil works including access roads
2) Procurement & installation of facilities related to the expansion of Hurghada wind farm distribution point including the following:
   - ✓ Additional ways for photovoltaic power plant project financed by JICA (Japan International Cooperation Agency)

3) Environmental considerations (mitigation measures & monitoring)
4) Associated consulting services

Section 3 Overall Goals of the Proposed Project

Developing Hurghada photovoltaic power plant along with red sea area is contributing to the following:

- ✓ To increase power supply, and reduce greenhouse gas emission by constructing photovoltaic power plants
- ✓ To contribute to the economic and social development by saving domestic fossil fuel consumption

Section 4 Objectives of the Preparatory Survey and Terms of Reference (TOR)

(1) Study Objective

To formulate the Project in a more sustainable and effective manner in consideration of environmental and social impacts

(2) TOR

TOR of this study is as follows:

TOR 1: Review and confirm the background and necessity of the Project

1. To review the current situation and issues of power sector and renewable energy
   - Basic information of power sector such as present and future plan of energy consumption, peak demand, installed/available generation capacity, generated energy, tariff etc.
   - Review of power development plan
2. To review development plan of renewable energy
3. To review/confirm current situation and plans of solar power including checking appropriateness
4. To confirm the code or regulation for grid connection
5. To review the other donor's supporting status and policies of solar power
6. To review GoE's policy for private sector of solar power

TOR 2: Measuring solar radiation at candidate site

1. Installation of measuring system
   - Pyranometer and data logger system will be installed in the target site to measure solar radiation. (to be done by JICA)
2. Data collection

- Data collection and maintenance will be done periodically

TOR 3: Confirm basic data for candidate site

1. Data acquisition/confirmation
   - Solar radiation data at meteorological observatory
   - Geological condition, seismic condition, geographical condition
   - Meteorological conditions (temperature, wind, rain, lightening etc.)
   - Present situation and development plan of land use (restrictions by military, pipeline, water pipe etc.)
   - Infrastructure of surrounding area
   - Existing situation and development plan of power facilities

TOR 4: Propose project scope

1. To propose project scope in consideration with the below items:
   - Scale and capacity of photovoltaic power plant
   - Appropriate slope angle of panels
   - Most suitable arrangement and connection
   - Comparison between fixed and tracker system
   - Review specification of inverters
   - Power control system
   - Method of connection for panel – inverter - substation
   - Related substation and transmission line
   - Monitoring & control system and earth grounding system
2. To review the effect of voltage and frequency fluctuation caused by the photovoltaic power plant to the grid.
3. To study the adoption of high performance battery system for improving electrical quality, sunlight fluctuation and peak load cut. Points to be considered for installation of high performance battery are below:
   - Technical review for appropriate battery system considering the situation in Egypt
   - Appropriate capacity of the battery
   - Cost and benefit analysis with/without installation of the battery
   - O&M scheme and human resource for photovoltaic power plant with the battery
4. To confirm the idea of energy selling price to be produced from this photovoltaic power plant to EEHC (Egyptian Electric holding company) (Whether this price is same as wind project or not) in association with new electricity law which is not issued yet.
5. To estimate the total project cost and cost for ODA loan amount
6. To propose financing plan including phasing
7. To propose the implementation schedule

8. To propose the packaging of procurement
9. To examine the applicability of STEP (Special Terms for Economic Partnership)

TOR 5: Training

To propose technical assistance by grant aids

TOR6: Examine and propose the Implementation and O&M (Operation and Maintenance) organization

1. Implementation organization
   - To propose implementation organization incl. confirmation of role and responsibility for each section and PIU (Project Implementation Unit)
   - To review the technical capacity of NREA (New and Renewable Energy Authority)
   - To review the financial capacity of NREA
2. O&M organization
   - To review issues of current O&M organization
   - To propose measures to the above
   - To propose O&M organization structure

TOR7: Propose consulting service

1. TOR for consulting service
2. Necessity of engineers, specialists and M/M (Man/Month)
3. Schedule

TOR8: Assistance for preparation and relevant procedure of EIA

1. Implement EIA (Environmental Impact Assessment) in compliance with Egyptian regulation and JICA guideline, and propose mitigation and monitoring plan, including the following items:
   - To confirm domestic procedure for environmental and social consideration for this project
   - To assist preparing EIA and opening public consultation
   - To confirm the protection of the area neighboring the site
   - To assist preparation of organization for monitoring
2. To confirm the following items for social consideration
   - To confirm land acquisition and involuntarily resettlement
   - To propose resettlement action plan (when necessary)
3. To review JICA environmental check list based on the EIA study

TOR9: Examine the possibility of applying CDM (Clean Development Mechanism)

1. To assist preparing PIN (Project Idea Note) including estimation of reduced amount of GHG (Green House Gas) emission
2. To review current Egyptian DNA (Designated National Authority) and procedures for CDM

TOR10: Confirm Project Effect

1. To propose Operation and Effect indicators
2. To propose qualitative impact
3. To calculate EIRR (Economic Internal Rate of Return) and FIRR (Financial Internal Rate of Return)

Section 5 Approach of the Preparatory Survey

Hurghada photovoltaic power plant FS Study team (the Team) is carrying out this study based on the following method.

Clause 1 Approach for the TOR 1

1) For TOR 1-1, 1-2: Current situation / development plan

A) Current situation and issues of power sector and renewable energy

Confirmation on the following items by interview and data collection to identify the issues

- Demand-Supply balance in past and future projection
- Tariffs, basic information of power sector
- Power development plan

B) Current situation / development plan of renewable energy

Confirmation on the following items by interview and data collection to identify the issues

- Current situation of renewable energy including solar power
- Renewable energy development plan
- Fundraising plan to the above

2) For TOR 1-3, 1-4: Solar power status & grid code

Review and confirm the followings by interview and data collection

- Current situation of solar power (photovoltaic and solar thermal)
- Future plans for solar power
- Code/regulations for grid connections

3) For TOR 1-5: Other donors' supporting status and policies

Confirmation on the following items by interview and data collection

- Supporting policies of WB (World Bank), KfW (Kreditanstalt für Wiederaufbau), etc.
- Projects financed by the above donors
- Future projects to be supported by the above donors

Clause 2 Approach for the TOR 2

1) For TOR 2-1: Installation of measuring system

Preparation and installation of measuring system

- Assisting the company to be selected by JICA
- NREA is requested to do the followings:
  - ✓ To attend acceptance test of the measuring system at the site
  - ✓ To prepare a room for storage of data logger, lap-top computer, etc. for the measurement
  - ✓ To provide electricity for the measurements
  - ✓ To allow access to the site for installation and data collection

Clause 3 Approach for the TOR 3

1) For TOR 3-1: Data collection

- Data collection and maintenance will be done by local consultant every week at least.
- To compare the dust effect on the surface of photovoltaic module, one photovoltaic module will be cleaned up once a week and the other will be left as it is.
- The Measuring System will be supervised by GPRS (General Packet Radio Service), if applicable.
- Measuring system will be handed over to NREA after the completion of the Study.
- Training for operation of the measuring system will be done at the end of the Study.

Image of the measuring system is shown in Fig. 1-1.

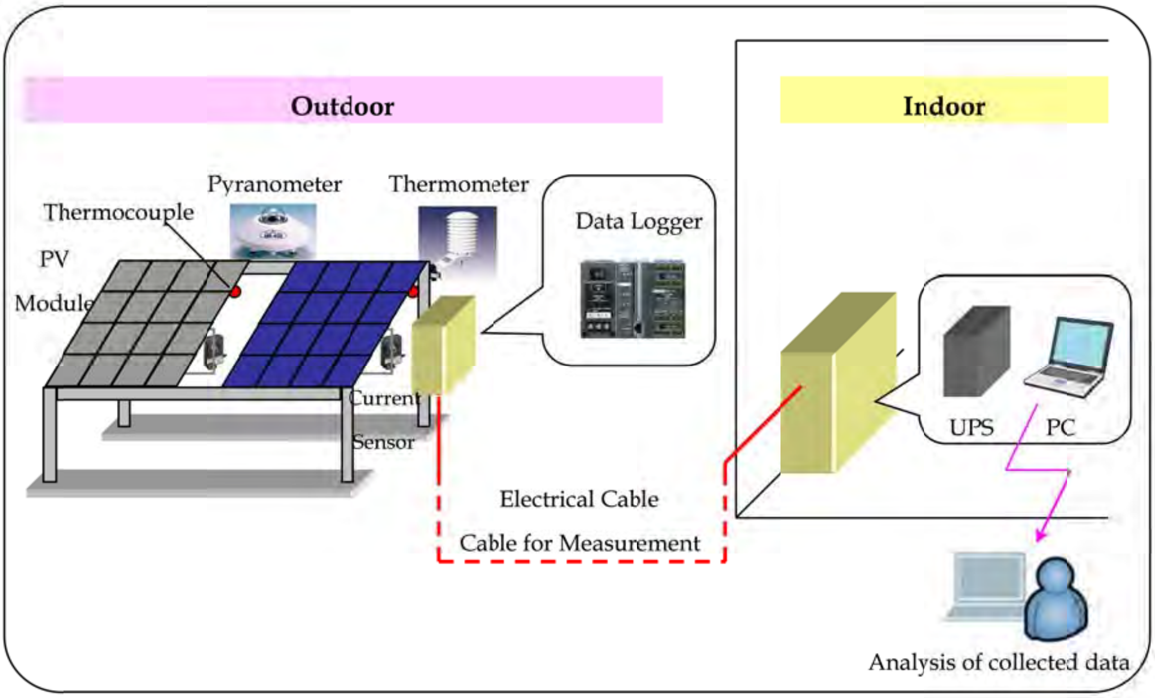


Fig.1-1 Image of the measuring system

Clause 4 Approach for the TOR 4

1) For TOR 4-1: Project scope

Confirmation on the following items by interview, data collection and site survey

- Appropriate scale and capacity of photovoltaic power plant
- Appropriate arrangement and connection considering the conditions of existing facilities
- Appropriate power control system for Egyptian power condition
- Existing substations and transmission lines
- Appropriate usage of voltage at internal lines and grid connections
- Appropriate control & monitoring system in consideration of the existing system of wind power
- Appropriate earth grounding system applying to the project based on Egyptian regulations

2) For TOR 4-2: Effect to the grid

Confirm effect to grid in terms of voltage and frequency fluctuation by photovoltaic power plant, as follows:

- Data acquisition of grid constant, existing data and future plan from EEHC/EETC
- Calculate grid condition by E-tap grid simulator
- Check grid conditions: power flow, voltage profile, frequency fluctuation

3) For TOR 4-3: High performance battery

Confirm necessity of high performance battery system for improving electrical quality and sunlight fluctuation, as follows:

- Calculate grid condition under installation of the battery system by E-tap
- Make comparison between conventional generator and hybrid system of photovoltaic power plant with the Battery

4) For TOR 4-4: Energy selling plan

Data collection and interview on the following items to grasp the situation and make proposal

- To confirm outline of Carbon fund or other benefit to renewable energy in the new electricity law
- To confirm NREA's idea for the selling price of this photovoltaic power plant
- To confirm ideas for compensation plan (financing plan) in case the above selling price is not enough for covering the expenditures
- To confirm latest selling (PPA: Power Purchase Agreement) price with EETC for the wind power plant including future increasing plan
- To investigate generation cost (kWh basis) for other photovoltaic power plant

5) For TOR 4-5: Cost

Data collection and interview on the following items to grasp the situation and make proposal

- Examine similar project costs
- Clarification of cost items if required
- Estimate project cost (foreign & local portion) considering the trend of the market
- Annual Fund Requirements

6) For TOR 4-6: Financing plan

Data collection and interview on the following items to grasp the situation and make proposal (dividing project into phases and/or co-financing)

- Available/applicable funds to the Project
- Amount to be allocated to the Project at once
- NREA’s budget allocation to the Project (foreign & local portion)
- Acceptable phasing
- To confirm Local financing plan (How will NREA allocates required project budget)
- To propose appropriate selling price to EETC under this photovoltaic power plant project in consideration with the results of IRR

7) For TOR 4-7, 4-8: Schedule & Packaging

Data collection and interview on the following items to grasp the situation and make proposal

- Confirmation of period for manufacturing and installation based on similar projects with current situation
- Propose project schedule considering JICA's requirements and standard procedures
- Confirmation of packaging of other solar projects
- Discussion of merit/demerit for several packaging ideas

8) For TOR 4-9: Applicability of STEP（Special Terms for Economic Partnership）

- Explanation about the outline of STEP
- Comparison between related products of Japanese and Others
- Propose Japanese products introduction
- Investigate Japanese manufactures' interest to this Project
- Pro vs. Con for STEP:
  - ✓ Grant Consulting Services
    - ➢ JICA can provide Japanese consultant on grant basis (basic design, detailed design and tender documents preparation)
    - ➢ Scope of work of the Consultant should be discussed
  - ✓ Fast Implementation
    - ➢ Seamless procedures between F/S and project formulation and implementation
  - ✓ Attractive Loan Conditions
    - ➢ Very low interest and long repayment period

Clause 5 Approach for the TOR 5 (Training)

Data collection and interview on the following items to grasp the situation and make proposal

- Required training in consideration with future photovoltaic power plants
- Currently performed training
- Available scheme within Japanese grant support

Clause 6 Approach for the TOR 6

1) For TOR 6-1: Implementation organization

Data collection and interview on the following items to grasp the situation and make proposal

- Current organization structure in NREA and EETC
- Situation of PIU or PMU (Project Management Unit) to be established for the Project
- Issues on implementation organization for photovoltaic power plants
- Technical and Financial capability of NREA and EETC
  (depend on the grid connection voltage level, EDC (Electricity Distribution Company) might be target)

2) For TOR 6-2: O&M organization

Data collection and interview on the following items to grasp the situation and make proposal

- To confirm O&M contracts with certain companies if available
- To confirm contents of periodical maintenance
- To confirm organization for operating existing wind power plants
- To confirm O&M cost in accordance with similar projects
- To grasp issues to be solved
- To propose measure to the above mentioned issues
- To propose suitable O&M organization structure

Clause 7 Approach for the TOR 7

Propose TOR and M/M for Consultant

- Scope of Work for consultant
- Required engineers and specialists
- Man Months allocation
- Budget estimation

Clause 8 Approach for the TOR 8

1) For TOR 8-1: Review environmental impact

Data collection and interview on the following items to grasp the situation and make necessary action

- Preparing TOR/EIA
  - ✓ Review the existing environmental reports of the project (particularly related EIA and ornithological reports) and identify unstudied information
  - ✓ Conduct EIA scoping and identify methodology of EIA
- Confirming EIA procedure in Egypt

- ✓ Confirm EIA procedure for general practices in Egypt and the project
- ■ Assist conducting EIA study
  - ✓ Undertake confirmation of current status, impacts caused by the Project and propose appropriate measures and monitoring plans
  - ✓ Conduct supplementary study for unstudied items
- ■ Prepare recommendations
  - ✓ Recommending mitigation measures and Environmental Management Plan
  - ✓ Estimate costs relating to environmental issues
- ■ Assist conducting public consultations
  - ✓ Confirm procedure of Egyptian and JICA Guideline on public consultation and information disclosure and adjust suitable TOR
  - ✓ Undertake consultations with necessary information disclosure and submit meeting records

2) For TOR 8-2: Confirm social consideration

Data collection and interview on the following items to grasp the situation and make necessary action

- ■ Confirm the necessity of land acquisition and resettlement
- ■ Assist in the preparation of resettlement action plan based on JICA environmental guideline if needed

3) For TOR 5-3: Review JICA's environmental checklist

Review the project based on the checklist of JICA guidelines for confirmation of environmental and social considerations

Clause 9 Approach for the TOR 9 (CDM)

Data collection and interview on the following items to grasp the situation

- ■ To assist in preparing PIN
- ■ To estimate reduced amount of GHG (Green House Gas) emission
- ■ To review Egyptian DNA and procedures for CDM

Clause10 Approach for the TOR 10 (Project effect)

Data collection and interview on the following items to grasp the situation and make proposal

- ■ Operation and Effect indicators
- ■ Qualitative impact
- ■ EIRR and FIRR

Section 6 Study Team Members and Schedule

1) Study Team Members

The study team consisted of 16 specialists as indicated in the following table:

Table 1-6-1 JICA study team member

Name	Specialty	Assignment
Mr. Shigeru KOMATSUZAKI	Team Leader	Total coordination and management ODA development
Mr. Hirokazu TSUJITA	Deputy team leader Planning photovoltaic power development	Photovoltaic power development High performance battery
Mr. Hiroshi SUGIHARA	Photovoltaic power generation	Photovoltaic power generation
Mr. Yoshitetsu FUJISAWA	Photovoltaic power generation	Photovoltaic power generation
Mr. Hisatoshi AKIYAMA	Measuring system	Measuring system
Mr. Hidekazu TAKASE	Measuring system	Measuring system
Mr. Masahiro OGAWA	Transmission line	Transmission line
Mr. Shin-ya NISHIMATSU	Substation and CDM	Substation & CDM
Mr. Noboru Yumoto	CDM	CDM
Mr. Hisashi SAITO	Substation	Substation
Mr. Misaki KITTAKA	Network Analyst	Network Analysis
Mr. Takashi KOIZUMI	Civil construction	Civil design
Ms. Akiko URAGO	Environmental & Social Consideration Expert	Environmental and social impacts
Mr. Shigeru SUZUKI	Financial Expert	Economic & Financial Analysis
Mr. Hironobu FURUYA	Logistics & Photovoltaic power generation support	Photovoltaic power generation
Ms. Fumiko IGARASHI	Logistics	Logistics

2) Local Consultant

The following local consultants have been hired to support the study Team. Name of the local consultant and its function in this study are as follows:

- Egyptrol (Egypt Engineering Services S.A.E): Power sector, Photovoltaic power, Substation and General issues
- Environics: Environmental issues (Baseline survey, draft EIA, Public consultation, etc.)

3) Study Schedule and objectives

Whole study schedule: from December 2010 to December 2012

Schedule of 1st mission in Egypt: from January14 to February 2, 2011

Objectives of the 1st mission in Egypt are as follows:

- Explanation of the Inception Report

- Site survey
- Data collection

2nd mission in Egypt: from April 9 to April 26, 2011

Objectives of the 2nd mission in Egypt are as follows:

- Follow up of 1st mission

3rd mission in Egypt: from July12 to Aug 12, 2011

Objectives of the 3rd mission in Egypt are as follows:

- Explanation of the basic design report
- Data collection regarding CDM

4th mission in Egypt: September 18 to October 19, 2011

Objectives of the 4th mission in Egypt are as follows:

- Explanation of the Interim Report
- Witness the installation of measuring system

5th mission in Egypt: February 18 to March 6, 2012

Objectives of the 5th mission in Egypt are as follows:

- Public consultation for scoping for EIA
- Maintenance and data checking for measuring system

6th mission in Egypt: June 4 to June 14, 2012

Objectives of the 6th mission in Egypt are as follows:

- Meeting for preparation of Draft Final Report
- Maintenance and data checking for measuring system

7th mission in Egypt: October 2 to October 15, 2012

Objectives of the 7th mission in Egypt are as follows:

- Confirmation of Draft Final Report
- 2nd Public Consultation
- Handing over of the measurement system

Table 1-6-2 Study Schedule

year	2010		2011												2012											
item / month	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Whole study schedule		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Measurement of solar radiation												■	■	■	■	■	■	■	■	■	■	■	■	■		
1st mission in Egypt			■																							
2nd mission in Egypt						■																				
3rd mission in Egypt									■	■																
4th mission in Egypt											■	■														
5th mission in Egypt																■	■									
6th mission in Egypt																				■						
7th mission in Egypt																								■		

Chapter 2: Current Situations and Issues of Electricity Power Sector

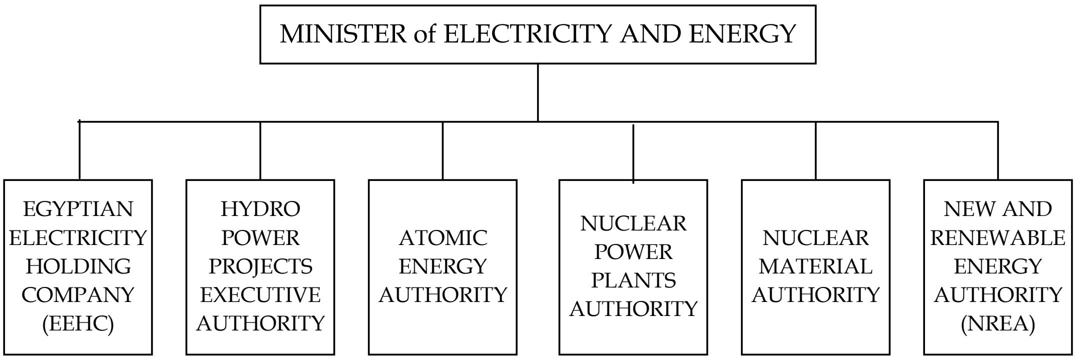
Chapter 2 Current Situations and Issues of Electricity Power Sector

Section 1 Egyptian Electricity Power Sector

Clause 1 Organizations and Human Resources

1) Organization

The Egyptian Electricity Authority (EEA) was established in 1976 and it was the vertically integrated electricity monopoly under Ministry of Electricity and Energy (MoEE) until the early 1990s. However, due to rapidly increasing electricity demand and projections of continuing growth in demand, the Egyptian Government introduced power sector reform in 1990s. Consequently, the power sector has been formed in 2001 and reformed as Fig. 2-1-1 from 2007.



Source: EEHC (Performance and Evaluation Division)

**In 2001, Rural Electrification Authority (REA) has established but REA has been disbanded and decomposed into other relevant companies in 2007.*

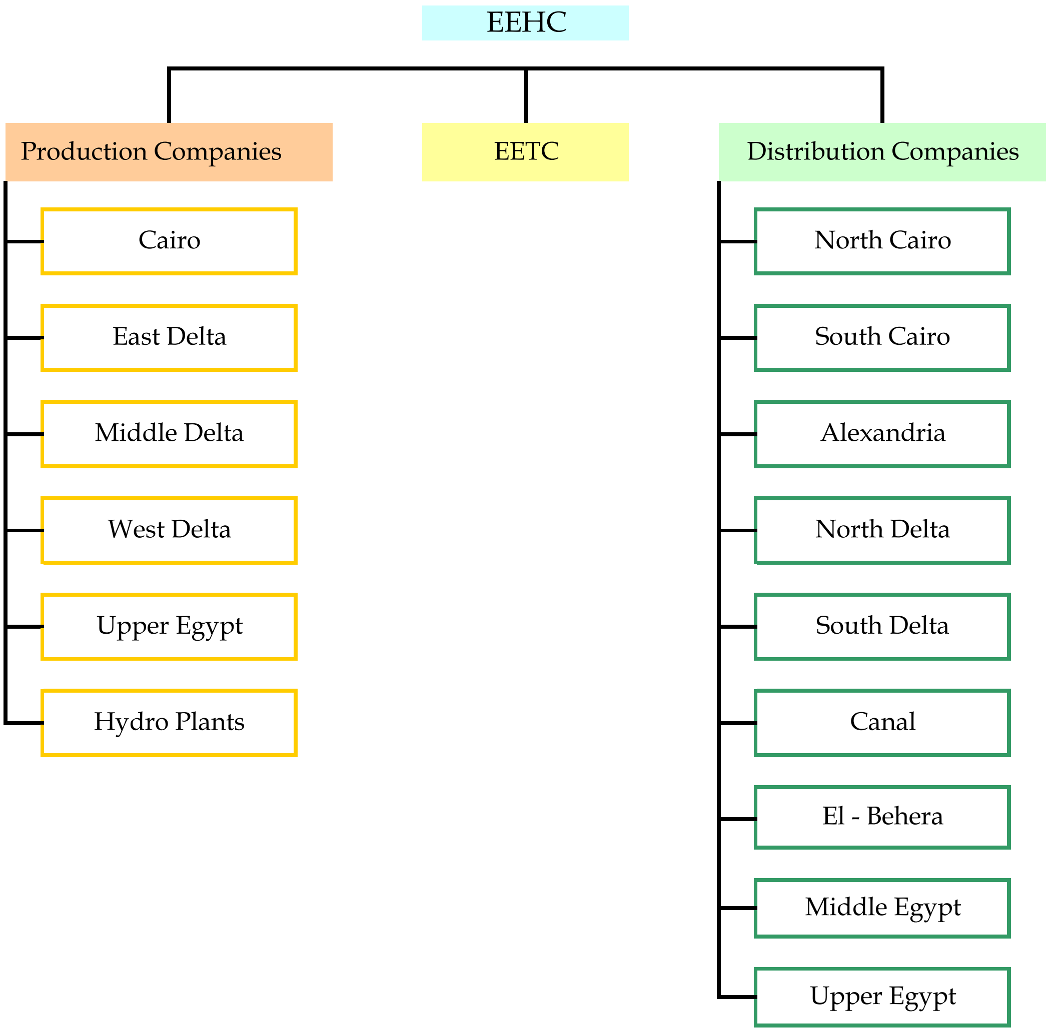
Fig. 2-1-1 Organization of Egyptian Electricity Power Sector

In line with the above power sector reform, EEA has been un-bundled and replaced by EEHC. Then EEHC has split to 3 major entity groups such as production company, transmission company and distribution company as described in Fig. 2-1-2.

Regarding production companies, six companies have been established. Five of them handle thermal power generation depending on region and one handles hydro power generation.

Regarding the transmission company, EETC (Egyptian Electricity Transmission Company) has been established as single buyer.

Regarding distribution companies, initially seven distribution companies have been established in accordance with the region. After that due to rapid power demand growth, numbers of distribution companies have been increased in several times, e.g., in 2001 Delta distribution company has been restructured into 2 companies (North Delta and South Delta) and in 2004 Cairo distribution company has been restructured into 2 companies (North Cairo and South Cairo). Then currently, there are 9 distribution companies in total.



Source: Annual Report of EEHC (2010/2011)

Fig. 2-1-2 Organization of EEHC group

2) Human Resources

Total number of employees of EEHC and its affiliated companies are 149403, 152961, 158331, 164129, 170513 and 176044 in total in 2005/2006, 2006/2007, 2007/2008, 2008/2009, 2009/2010 and 2010/2011, and the breakdown is shown below;

Table 2-1-1 Human resources of EEHC group companies

	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011
○ EEHC head quarter and electricity hospital:	2,853	2,923	2,978	3,069	3,193	3,031
○ EETC:	29,626	29,781	30,879	31,307	31,844	32,494
○ Production companies:	28,651	30,029	30,939	31,906	33,242	34,713
・ Cairo:	5,377	5,516	5,662	5,713	5,782	5,878
・ East Delta:	8,517	5,629	5,774	6,019	6,458	6,858
・ Middle Delta:	------	5,025	5,533	5,699	5,881	6,137
・ West Delta:	8,643	7,385	7,400	7,660	8,070	8,449
・ Upper Egypt:	2,715	3,088	3,150	3,282	3,436	3,555
・ Hydro Plants:	3,399	3,386	3,420	3,533	3,615	3,836
○ Distribution Companies:	88,273	90,228	93,535	97,847	102,234	105,806
・ North Cairo:	9,816	10,294	10,529	11,116	11,973	12,655
・ South Cairo:	11,824	12,448	12,995	14,341	15,243	16,592
・ Alexandria:	13,014	13,016	13,061	13,279	13,324	13,414
・ Canal:	15,195	15,508	16,651	16,903	17,021	17,199
・ North Delta:	7,624	7,710	7,989	8,618	8,920	9,131
・ South Delta:	8,357	8,503	9,010	9,054	10,544	10,871
・ El- Behera:	6,884	6,997	7,123	7,460	7,564	8,126
・ Middle Egypt:	8,733	8,773	9,020	9,443	9,787	9,821
・ Upper Egypt:	6,826	6,979	7,157	7,633	7,858	7,997

Source: Annual Report of EEHC (2010/2011)

Total number of employees of NREA is 864, 935, 996, 950, 1011 and 1109 in 2005/06, 2006/07, 2007/08, 2008/09, 2009/10 and 2010/11 and the breakdown is shown below:

Table 2-1-2 Human resources of NREA

	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
Engineers	144	167	171	180	200	229
Technicians	165	189	222	220	221	270
Accountants	96	116	125	123	118	119
Physicians & Lawyers	14	14	14	13	12	12
Administrators	281	279	294	220	282	285
Others	164	170	170	194	178	194
Staff No.	864	935	996	950	1,011	1,109

Source: Annual Report of NREA (2010/2011)

Clause 2 Power Demand Forecast

1) Actual Record of Power Demand (Peak Load)

According to EEHC's annual report, actual record of peak load and power sales is summarized in Table 2-1-3.

Table 2-1-3 Peak load and Sales Energy

Year	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12
Peak Demand (MW)	12,376	13,326	14,401	14,735	15,678	17,300	18,500	19,738	21,330	22,750	23,470	25,705
Growth Rate of Peak Load (%)	5.5	7.7	8.1	2.3	6.4	10.3	6.9	6.7	8.1	6.7	3.2	9.5
Energy Sales (GWh)	64,807	69,463	74,947	80,655	85,781	92,859	98,812	107,226	112,617	120,180	126,934	145,640
Growth Rate of Energy Sales (%)	6.6	7.2	8.0	7.6	6.4	8.3	6.4	8.5	5.0	6.7	5.6	14.7
Growth Rate of GDP (%)	3.4	3.2	3.1	4.1	4.9	6.9	7.1	7.2	4.6	5.1	1.8	

Source: Annual Report of EEHC (2010/2011) and date provided from EEHC (for 2011/12) during final mission, http://www.indexmundi.com/. for GDP

The averaged GDP (Gross Domestic Product) growth rate in Egypt during 2000/01 – 2011/12 is 4.67% and the averaged energy sales growth rate in the same period is 8.27%. Accordingly, the averaged electricity elasticity[1] / GDP in the same period is 1.77 which shows necessity of energy efficiency situation.

Similar to 2009, 2010, the summer of 2011 also had to face several load shedding in many regions of the Country. The situation seems to be getting tenser up to this year with tendency of growing more in the future.

The Team assumes that the growth of peak load is squeezed by insufficient power resources accordingly potential of peak load is higher than the recorded values.

2) Forecasted Power Demand

According to the data provided by EEHC, expected average annual growth rate of peak load is summarized in Table 2-1-4.

Table 2-1-4 Expected average annual growth rate of peak load

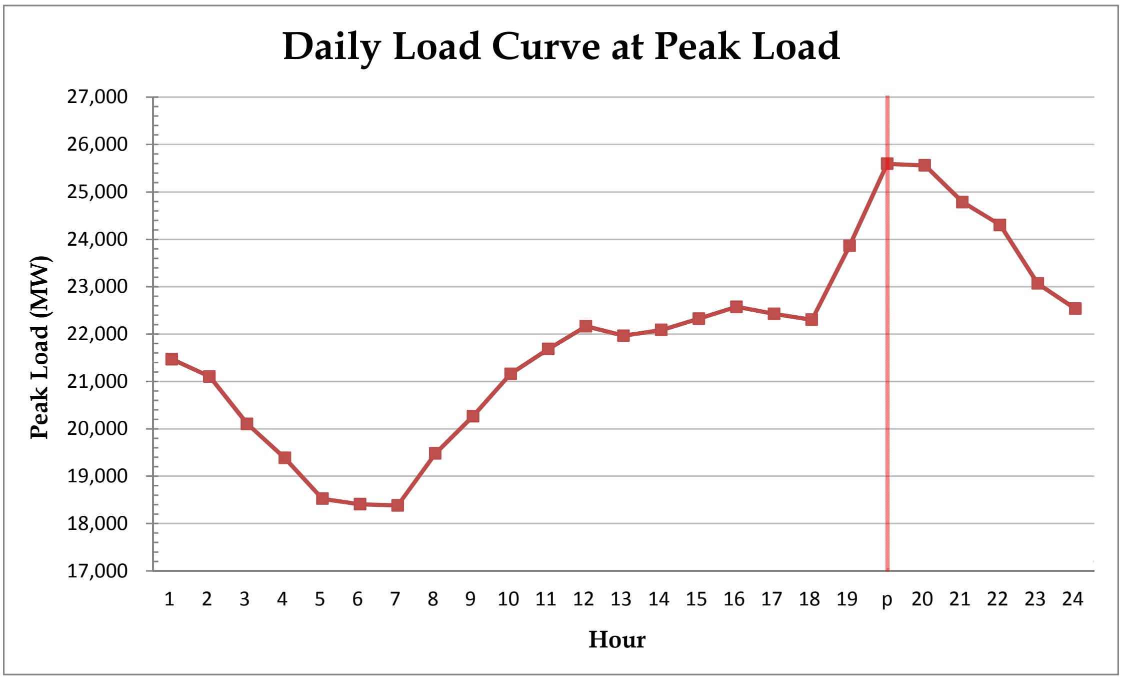
Year	12/13	13/14	14/15	15/16	16/17
Peak Load (MW)	26,922	28,490	30,201	32,034	35,850
Growth Rate of Peak Load (%)	6.0%	5.8%	6.0%	6.1%	11.9%

Source: Data provided from EEHC during final mission

[1] Electricity Elasticity =Demand Growth (%) / GDP Growth (%); long term of this elasticity is convergence to 1 if no effort to energy efficiency action is taken place. In Japanese past trend, level of this elasticity can be divided into some phases such as more than 1 when high economic growth period with less effort for energy efficiency(1960's), less than 1 when effort of energy efficiency was made (1970' and by mid of 80's),etc.

3) Daily load curve

Peak load of whole energy sales was at the latest, 25,593 MW occurring on 18th of June 2012. Daily load curve of UPS on this day is shown on Figure 2-1-3.



Source: Data provided from EEHC

Fig. 2-1-3 Daily Load Curve on 18th of June, 2012

4) Load Factor

Increasing load factor will diminish the average unit cost (demand and energy) of the kWh. Depending on situation, improving the load factor could mean substantial savings. The load factor corresponds to the ratio between average load and the peak load capacity.

According to the annual report of EEHC and data provided from EEHC, the load factor is recorded as the following table.

Table 2-1-5 Load factor record

Year	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12
Peak Demand (MW)	12,376	13,326	14,401	14,735	15,678	17,300	18,500	19,738	21,330	22,750	23,470	25,705
Total Power Generation (GWh)	77,956	83,003	88,951	94,913	100,996	108,368	114,349	125,129	131,040	137,900	146,796	157,400
Load Factor (%)	72%	71%	71%	74%	74%	72%	71%	72%	70%	69%	71%	70%

Source: Annual Report of EEHC (2010/2011), data provided from EEHC (for 2011/12) during final mission.

According to EEHC, the load factor is set as 71 % for demand forecast.

Clause 3 Power Facilities

1) Generation

In Egypt, three kinds of power plant are available, such as hydro, thermal and wind. Among those three, thermal is major and it is occupying about 87% of the total generation capacity. Installed capacity for each type based on the annual report 2010/11 is as follows:

- Hydro power plants: 2,800 MW
- Thermal power plants: 21,514 MW
- Wind power plant: 547 MW
- Solar power plant: 140 MW
- Private sector BOOTs: 2,048 MW
- Total: 27,049 MW

The installed capacity and commissioning date of each existing power plant is summarized in Table 2-1-6.

Table 2-1-6-(1) Installed Capacity and Commissioning date of each Power Stations (1)

<Hydro>

Area	Power Station	unit No.	Installed Capacity	Available Capacity	Type	Com. Date
Upper Egypt	Essna	1	14.28	-	hydro	Oct-93
	(86MW)	2	14.28	-	hydro	Oct-93
		3	14.28	-	hydro	Oct-93
		4	14.28	-	hydro	Oct-93
		5	14.28	-	hydro	Oct-93
		6	14.28	-	hydro	Oct-93
	Aswan Dam I	1	40	-	hydro	Mar-60
	(280MW)	2	40	-	hydro	May-60
		3	40	-	hydro	Jul-60
		4	40	-	hydro	Oct-60
		5	40	-	hydro	Apr-60
		6	40	-	hydro	Jul-60
		7	40	-	hydro	Dec-60
	Aswan Dam II	1	67.5	-	hydro	Jul-85
	(270MW)	2	67.5	-	hydro	Oct-85
		3	67.5	-	hydro	Dec-85
		4	67.5	-	hydro	Feb-86
	Aswan High Dam	1	175	-	hydro	Oct-67
	(2100MW)	2	175	-	hydro	Oct-67
		3	175	-	hydro	Dec-67
		4	175	-	hydro	Apr-68
		5	175	-	hydro	Jul-68
		6	175	-	hydro	Dec-68
		7	175	-	hydro	Jul-69
		8	175	-	hydro	Jun-69
		9	175	-	hydro	Dec-69
		10	175	-	hydro	Apr-70
		11	175	-	hydro	Jun-70
		12	175	-	hydro	Jul-70
	New Naga Hamadi	1	16	-	hydro	08
	(64MW)	2	16	-	hydro	08
		3	16	-	hydro	08
		4	16	-	hydro	08
	<Hydro Total>		2,799.7			

<Thermal >

Company	Power Station	unit No.	Installed Capacity	Available Capacity	Type	Com. Date
Cairo	Shoubra El-Kheima (ST)	1	315	315	steam	Dec-84
	(1260MW)	2	315	315	steam	May-85
		3	315	315	steam	Sep-85
		4	315	315	steam	May-85
	Shoubra El-Kheima (GT)	1	35	35	gas	88
	(35MW)					
	Cairo West (ST)	1	87.5	87.5	steam	Jan-66
	(350MW)	2	87.5	87.5	steam	Apr-66
		3	87.5	87.5	steam	Jul-66
		4	87.5	87.5	steam	Aug-79
	Cairo West Ext. (ST)	1	330	330	steam	Feb-95
	(1360MW)	2	330	330	steam	Apr-95
		3	350	350	steam	Apr-11
		4	350	350	steam	May-11
	Cairo South 1 (CC)	1	110	110	gas	Jun-89
	(450MW)	2	110	110	gas	Jun-89
		3	110	110	gas	Aug-89
		5	60	60	steam	Apr-65
		6	60	60	steam	Apr-65
	Cairo South 2 (CC)	1	110	110	gas	Feb-95
	(165MW)	1	55	50	steam	Feb-95
	Cairo Notth (CC)	1	250	250	gas	Aug-04
	(1500MW)	2	250	250	gas	Aug-04
		3	250	250	steam	Jan-06
		4	250	250	gas	Apr-06
		5	250	250	gas	Apr-06
		6	250	250	steam	Aug-08
	El-Tebeen (ST)	1	350	350	steam	Aug-10
	(700MW)	2	350	350	steam	Sep-10
	Wadi Hof (GT)	1	33.3	30	gas	Aug-88
	(100MW)	2	33.3	30	gas	Aug-88
		3	33.3	30	gas	Aug-88
	< Cairo Total >		5,920.0	5,905.0		

<Thermal (cont.)>

Company	Power Station	unit No.	Installed Capacity	Available Capacity	Type	Com. Date
East Delta						
	Demietta (CC)	1	132	120	gas	Mar-89
	(1200MW)	2	132	120	gas	Mar-89
		3	132	120	gas	Apr-89
		4	132	120	gas	Aug-89
		5	132	120	gas	Apr-89
		6	132	120	gas	Aug-89
		1	136	120	steam	Jul-93
		2	136	120	steam	Feb-93
		3	136	120	steam	Feb-93
	Ataka (ST)	1	150	150	steam	Jan-85
	(900MW)	2	150	150	steam	Apr-85
		3	300	300	steam	Apr-87
		4	300	300	steam	Jul-89
	Abu Sultan (ST)	1	150	150	steam	May-83
	(600MW)	2	150	150	steam	Aug-83
		3	150	150	steam	Oct-84
		4	150	150	steam	Oct-86
	Shabab (GT)	1	33.5	30	gas	Oct-82
	(134MW)	2	33.5	30	gas	Nov-82
		3	33.5	30	gas	Dec-82
		4	33.5	30	gas	Jun-11
	Port Said (GT)	1	24.0	13	gas	Jan-84
	(73MW)	2	24.0	13	gas	Jun-77
		3	24.6	14	gas	Jan-84
	Arish (ST)	1	33	33	steam	Jul-99
	(66MW)	2	33	33	steam	Dec-98
	Oyoun Mousa (ST)	1	320	320	steam	00
	(640MW)	2	320	320	steam	01
	Sharm El-Sheikh (GT)	1	23.7	23.7	gas	79
	(178MW)	2	23.7	23.7	gas	79
		3	24.3	24.3	gas	79
		4	24.3	24.3	gas	79
		5	24.3	24.3	gas	79
		6	24.3	24.3	gas	79
		7	5.8	5.8	gas	96
		8	5.8	5.8	gas	96
		9	5.8	5.8	gas	97
		10	5.8	5.8	gas	86
		11	5	5	gas	
		12	5	5	gas	
	Hurghada (GT)	1	23.5	23.45	gas	91
	(143MW)	2	23.5	23.45	gas	92
		3	23.5	23.45	gas	91
		4	24.3	24.27	gas	95
		5	24.3	24.27	gas	96
		6	24.3	24.27	gas	97
	BOOT Suez Gulf (ST)	1	341.25	341.25	steam	02
	(682.5MW)	2	341.25	341.25	steam	02
	BOOT Port Said East (ST)	1	341.25	341.25	steam	03
	(682.5MW)	2	341.25	341.25	steam	03
	< East Delta Total >		5,298.5	5,132.0		

Note: Blue colored portion is private (BOOT (Built-Operation-Own-Transfer)).

Source: Annual Report of EEHC (2010/2011)

Table 2-1-6-(2) Installed Capacity and Commissioning date of each Power Stations (2)

<Thermal (cont.)>

Company	Power Station	unit No.	Installed Capacity	Available Capacity	Type	Com. Date
Middle Delta	Talkha (CC) (290MW)	1	24.7	22	gas	Dec-79
		2	24.7	22	gas	Dec-79
		3	24.7	22	gas	Dec-79
		4	24.7	22	gas	Dec-79
		5	24.7	22	gas	Dec-79
		6	24.7	22	gas	Dec-79
		7	24.7	22	gas	Mar-80
		8	24.7	22	gas	Mar-80
		1	46.0	40	steam	Apr-89
		2	46.0	40	steam	Mar-89
	Talkha 750 (CC) (750MW)	1	250	250	gas	Aug-06
		2	250	250	gas	Aug-06
		3	250	250	steam	Aug-06
	Talkha 210 (ST) (420MW)	1	210	210	steam	Oct-93
		2	210	210	steam	May-95
	Nubaria 1,2 (CC) (1500MW)	1	250	250	gas	Aug-05
		2	250	250	gas	Aug-05
		3	250	250	gas	Sep-05
		4	250	250	gas	Sep-05
		5	250	250	steam	Aug-06
		6	250	250	steam	Sep-06
	Nubaria 3 (CC) (750MW)	1	250	250	gas	09
		2	250	250	gas	09
		3	250	250	gas	09
	Mahmoudia (CC) (316MW)	1	25	20	gas	Mar-83
		2	25	20	gas	Mar-83
		3	25	20	gas	Apr-83
		4	25	20	gas	May-83
		5	25	20	gas	May-83
		6	25	20	gas	May-83
		7	25	20	gas	May-83
		8	25	20	gas	Jun-83
		9	58.7	20	gas	Nov-95
		10	58.7	43	steam	Dec-95
	El-Atf (CC) (750MW)	1	250.0	250	gas	10
		2	250.0	250	gas	10
		3	250.0	250	steam	10
	<Middle Delta Total>		4777.4	4649.0		

<Thermal (cont.)>

Company	Power Station	unit No.	Installed Capacity	Available Capacity	Type	Com. Date
Upper Egypt	Walidia (ST) (624MW)	1	312	300	steam	Mar-92
		2	312	300	steam	Mar-97
	Kuriemat (ST) (1254MW)	1	627	627	steam	Nov-97
		2	627	627	steam	Oct-99
	Kuriemat 2 (CC) (750MW)	1	250	250	gas	07
		2	250	250	gas	07
		1	250	250	steam	09
	Kuriemat 3 (CC) (500MW)	1	250	250	gas	09
		2	250	250	gas	09
		1	250	0	steam	09
		*The steam turbine in not in operation.				
	Assiut (ST) (90MW)	1	30	30	steam	Dec-66
		2	30	30	steam	Apr-67
		3	30	30	steam	Jun-67
	Kuriemat (Solar/Therma (140MW)	1	70	70	gas	Jul-11
		2	50	50	gas	Jul-11
		3	20	20	gas	Jul-11
		*Available capacity needs to be confirmed.				
	< Upper Egypt Total >		3,608.0	3,334.0		

<Thermal (cont.)>

Company	Power Station	unit No.	Installed Capacity	Available Capacity	Type	Com. Date
West Delta	Kafr El Dawar (ST) (440MW)	1	110	100	steam	Feb-80
		2	110	100	steam	Mar-80
		3	110	100	steam	Dec-84
		4	110	95	steam	Nov-86
	Damanhour Ext (ST) (300MW)	1	300	300	steam	Jan-91
	Damanhour (Old) (ST) (195MW)	1	65	65	steam	68
		2	65	65	steam	68
		3	65	65	steam	69
	Damanhour (CC) (156.5MW)	1	24.6	23.5	gas	May-85
		2	24.6	23.5	gas	May-85
		3	24.6	23.5	gas	Jun-85
		4	24.6	23.5	gas	Jun-85
		5	58	50	steam	Dec-95
	El-Suif (GT) (200MW)	1	33.3	20	gas	Dec-81
		2	33.3	20	gas	Jan-82
		3	33.3	20	gas	Feb-82
		4	33.3	20	gas	Nov-83
		5	33.3	20	gas	Dec-83
		6	33.3	20	gas	Mar-83
	Karmouz (GT) (23.1MW)	1	11.4	9	gas	May-80
		2	11.7	0	gas	Jul-80
	Abu Kir (ST) (911MW)	1	150	150	steam	May-83
		2	150	150	steam	Nov-83
		3	150	150	steam	Jul-84
		4	150	150	steam	Oct-84
		5	311	311	steam	May-91
	Abu Kir (GT) (24.3MW)	1	24.27		gas	83
	Sidi Krir 1,2 (ST) (640MW)	1	320	320	steam	Sep-00
		2	320	320	steam	Nov-99
	Sidi Krir (CC) (750MW)	1	250	250	gas	10
		2	250	250	gas	10
		3	250	250	steam	10
	Matrouh (ST) (60MW)	1	30	30	steam	90
		2	30	30	steam	90
	BOOT Sidi Krir 3 & 4 (ST	3	341.25	341.25	steam	02
		4	341.25	341.25	steam	02
	< West Delta Total >		4,382.4	4,206.5		

	< Thermal Total >		23,986.3	23,226.5		

<Wind>

Area	Power Station	unit No.	Installed Capacity		Type	Com. Date
East Delta	Zafarana (546.5MW)	-	63	-	wind	03/04
		-	77.22	-	wind	06
		-	406.3	-	wind	10
	< Wind Total >		546.5			

< Total >			27,332.5			

Note1: Blue colored portion is private (BOOT).
Note2: Unit No.4 of El-Shabab PP is not mentioned in the Annual Report.
Note3: Steam unit of El-Kureimat PP is mentioned of not being in commission in the Annual Report.
Source: Annual Report of EEHC (2010/2011)

2) Transmission Line Network

EETC is single buyer and only one company for T/L network management, operation and maintenance.

Main functions of EETC are as follows:

- Management, operation and maintenance of electric power transmission grids
- Control transmission grids on extra and high voltage through NECC (National Energy Control Center) and RCCs (Regional Control Center)
- Coordinate with production companies and distribution companies for providing electric power locally and with neighboring countries

The main transmission line (T/L) network in Egypt is composed of the followings:

- 500kV T/L (400kV T/L is using for interconnection between Jordan and Egypt)
- 220kV T/L
- 132kV T/L (to be faded out gradually)
- 66kV T/L
- 33kV T/L (to be faded out gradually)

Regarding 500kV T/L network, it was introduced at the time of Aswan High Dam completion (1967) along the Nile River running south to north, from Aswan High Dam to Cairo with 2 circuits, approx. 800km.

Regarding 132 kV T/L network, it was introduced at the time of No.1 Aswan Dam completion in 1960. Currently, the 132kV T/L network is operated in Upper and Middle Egypt zones only.

Summary of transformer capacities and transmission line length in each zone is shown in Table 2-1-7 and Table 2-1-8 respectively.

Table 2-1-7 Transformer Capacity (MVA)

Zone	500kV	220kV	132kV	66kV	33kV
Cairo	1,500	9,940	-	13,642	-
Canal	1,750	8,673	-	6,611	-
Delta	-	4,050	-	5,631	-
Alexandria & West Delta	-	5,350	-	6,862	-
Middle Egypt	3,285	2,875	893	3,145	855
Upper Egypt	1,980	3,290	2,590	3,551	927
Total	8,515	34,178	3,483	39,442	1,782

Source: Annual Report of EEHC (2010/2011)

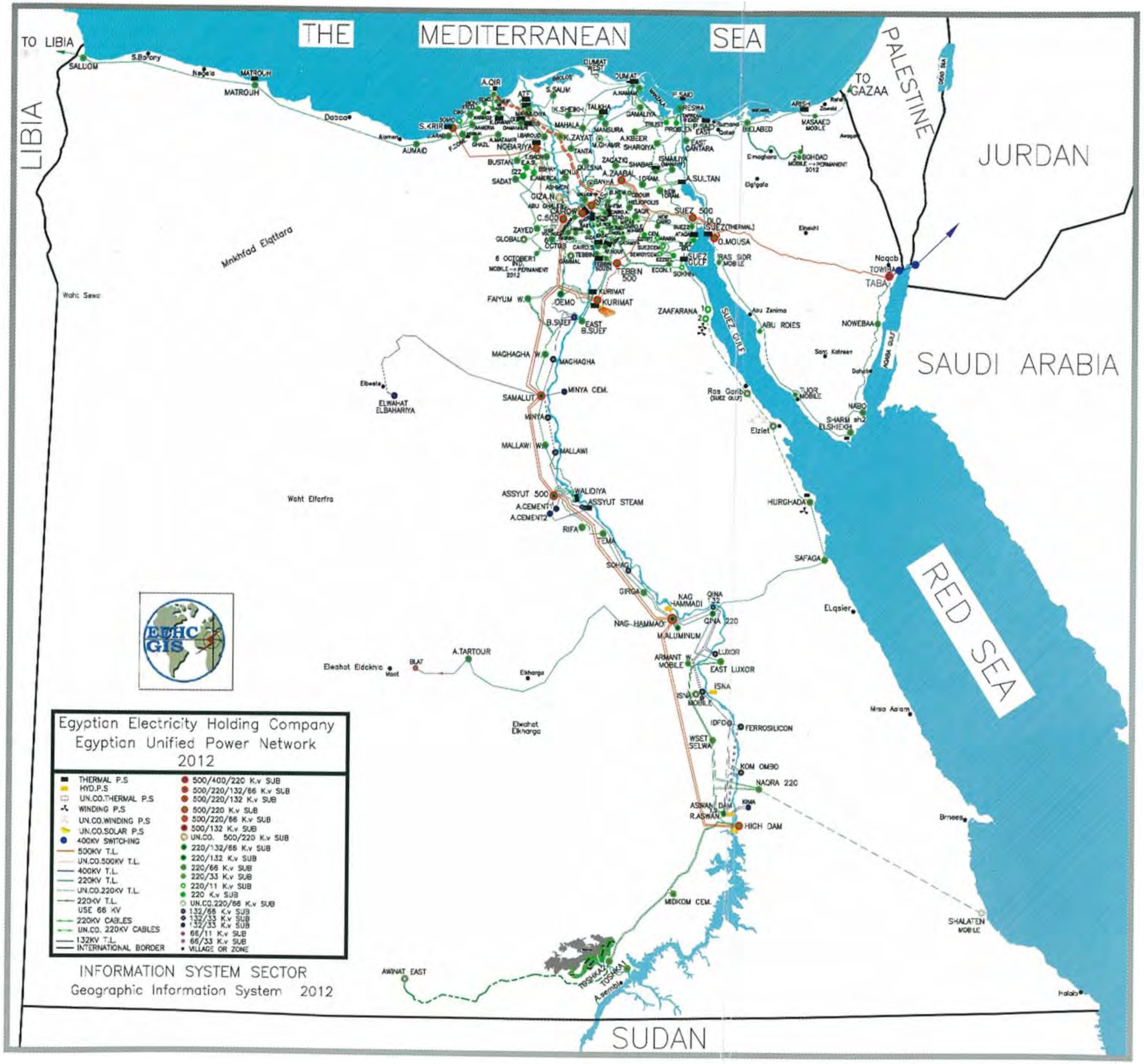
Table 2-1-8 Transmission Line Length (km)

Zone	500kV	400kV	220kV	132kV	66kV	33kV
Cairo	212	-	1,284	-	2,804	-
Canal	409	33	5,330	-	3,395	-
Delta	-	-	1,575	-	3,332	-
Alexandria & West Delta	217	-	3,446	-	3,949	-
Middle Egypt	885	-	2,312	1,175	2,427	1,276
Upper Egypt	756	-	2,210	1,309	2,418	1,433
Total	2,479	33	16,157	2,484	18,361	2,709

Source: Annual Report of EEHC (2010/2011)

Transmission Line Network diagram on 2012 is shown in Fig. 2-1-4.

Fig.2-1-4 T/L Network diagram on 2012



Source: Annual Report of EEHC (2010/2011)

3) Distribution

As stated in Clause 1 of this section, there are 9 EDCs in Egypt now. The main function of the EDCs is as follows:

- Distributing and selling electric power to customers
- Purchasing electric power from EETC, electricity production companies, industries and other IPPs (Independent Power Producer) (medium and low voltage only)
- Managing, operating and maintaining medium and low voltage grids

Summary of medium and low voltage grids in 2010/2011 is shown in Table 2-1-9.

Table 2-1-9 Summary of Distribution Grids

		North Cairo	South Cairo	Alex.	Canal	North Delta	South Delta	El Behera	Middle Egypt	Upper Egypt	Total
Length of Medium Voltage Grid (km)	Overhead lines	515	2,927	577	14,142	9,761	7,483	12,596	15,901	10,324	74,226
	Underground cables	13,991	17,535	10,053	16,197	5,255	3,182	3,869	4,943	5,380	80,405
	Total	14,506	20,461	10,630	30,340	15,015	10,665	16,465	20,845	15,704	154,631
Length of Low voltage Grid (km)	Overhead lines	2,785	4,475	2,774	29,159	21,848	17,526	14,827	32,928	28,912	155,234
	Underground cables	28,999	30,280	5,638	13,451	2,698	774	2,400	1,828	1,496	87,564
	Total	31,784	34,755	8,411	42,610	24,547	18,300	17,227	34,756	30,408	242,798
Distribution Transformers capacities (MVA)		11,494	11,398	4,273	10,398	4,293	3,738	3,841	4,404	4,086	57,925

Source: Annual Report of EEHC (2010/2011)
Note: medium voltage means 22kV and 11kV, low voltage means 0.4kV

4) Losses

Loss data in power system is shown in Table 2-1-10. The data shows that the distribution network loss constitutes more than half of total losses.

Table 2-1-10 Loss in Power System

Year	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
Generation loss	3.63%	3.64%	3.43%	3.25%	3.13%	3.40%	3.03%	3.13%
Transmission line loss	3.78%	3.72%	3.73%	3.71%	3.89%	3.82%	4.23%	3.64%
Distribution network loss	10.38%	10.28%	9.38%	9.24%	9.14%	8.64%	7.90%	8.38%

Source: Data provided form EEHC during 6^{th} / final mission

Clause 4 PDP (Power Development Plan)

1) PDP

EEHC develops the long term power development plan by 5 years intervals with authorization from MoEE. EEHC reviews PDP every year in consideration of current power situation.

The latest PDP provided by EEHC and NREA is summarized in Table 2-1-11.

At the latest situation of this continuing heating summer, peak of the demand went up more than 25,500 MW in June 2012 (fiscal year 2011/12) which was about 2,000MW more than those power demand in the previous year, e.g., 23,470MW. The high rising demand of the country is increasing faster than the capacity expansions and is leading to intermittent blackouts.

Then, MOEE decided to introduce additional 17,000 MW generation capacity through expansions worth 120 billion LE (approx. 20 billion USD) by 2017.

To take measures for the above situation other than new power developments, a project of exchanging approx. 3,000 MW through international DC power lines between Saudi Arabia and Egypt is in progress. Both countries will be taking advantage of the exchange as peak use hours differ from one another.

In addition to the above, NREA developed wind and solar energy development plan in line with GoE's national development plan. The total development capacity from 2012/13 to 2026/27 is as follows:

- Wind power plant: 9,720MW
- Solar power plant (CSP): 2,800MW
- Solar power plant (PV): 700MW

2) Retirement Plan

In 2006, EEHC made a long term retirement plan for power plants during 2009/10-2026/27 based on the life time of each power plant. The life time for each power plant applied in EEHC plan is as follows:

- Hydro power plant: 50-70 years
- Thermal power plant: 30-50 years
- Wind power plant: 20 years

The retirement plan for the period 2012/13-2026/27 is summarized in Table 2-1-12.

Table 2-1-11 Long Term Development Plan during the period of 2011/12-2026/27

Plant Name	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	Total
Zafarna Wind																	0
Suez Gulf Wind			200	710	400	700	500	2,510									5,020
East-West Nile Wind						200	4,000					100	100	100	100	100	4,700
Solar Units					100	150	150	200	250	250	250	250	250	250	350	350	2,800
Photo Voltatic cells					20	20	40	40	40	60	80	80	80	80	80	80	700
Damitta (GT)	500																500
Fayoum West (GT)	500																500
High Voltage Site (GT)	500																500
Abu Kir (ST)	650	650															1,300
Ain Sokhna (ST)			1,300														1,300
Banha (CC)		500	250														750
Giza North (CC)		1,000	500	500	250												2,250
Dairout BOO (CC)			1,500	750													2,250
Suez (ST)				650													650
Mini & Small Hydro Units				32													32
Helwan South (ST)					1,950												1,950
Aiaat (ST)						1,300	650										1,950
Qena (ST)					650	650											1,300
Safaga (ST)						650	650										1,300
Steam Units							650	650	1,950	650	1,300	1,300	3,250	1,950	2,600	2,600	16,900
Combined Cycel Units							1,000	1,000	750	1,250	1,000	1,250	1,000	1,250	1,000	250	9,750
Nuclear								1,000		1,000		1,000		1,000		1,000	5,000
Total capacity (MW)	2,150	2,150	3,750	2,642	3,370	3,670	7,640	5,400	2,990	3,210	2,630	3,980	4,680	4,630	4,130	4,380	61,402

Source: Data provided from EEHC and NREA during final mission

Table 2-1-12 Long Term Retirement Plan during the period of 2012/13-2026/27

Plant Name	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	Total
Shoubra	35											315	630		315	
Sharm El-Sheik	178															
Hurghada GT	143															
El-Salam	22															
Suez GT	17															
Cairo West	350															
Abu Qir GT		24														
Port Said GT		49	24													
Karmouz GT		23														
Mahmodia GT		50														
Siuf GT		133														
Shabab GT		167														
Wadi Houf GT			100													
Asiut				30	60											
Damanhour						130	65									
Kafr Dawar								220				110		110		
Abu Kir											300	300				
Abu Soltan											300	150		150		
Ataka													300		300	
Wind								65				30	45	45		
Total capacity (MW)	745	446	124	30	60	130	65	285	0	0	600	905	975	305	615	5,285

Source: Data provided from EEHC during 6th mission

3) Reserve Margin

Target level of reserve margin in EEHC is about 15-17%.

Formula of the reserve margin is shown below.

$$\text{Reserve Margin (\%)} = \frac{\textit{Available Capacity} - \textit{Peak Load (sending end)}}{\textit{Peak Load (sending end)}} \times 100$$

The following items should be taken into consideration when deciding the reserve margin:

- LOLE[2] (loss of load expectation) service level is 0.997 (day per year)
- Error of demand forecast, (generally a value of 3% is adopted)
- Generation auxiliaries

[2] LOLE is a mathematical expectation of the number of days (or hours) in the year which the available generation plat will be inadequate to meet the instantaneous demand.

EEHC adopted a LOLE target value of 0.997 (day/year), which is equivalent to the power shortage probability of one day per year. Based on the Team's experience with other developing countries, a LOLE of 0.997 (day/year) is approximately equivalent to a reserve margin of about 10%.

Forecast peak loads are defined as the value at the generation end, whereas the Team defines the reserve margin using the formula shown previously. Generation auxiliary consumption (loss) rates should, therefore, be taken into consideration for the forecast conditions. The average of generation auxiliary consumption (loss) rates in Egypt is about 3.13% in 2010/11.

Consequently, the target value for the reserve margin is estimated to be around 17%, which is the summation of three factors previously mentioned, i.e. LOLE, error of demand forecast and generation auxiliary consumption (loss) rate.

Estimated reserve margin in Egyptian power network is shown in Fig. 2-1-5.

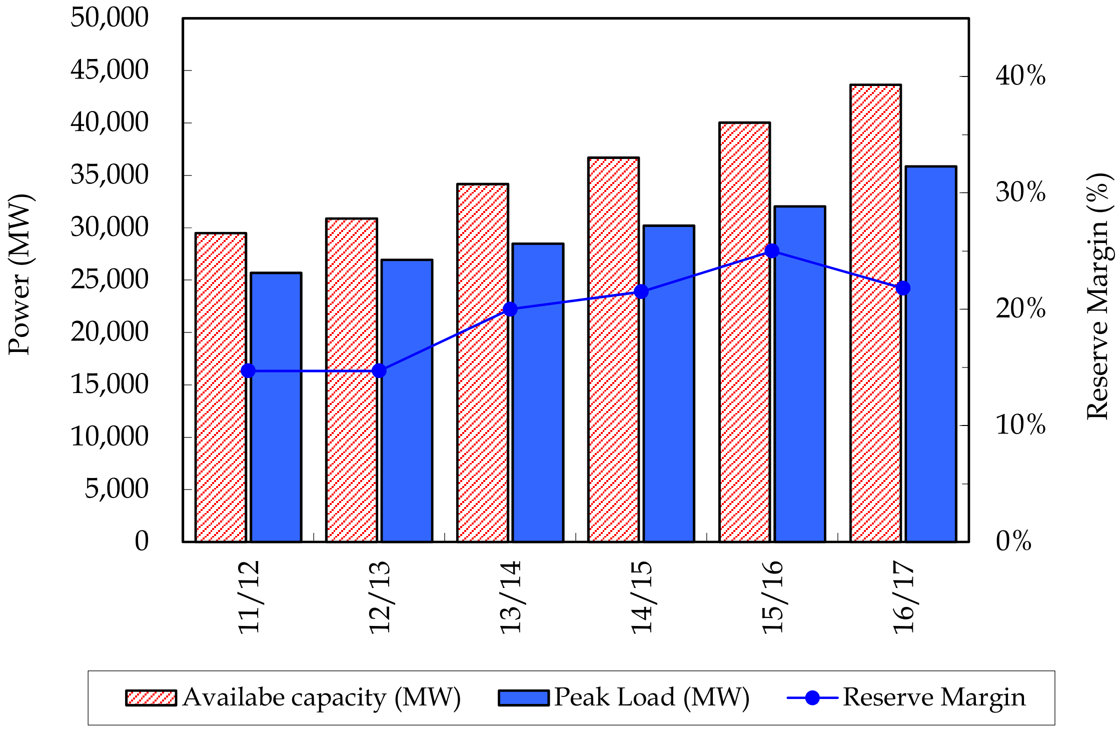


Fig. 2-1-5 Reserve margin in Egyptian power network up to 2016/17

Source: Analysis by JICA Study Team based on provided data

Clause 5 Tariff

The movement of the tariff structure from fiscal year 2003/2004 to 2009/2010 is shown in Table 2-1-13 as follows:

Table 2-1-13 Movement of End-User Power Tariff Rates

Pt./kWh

Category	2004	2005	2006	2007	2008	2009	2010	Price increase ratio
1) Power Service on Very High Voltage (Pt./KWh)								
1.Kima	4.7		4.7	4.7	4.7	4.7	4.7	0.0%
2.Metro- Ramsis			6.8	6.8	6.8	6.8	6.8	0.0%
3.Phosphate Abu-Tartour			6.8	6.8				
4.Somed			22	25.4	27.3	27.3	27.3	24.1%
5.Energy Intensive industries *1*2				13.33	20.2	20.2		
a- Out of peak							21.7	62.8%
b- During peak							32.6	144.6%
6.Other Industries *1*3					13.9	13.9		
a- Industries (Glass – Ceramic & Borcelen)							15.9	14.4%
b- Other industries (not mentioned above)							15.14	8.9%
7.Other Consumers	6.8		10.3	11.9	12.9	12.9	12.9	89.7%
2) Power Service on High Voltage (Pt./KWh)								
1.Metro – Toura				11.34	11.34	11.34	11.34	0.0%
2.Energy Intensive industries *1*2				16.13	24.5	24.5		51.9%
a- Out of peak							26.3	63.1%
b- During peak							39.5	144.9%
3.Other Industries *1*3					16.8	16.8		
a- industries (Glass – Ciramic & Borcelen)							19.2	14.3%
b- Other industries (not mentioned above)							18.6	10.7%
4.Other Consumers	11.34		12.5	14.4	15.7	15.7	15.7	38.4%
3) Housing Companies (Pt./KWh)	10.7		12	13.9				

Category	2004	2005	2006	2007	2008	2009	2010	Price increase ratio
4) Power Service on Medium & Low Voltage								
1. More than 500 kW								
a- Energy Intensive industries *1 *2								
* Demand Charge (LE/kW-month)				9	10.4	10.4	12.1	34.4%
* Energy Rates (Pt./kWh) *3				22.03	33.4	33.4		
**Out of peak							35.8	62.5%
**During peak							53.8	144.2%
b- Other Industries *1 *4								
* Demand Charge (LE/kW-month)							11.1	18.9%
* Energy Rates (Pt./kWh)							26.3	14.3%
*Other industries (not mentioned above.) :								
- Demand Charge (LE/kW-month)					9.5	9.5	11.1	18.9%
- Energy Rates (Pt./kWh)					23	23	25.5	10.9%
c- Other Customers								
* Demand Charge (LE/kw-month)	7.3	7.67	8	8.6	9	9.5	9.5	30.1%
* Energy Rates (Pt./kWh)	15.35	16.12	17	18.3	19.7	21.4	21.4	39.4%
2. Up to 500 kW								
a-Agriculture	7	8.5	9	9.7	10.4	11.2	11.2	60.0%
b-Other consumer (Government & Utilities)	18	18.9	20	21.5	23.1	25	25.0	38.9%
5) Residential								
1. first 50 kWh monthly	5	5	5	5	5	5	5	0.0%
2. 51-200 kWh monthly	8.3	8.72	9.2	10	10.7	11	11	32.5%
3. 201-350 kWh monthly	11	11.85	12.5	13.6	14.9	16	16	45.5%
4. 351-650 kWh monthly	15	16.8	18	19.6	21.6	24	24	60.0%
5. 651-1000 kWh monthly	21	23.7	25.5	28	31.1	39	39	85.7%
6. More than 1000 kWh monthly	25	28.5	31	34.2	38	48	48	92.0%
6) Commercial								
1. first 100 kWh monthly	18	18.9	19.8	21.3	22.9	24	24	33.3%
2. 101-250 kWh monthly	26	27.3	28.7	30.9	33.5	36	36	38.5%
3. 251-600 kWh monthly	33.2	34.8	36.6	39.3	42.5	46	46	38.6%
4. 601-1000 kWh monthly	41	43.05	45.3	48.7	52.5	58	58	41.5%
5. More than 1000 kWh monthly	43	45.15	47.5	51.1	55	60	60	39.5%
7) Public Lighting	30	31.5	33.1	35.6	38.3	41.2	41.2	37.3%

Notes

**1 Electricity Prices applied to industries Subjected to Prime Minster Decree*

**2 Energy intensive industries before2009 is (Glass - Ceramic - Chemicals - Iron - Cement -Fertilizers - Aluminum - Cupper - Petrochemicals).*

Energy intensive industries in 2010 are (Iron - Cement -Fertilizers - Aluminum - Cupper - Petrochemicals).

**3 Average of "Out of peak" and "During peak"*

**4 Other Industries (food - Textile - Pharmaceutical Industries - Engineering - ....)*

No end-user power price information in Annual Report of EEHC 2004/2005

The prices are based on Power Factor 0.9

Source: Annual Report of EEHC 2009/10 & Data provided from EEHC during 6th mission

The latest tariff structure of fiscal year 2011/2012, was provided from EgyptERA (Egyptian Electric Utility and Consumer Protection Regulatory Agency) as shown in Fig. 2-1-6 after final mission. Section 2, Clause 3 of this Chapter describes the objectives and activities of EgyptERA.

Tariff structure

Prices of selling the electricity power

Consumers	Price
1) Power Service on Extra High Voltage (Pt./ KWh)	
Kima	4.7
Metro - Ramsis	6.8
Arabian Company for Petrol Pipes (Somed)	27.3
a)Energy Intensive Industries (Iron-Cement-Fertilizers-Aluminum-Copper-Petrochemicals)*	27.7
* Fixed Demand charge (**L.E / Kw- month)**	12.1
* Prices of the consumed electricity power increased by 50% in this sectors during the peak hours (four hours and its start will be determined by The Ministry of Electricity and Energy)	
b) Industries (Glass - Ciramic and Borclen)	25.2
* Fixed Demand charge (**L.E / Kw- month)**	11.6
c) Others Industries (not mentioned in a & b)	15.4
* Fixed Demand charge (**L.E / Kw- month)**	11.1
d) Other Consumers	12.9
2) Power Services on High Voltage (Pt./ KWh)	
Metro - Toura	11.34
a)Energy Intensive Industries (Iron-Cement-Fertilizers-Aluminum-Copper-Petrochemicals)*	30.0
* Fixed Demand charge (**L.E / Kw- month)**	12.1
* Prices of the consumed electricity power increases by 50% in this sectors during the peak hours (four hours and its start will be determined by The Ministry of Electricity and Energy)	
b) Industries (Glass - Ciramic and Borclen)	28.6
* Fixed Demand charge (**L.E / Kw- month)**	11.6
c) Others Industries (not mentioned in a & b)	18.6
* Fixed Demand charge (**L.E / Kw- month)**	11.1
d) Other Consumers	15.7
3) Power Service on Medium and Low Voltage (Pt./ KWh) **3-1 - More than 500 KW**	
a)Energy Intensive Industries (Iron-Cement-Fertilizers-Aluminum-Copper-Petrochemicals)*	35.8
* Fixed Demand charge (**L.E / Kw- month)**	12.1
b) Industries (Glass - Ciramic and Borclen)**	32.7
** Fixed Demand charge (**L.E / Kw- month)**	11.6
c)** Others Industries (not mentioned in a & b)	25.5
** Fixed Demand charge (**L.E / Kw- month)**	11.1
d) Other Consumers	21.4
Demand charge for the actual recorded maximum load (**L.E/ KW)**	9.5
3-2 up to 500 KW	
a) Agriculture and Land Reclamation*	11.2
*Charge for electricity consumption per fedan for Irrigation by groups (**L.E**)	135.2
b) Other Consumers	25.0
4) Residential:	
1) First 50 KWh monthly	5.0
2)51- 200 KWh monthly	11.0
3)201-350 KWh monthly	16.0
4)351-650 KWh monthly	24.0
5) 651- 1000 KWh monthly	39.0
6) More than 1000 KWh monthly	48.0
5) Commercial:	
1) First 100 KWh monthly	24.0
2)101-250 KWh monthly	36.0
3)251-600 KWh monthly	46.0
4)601- 1000 KWh monthly	58.0
5) More than 1000 KWh monthly	60.0
6) The public and traffic lights (Pt./ KWh)	41.2

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Fig. 2-1-6 Tariff structure of fiscal year 2011/2012

Source: Data provided from EgyptERA

Regarding tariff for industrial companies it has been divided into two groups based on the Prime Ministry Decree as shown in Fig. 2-1-7.

Tariff Price to be applied
According to the Prime Minister decree no. 37/11/11/4 for the year 2011
Starting from 1st Jan. 2012

Firstly: The prime minister's decree no. 37/11/11/4 has to be applied for determining the electricity price for Industrial companies which ensure dividing the industrial sectors into two groups according to the following:

First Group: For the Energy intensive industries (Iron - Cement - Fertilizers - Aluminium - Cupper - Petrochemicals)

First Group	Price according to Prime Minister's decree number 2130 for the year 2010 on the base that natural gas price is 3 U$ dollars for each million Thermal Unit starting from 1st July 2010		Price according to Prime Minister's decree number 37/11/11/4 on the base that natural gas price is 3 U$ dollars for each million Thermal Unit starting from 1st Jan. 2012	
	Out of peak	During peak	Out of peak	During peak
Very High voltage	21.7	32.6	27.7	41.5
High voltage	26.3	39.5	30	45
Medium voltage Fixed price for Energy	35.8	53.7	35.8	53.7
Fixed demand charge (LE/kw-month)	12.1		12.1	

Second Group: For other industries sectors (Glass - Ceramic & Porcelain)

Second Group	Price according to Prime Minister's decree number 2130 for the year 2010 on the base that natural gas price is 2.3 U$ dollars for each million Thermal Unit starting from 1st July 2010	Price according to Prime Minister's decree number 37/11/11/4 on the base that natural gas price is 2.3 U$ dollars for each million Thermal Unit starting from 1st Jan. 2012
Very High voltage	15.9	25.2
High voltage	19.2	28.6
Medium voltage Fixed price for Energy	26.3	32.7
Fixed demand charge (LE/kw-month)	11.1	11.6

Secondly: Third Group: Including all the other industrial sectors not mentioned in the First & Second groups.

The price increase for this goup was postponed to be done in future phase because it will effect all the products and services offered to the citizens

Third Group	Price according to Prime Minister's decree number 2130 for the year 2010 on the base that natural gas price is 2 U$ dollars for each million Thermal Unit starting from 1st July 2010	Price according to Prime Minister's decree number 37/11/11/4 on the base that natural gas price is 2 U$ dollars for each million Thermal Unit starting from 1st Jan. 2012
Very High voltage	15.4	15.4
High voltage	18.6	18.6
Medium voltage Fixed price for Energy	25.5	25.5
Fixed demand charge (LE/kw-month)	11.1	11.1

Prices of the consumed electricity power in the first group will be increased by 50% during the peak hours (four hours a day and its starting time will be determined by the Ministry of Electricity and Energy).

Fig. 2-1-7 Tariff for industrial companies

Source: Data provided from EgyptERA

EETC transfers power to 9 EDCs and EDCs sell electricity to end users in normal case. But for customers who are connected to HV or VHV lines, EETC sells electricity directly to customers from Category 1) to 3) in Table 2-1-13. Usually, those customers are large scale and large demand entities.

The unit price of each category has been increased for these years but the increase ratios are different for each category. In general, higher rates are set for large demand customers and lower rates are set for small demand customers. Electricity tariff structure is a kind of income redistribution system. The rate for the first 50 kWh monthly residential uses remains the same for more than 7 years. It seems to be a reflection of government policy for low income households.

Power tariffs to end-users have been raised and those tariffs are expected to be increased in the near future. There are many factors which may affect electricity price to end-users, such as inflation rate, electricity demand, electricity production costs, electricity transmission costs, electricity distribution costs and other social factors such as, population increase, economic situation and political situation. Analyzing past and present situation of the above factors in Egypt, the Team may not expect drastic change in these situations in the near future. If so, trend of power tariff will not be so different from past tendency.

Section 2 New and renewable energy

Clause 1 Current situation of new and renewable energy

The Government of Egypt (GoE) realized in the early 1980' that conventional energy sources would fall short of satisfying the growing energy needs, thus, requiring other resources for establishing an optimum energy mix along with implementing energy conservation measures. Accordingly, a national strategy for promotion and development of renewable energy applications and energy conservation measures was formulated in 1982 as an integral part of the national energy planning.

In 1986, the New & Renewable Energy Authority (NREA) was established to act as the national focal point to introduce and promote renewable energy technologies for potential applications, particularly generating electricity on a commercial scale together with implementation of related energy conservation measures.

On April 10, 2007, The Supreme Energy Council in Egypt adopted a resolution on an ambitious plan aiming at increasing the contribution of renewable energy to reach 20% of total energy generation by 2020 including 12% from wind energy and hydro power and other renewable resources by 8% solar energy.

The target will be met by scaling up grid connected wind energy capacity to reach 7200MW in 2020 producing about 31 billion kWh yearly, in addition to other renewable energy such as solar and hydro power, with rising trend for solar energy.

1) Current situation and development plan for Wind Energy

a) History and outline of wind power in Egypt

In 1988, the 1st demonstration wind park was established in Ras Gharib on the Gulf of Suez constituted of 4 units, 100kW each, stall regulated machine, WINCON type which were fully imported from Denmark.

In 1992, the 2nd demonstration wind park was established in Hurghada on the Red Sea Coast and associated with program for transfer of manufacturing technology which resulted in the local manufacture of 45% of the value of equipment comprising towers, blades and nacelles. The Hurghada demonstration wind park is constituted of 4 units, 100kW each, partly locally manufactured wind mills. This wind park was connected to the local electrical distribution grids with fully successful operation.

Photo2-2-1 Hurghada demo wind park

NREA has implemented wind energy projects at NREA site in Hurghada. The wind park consists of 38 wind turbines with total installed capacity of 5MW including different designs and sizes in the following phases:

- The 1st phase: 1MW capacity was operated in June 1993 using 10 units, 2 blades & 100kW each, pitch regulated machine, Ventis type
- The 2nd phase: 2MW capacity was operated in June 1994 using 20 units, 3 blades & 100kW each, stall regulated machines, WINCON type
- The 3rd phase: 1.8MW capacity was operated in 1995 using 6 units, 3 blades & 300kW each, stall regulated machines Nordtank type
- Rehabilitation and installation of 2 wind turbines (100kW each) that were previously erected in Ras Gharib

Photo2-2-3 Hurghada wind park (WINCON type)

Photo2-2-4 Hurghada wind park (Ventis & Nordtank)

b) Zafarana Wind Park

The assessment of the wind energy resources along the Red Sea Coast has shown a very high potential. An area of 80km^2 was dedicated for NREA by a presidential decree as an institutional support and GOE Commitment to the wind energy program. The program was to construct a 600MW wind park in successive stages. Each stage was planned to be about 60MW capacity. NREA planned that 300MW shall be jointly financed through the state budget and donor countries, while the private sector are encouraged to finance the other 300MW under BOOT (Built-Operation-Own-Transfer) or BOO (Built-Operation-Own) schemes. But this scheme has been changed and all the area was developed by NREA with donors' support.

A 220/22kV substation equipped with 75MVA transformers at Zafarana was established together with 220kV transmission line for connection to the nearest substation in national grid. The old transformers have been replaced by 125MVA transformers.

And another 220/22kV substation was established with 220kV transmission line as an extension to connect the latest stage of wind turbines.

Zafarana Wind Park is developed as the following stages and phases:

- 1st stage: 60MW in cooperation with DANIDA
  - ✓ 1st phase: 30MW in total, 600kW each, Nordex type, operated in March 2001
  - ✓ 2nd phase: 30MW in total, 660kW each, Vestas type, operated in December 2003
- 2nd stage: 80MW in cooperation with KfW
  - ✓ 1st phase: 33MW in total, 600kW each, Nordex type, operated in March 2001
  - ✓ 2nd & 3rd phase: 47 MW in total, 660kW each, Vestas type, operated in December 2003
- 3rd stage: 85MW in cooperation with Spanish government
  - ✓ 85MW in total, 850kW each, Gamesa type, operated in April 2007
- 4th stage: 120MW in cooperation with JBIC
  - ✓ 120MW in total, 850kW each, Gamesa type, operated in June 2009
- 5th stage: 80MW in cooperation with KfW
  - ✓ 80MW in total, 850kW each, Gamesa type, operated in 2008
- 6th stage: 120MW in cooperation with DANIDA
  - ✓ 120MW in total, 850kW each, Gamesa type, operated in 2010


Photo2-2-5 Zafarana wind park 1


Photo2-2-6 Zafarana wind park2

c) Future projects

According to PDP provided from NREA (Table 2-1-11), NREA plans to implement wind projects with total capacities of 9,720W by 2026/27 as part of its strategy to promote wind energy. NREA is currently attempting to achieve wind projects with total capacity of 1,120MW as described in the following:

[540MW wind farms in Gulf El Zayt are under implementation]

- ✓ 200MW wind farm in cooperation with KfW, EIB and EU.
  - ✧ Consultancy contract was signed in Nov.2009, and planned to start operation in the middle of 2013.
- ✓ 220MW wind farm in cooperation with JICA.
  - ✧ The loan agreement was signed in Mar.2010 and consultancy contract was made in 1st July 2012, and it is expected to be completed and operated in the middle of 2015.
- ✓ 120MW wind farm in cooperation with Spain.
  - ✧ NREA has already prepared tender documents and have sent it to the Spanish side, these are being reviewed now. It is expected to be completed and operated in Oct.2014.

[580MW wind farms are being financed]

- ✓ Two wind farms with capacities of 180MW (140MW +40MW) are planned in the Gulf of Suez.
- ✓ 200MW wind farm with Masdar Company which is owned by Abu Dhabi government.
- ✓ 200MW wind farm project in cooperation with KfW, French Development agency, European Investment Bank, and EU is planned to be in Gulf of Suez.

In addition to the on-going above projects, the following projects are under preparation/negotiation:

- ✓ 700MW wind farm projects in West Nile valley including 200MW project to be supported by JICA (under studying).
- ✓ Private sector projects with the total capacity of 1,370 MW are under preparation/negotiation.

2) Current situation of solar power developed by NREA

a) Solar heater

During the 1980's, 1000 of solar flat plate water heaters were imported and installed by MoEE. As a result, 10 local solar thermal product companies were established in Egypt. Nowadays, about 400 thousand solar heaters have been manufactured and installed in Egypt until the year 2009. Disseminating solar heaters project in hotels located in Red sea and Sinai is under implementation nowadays. This project is implemented with the cooperation with Italian government and United Nations Environmental Program (UNEP).

Photo2-2-7 Solar water heater
Medical center: 2008
Source: Annual Report of NREA 2009/2010

b) Kuraymat 140MW integrated solar combined cycle power plant

The project based on parabolic trough technology integrated with combined cycle power plant using natural gas as a fuel. The capacity of the project is 140MW including solar share of 20MW. Total cost is 340Million US$. The project has completed and operated in 2011.
Solar portion's cost is approximately 75.6Million US$ (including foreign and local portion), thus, unit price of solar thermal generation is approximately 3.8US$/W in this project.

Photo2-2-8 Solar Thermal Plant
in Kuraymat: 2010
Source: Annual Report of NREA 2009/2010

c) Photovoltaic systems

The total capacity of photovoltaic systems in Egypt is around 10 MW. Purpose of installation is for lighting, water pumping, wireless communications, cooling, and commercial advertisements on highway. They are used at rural and remote areas of small scattered loads which are far away from national grid.

Photo2-2-9 Off grid Photovoltaic system at remote area : (Awlad El Shikh Behera)
Source: Annual Report of NREA 2009/2010

Lighting villages project in cooperation with the Italian ministry of environment was accomplished to supply electricity to two remote settlements in Matrouh Governorate by photovoltaic system. The project consists of the following:

- ✓ Lighting of 100 houses and 40 street light units.
- ✓ 1 school and 3 mosques.
- ✓ 2 medical clinic units.

The project has been completed and operated since Dec.2010.

Photo 2-2-10 Lighting village project1

Photo 2-2-11 Lighting village project2

3) Current situation of photovoltaic power plant developed by another sector

First grid connected type photovoltaic power plant in Egypt has been built in November 2011 by public company named Arab Organization for Industrialization (AOI).

Photovoltaic power plant is situated in a suburb of the Greater Cairo. It has been installed in the site of their factory. The team visited the site, and made a confirmation of their situation.

The photovoltaic power plant has 500kW fixed frame photovoltaic modules and 100kW 2-axis sun-tracking system. Tilted angle of fixed frame is 26 degree. And the distance between 2 arrays is 2.5 times of the height of the array, thus arrays height is 1.8meter, distance between 2 arrays is 5 meter. This distance seems enough for taking into consideration the effect of the shadow of southern array.

Their modules are poly-crystalline type Chinese products manufactured by Torina solar, and Inverters are Spanish products manufactured by Gamesa.

Sun tracking system is operated by scheduled programming controller. They have mentioned that the tracking system is able to earn more 30-40% additional power than the fixed system.

Generated power is sent by connected line to the grid, however they have no contract to selling electricity to EETC. They mentioned that they are waiting for the issuing of the new electric power law which will enable them to sell electricity from photovoltaic power plant.

Modules are cleaned by high pressure water sprayer. Cleaning period is determined by the conditions of the modules. It was informed that the cleaning interval is approximately 1months normally, but in the dusty season, it will be 2-3weeks. A machine with a water nozzle and 600 liter water tank on the carriage is used, as shown in following photo. This machine can wash each 25kW modules by using 1 water tank (600 liter).

Photo 2-2-12 500kW fixed frame PV system in Cairo

Photo 2-2-13 100kW PV system with sun tracking system in Cairo

Photo 2-2-14 PV washing machine using high pressure water

Clause 2 Solar Power Development Plan

1) NREA

Solar projects are considered one of the main aspects to increase the contribution to renewable energies and NREA's latest power development plan described in Table 2-1-11, which includes:

- ✓ Solar thermal electricity generation plants, with total capacity of 2,800 MW
- ✓ Photovoltaic power plants, with total capacity of 700 MW

One of the solar thermal projects with capacity of 100 MW is proposed in Kom Ombo city. For photovoltaic power plant projects with capacity of 20MW is proposed neighboring above solar thermal power plant also in Kom Ombo city other than this study.

Feasibility study of the solar thermal project is implemented through cooperation with KfW. The World Bank agreed to participate in financing the project through soft loan with amount of 100 million dollar under the Clean Technology Fund (CTF) program with the possibility of allocating 1 million dollar for preparing all the relating studies.

And Egyptian government presented an official request to the African Development Bank and the World Bank to get 300 million dollar as soft loan.

NREA participates in the EU Program Exploring & Motivating sustainable Power markets (EM Power). The country visit report has been prepared and the Kom Ombo site has been selected as one of the best sites for implementing CSP project and Farafra Oasis for photovoltaic project to be development under EM Power.

Feasibility study of the photovoltaic power plant in Kom Ombo is under preparation (Expression of interest for the Consultant was closed on October 8, 2012). This study is donated by French Agency Development (AFD) by grant of 800,000 Euro. Technical, financial, environmental and economic impact will be studied, and the term of study will be 8 months.

Clause 3 Power Sector Reform for New and Renewable Energy

1) Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA)

EgyptERA is operated since 2001. According to EgyptERA, objectives of EgyptERA are as follows:

- ✓ Regulates and supervises all electricity generation, transmission and distribution.
- ✓ Issuing licenses for the construction, management, operation, and maintenance of the electric power generation.
- ✓ Ensures availability of supply to users at the most equitable prices and considers environmental issues.
- ✓ Prepares for fair competition in the field of electricity including generation and distribution.
- ✓ Prevents any monopoly within the electricity market.
- ✓ Considers interests of customers, producers, transmitters, and distributors.
- ✓ Approval of guidelines, codes and schemes related to energy supplying projects.
- ✓ Promote and support investments in renewable energy projects.

2) Direction of new renewable energy laws and decrees

Although new frame work for renewable energy to be defined in decrees as well as new electricity law, which will support the renewable energy development are not issued yet, EgyptERA assumes four strategies for the project implementation mechanisms. Such mechanisms will be used for promoting renewable energy development in direction to be defined in new renewable energy laws and new related decrees.

The four strategies are summarized as follows:

- ✓ 1st mechanism: Projects established by NREA
- ✓ 2nd mechanism: Projects established by private sectors through Egyptian Electric Transmission Company (EETC) by competitive biddings (BOO)
- ✓ 3rd mechanism: Projects established by EETC through Feed-in-Tariff (FIT)
- ✓ 4th mechanism: Projects established through constructing and operating renewable energy power plants, and then selling the generated electricity to customers directly.

Regulations for those implementation strategies are as follows:

- ✓ "Guidelines for Energy Supply to Investment Projects" approved by EgyptERA
- ✓ The Cabinet approved regulations for land allocations for wind power plants

- ✓ The Grid Code and the Wind Code (the draft Grid Code is as attached in Appendix 2-1)
- ✓ Implementation of certificate scheme called "Guarantee of Origin (GoO)"

It is noteworthy mentioning that, there also is an activation of "Renewable Energy Fund (RE Fund)", which was approved by the Cabinet in 2012 to cover the cost difference between production and selling price.

Details of the "Promoting Investments in Renewable Energy Projects" are shown in Appendix 2-2.

Section 3 Supporting Status and Policies of other Donors

Clause 1 Supporting Status and Policies of Africa Development bank (AfDB)

1) Outline of AfDB

Outline of AfDB is as follows:

- Head quarter office of AfDB is located in Tunisia. There are 250 branch offices in African countries. AfDB has Egypt field office since 2000.
- AfDB has 3 types of fund schemes. African development fund for low incoming country, another is African development bank for commercial, and the third one is Fund for African Private-Sector Assistance (FAPA).

2) Supporting projects and studies for Egyptian power sector

a) Committed projects (loan or grant)

- ✓ Four Combined cycle steam turbine generation projects.

b) Studies

- ✓ Wind farm project Technical feasibility study stage for NREA and private sector. They are measuring wind resources now. The sites located northern side of Gulf El Zayt. KfW is covering private company's sector.
- ✓ Integration study of wind power future development plan for EETC by grant.
- ✓ Environmental study for NREA Kom Ombo 100MW solar power plant.
- ✓ Steam turbine or Bio-gas turbine of waste energy for private sector.
- ✓ Future energy structure study including nuclear power.
- ✓ Energy efficiency of generation side.

3) Supporting Policy

- ✓ AfDB is interested in energy efficiency of power generation and demand side in electric power sector.
- ✓ AfDB is supporting all kind of generation such as conventional generation and clean energy.

Clause 2 Supporting Status and Policies of World Bank (WB)

1) Outline of WB

Outline of WB is as follows:

- The World Bank comprises the International Bank for Reconstruction and Development (IBRD) and the International Development Association (IDA).
- Head quarter office of WB is located in United States of America.
- WB has more than 9,000 employees in more than 100 offices worldwide.

- WB has been invested from many countries, but practically, WB is raising almost all the development funds by issuing a WB bond in financial market.

2) Supporting projects and studies for Egyptian power sector

- ✓ The development of the Wind Power Development Project. First component is transmission infrastructure financed by IBRD/ Clean Technology Fund (CTF), European donors led by European Investment Bank, but including Agence Francaise de Developpment (AfD)/Neighborhood Investment Funds (NIF) and kfW/NIF. Second component is technical assistance to support the expansion of Egypt's wind generation program. Third component is Gulf of Suez 250 MW BOO project by a private sector operator under a BOO approach.
- ✓ The Giza North Power Project. It contributes to improving the security and efficiency of electricity supply in a sustainable manner. First component is Giza north power plant. Second component is the technical assistance. Third component is the project financing.
- ✓ Kuraymat Integrated Solar Combined Cycle Power Project. First component is design, construction and operation of the Integrated Solar Combined Cycle Plant. Second component is capacity building to NREA to ensure the smooth integration between the solar and the combined cycle portions of the plant. Third component is implementation of the environmental monitoring plan.

3) Supporting Policy

- ✓ WB is a unique partnership to reduce poverty and support development.
- ✓ The IBRD aims to reduce poverty in middle-income and creditworthy poorer countries, while IDA focuses exclusively on the world’s poorest countries.

Section 4 Necessity and Rationale of the Project

Necessity and rationale of new and renewable energy particularly wind energy and solar energy is summarized below:

- ✓ Present Egyptian energy structure is relied on a fossil energy.
- ✓ Dioxide carbon gas will increase in relation with energy growth, if the current situation remains the same.
- ✓ Fossil energy resources are assumed to be depleted in near future, and cost might increase.
- ✓ Energy resource should be distributed to many kinds of energy resources for energy security.
- ✓ Taking the above situation into consideration, new and renewable energy is one of the solutions for the energy issues.
- ✓ Egypt has many resources such as strong wind and dense solar radiation, thus Egypt is appropriate for using wind energy and solar energy.
- ✓ Development of wind energy and solar energy are one of the countermeasures for prolonging fossil energy exhaustion and multiplying of Egyptian resources.

Thus, "Supreme Council of Energy" was established by GoE in 2006. They had adopted a resolution to cover 12% of the generation capacity development plan of up to 2011, and by 2020 to cover 20% of the total generation capacity with renewable energy in their plan in 2006.

Necessity and rationale of photovoltaic power is summarized below:

- ✓ Solar energy can be converted to electricity by solar thermal generation and photovoltaic power.
- ✓ Both Solar thermal and photovoltaic power have merits and weak points. For example, although the photovoltaic cannot generate electricity in the evening peak time without costly batteries, solar thermal can continue to generate by using simple heat storage system. On the other hands solar thermal will be more costly for installation and O&M than photovoltaic. Actual situation and comparison between the two systems are described in the following clause.

Clause 1 Comparison between Photovoltaic and Solar Thermal

Although NREA have already had an experience of solar thermal plant in Kuraymat, large scale photovoltaic power plant is going to be the first experience in Egypt.

Existing major solar thermal plants in the world are listed in Table 2-4-1.

In these days a lot of concentrate type large scale photovoltaic power plants are constructed worldwide. In the world, 33% of the total installed capacity of the photovoltaic power is concentrate type photovoltaic power plant (See Fig. 2-4-1). Total capacity of whole photovoltaic power and concentrate type photovoltaic, for each country is shown in Fig. 2-4-2.

Table 2-4-1 Existing solar thermal plants

Country	Name of the project	Type	Capacity (MW)	Commissioning year
German	Solar Tower Julich	Tower	1.5	2008
Spain	PS10/Abengoa	Tower	11	2006
	Andasol1&2/Solar Millennium, ACS Cobra	Trough	100	2008-2009
USA	SEGS I/Luz, Solel	Trough	13.8	1984
	SEGS II-VII/Luz, Solel	Trough	180	1984-1989
	SEGS VIII-IX/Luz, Solel	Trough	160	1989-1990
	Saguaro APS Plant / Solargenix	Trough	1	2006
	Nevada Solar One / Acciona	Trough	64	2007
	Kimberlina / Ausra	Fresnel	5	2008
Egypt	Kuraymat	Trough Combined cycle	20 (Solar portion)	2011

Source: NEDO report "study current technological situation and various issues for penetration of unutilized energies" Feb.2009

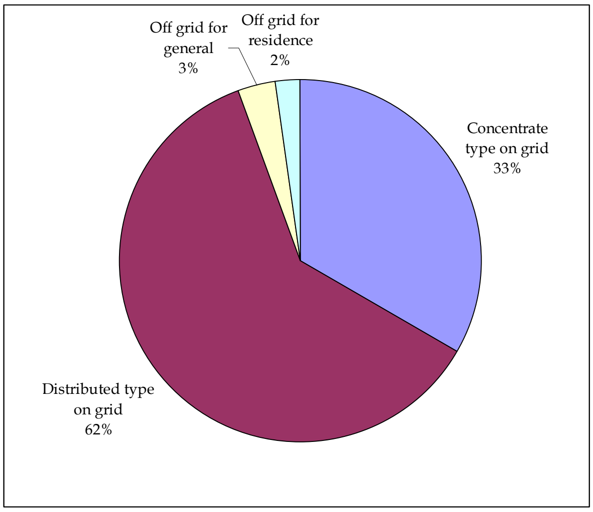
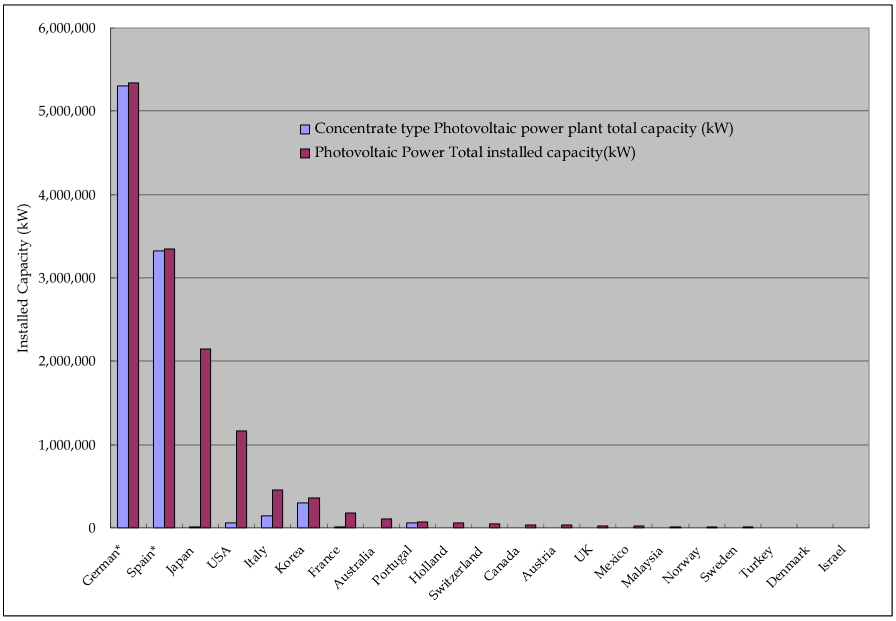


Fig. 2-4-1 Total installed capacity of photovoltaic classified by installation type

Source: NEDO report "wide range of research cooperation among advanced countries through collaboration in research and development on photovoltaic power generation within the framework of IEA PVPS, the activities for PVPS Task 1," Feb.2009



* Data of German and Spain are not divided to concentrated and distributed.

Fig. 2-4-2 Total installed capacity and total capacity of concentrate type photovoltaic power for each country

Source: NEDO report "wide range of research cooperation among advanced countries through collaboration in research and development on photovoltaic power generation within the framework of IEA PVPS, the activities for PVPS Task 1," Feb.2009

Here, the JICA Study Team (the team) made a comparison between solar thermal and photovoltaic power.

- Merit of solar thermal
  - ✓ Solar thermal can generate in the evening if it uses heat storage system.
  - ✓ It can be combined with conventional thermal plant, thus, it would be able to apply to big plant such as more than 100MW.
- Weak point of solar thermal
  - ✓ Solar thermal has a complex heat tube for centralizing heat to the turbine, thus, it requires high level maintenance work.
  - ✓ Concentrate Solar Power (CSP) system requires precise solar tracking system, thus, it also requires high level maintenance.
  - ✓ Solar thermal requires huge amount of water for cooling system. In the desert situation such as along red sea coast, huge amount of water is difficult to obtain.
  - ✓ It requires much water for cooling and produces much waste heat; therefore, it requires relatively deep EIA study.
  - ✓ This plant is constructed from huge amount of steel; therefore, construction cost will be fluctuated by market price of steel.

- Merit of photovoltaic
  - ✓ Photovoltaic has a very simple structure of system and it does not have movable parts in the system, thus, it requires very easy maintenance work.
  - ✓ Life time of the photovoltaic is longer than solar thermal, because there is no conventional generator, and all the equipment are static.
  - ✓ Photovoltaic does not have any boiling water or rotary equipment; therefore, the plant is very safe for not only the staffs but also for the public.
- Weak point of photovoltaic
  - ✓ Photovoltaic can generate only in the day time. If it is required supplying power in the evening peak time, it needs to install battery storage system. But cost of battery system is relatively expensive in actual situation.
  - ✓ Almost all photovoltaic modules are produced from silicon; therefore, cost of module will be fluctuated by market price of silicon.

Efficiency of photovoltaic and solar thermal is almost same level.
And the price of photovoltaic is going down drastically, because of global competition of a lot of production companies. Therefore, total price of the two systems is almost same level in actual situation.

Cost comparison of solar thermal and photovoltaic is shown in Fig.2-4-3. Cost of solar thermal is reference from previous study report, and cost of photovoltaic is a result of an interview with actual photovoltaic manufacturer who provide to large scale photovoltaic plants worldwide. The photovoltaic cost was give after asking about the actual cost and future prediction of total plant cost for 20MW photovoltaic plant.

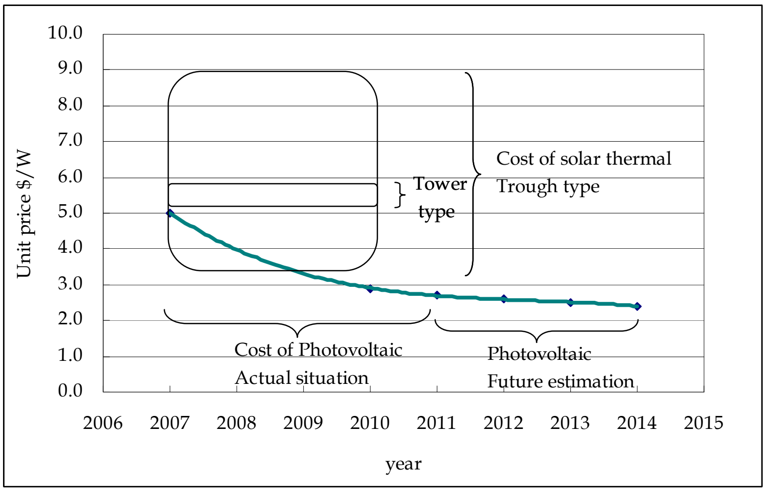


Fig. 2-4-3 Cost comparison of solar thermal and photovoltaic power

Source: NEDO report "study current technological situation and various issues for penetration of unutilized energies" Feb.2009 and added by the team

Comparison of solar thermal and photovoltaic power is shown in the following table. Although two systems will generate electricity nearly with the same energy, characteristics are different. Therefore mixing the two systems in the national grid is one of the solutions for adopting solar energy.

Table 2-4-2 Comparison of solar thermal and photovoltaic

	Solar thermal	Photovoltaic (PV)
Output energy control	It can be controlled as load following. It can apply to evening peak load with using heat storage system.	It can NOT be controlled as load following, except for installation of large capacity battery.
Installation cost	The cost is decreasing gradually.	The cost is decreasing dramatically. It seems to have become relatively cheap.
Operation and maintenance	It requires high level operation and maintenance technique.	Very simple structure. Easy to operate and maintain.
Environmental impact	It requires much water for cooling system, and produces much waste heat.	It doesn't have a big environmental impact.
Conversion efficiency	Almost same level as photovoltaic	Almost same level as solar thermal
Lifetime	Heat tube and turbine generator require replacing periodically.	Relatively long

Clause 2 Necessity of this Project

With considerations of Clause 1 of Section 2 and as stated in the power development plan (2011/12-2026/27) in Table 2-1-11, total capacity of 700 MW photovoltaic (PV) power plant is to be looked at for the project considering the following points;

- To achieve the goal to cover 20% of the total generation capacity with renewable energy by 2020, solar power takes an important part (2.2% of the 20%) while wind power is 12% and hydro power, 5.8%.
- Already, CSP has put in operation at Kuraymat Solar Thermal Power Plan whose total installed capacity is 140MW with solar share of 20MW.
- It should be realized that, from these backgrounds, to start a pilot project with PV power as soon as possible is necessary (NREA hopes that this project will be completed by end of 2016).
- This pilot project of PV will be a milestone for future expansion of PV projects with giving favorable results, and also will be the beginning of the continuous

expansions of PV projects for the future.

Taking into account the above, the Team understood that this PV project is indispensable for Egyptian power sector with the earliest implementation.

Chapter 3: Outline of the Project Scope

Chapter 3 Outline of the Project scope

Section 1 Basic data

Clause 1 Site location in Hurghada

1) Location

Site location for this project is situated in northern part of Hurghada city near by El-Gouna town, location on the map is shown in Fig. 3-1-1-1. Target site is located in NREA's Hurghada wind farm.

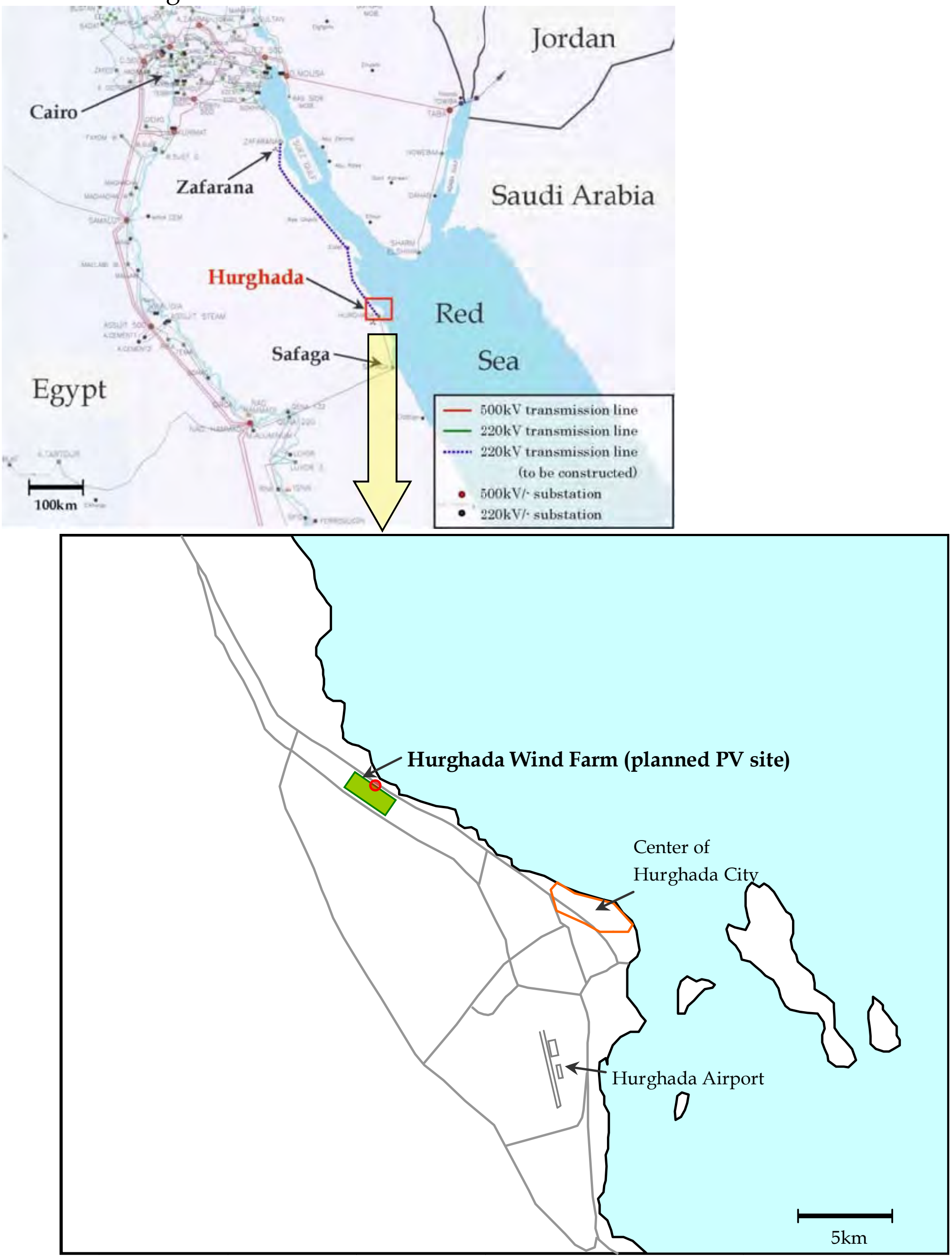


Fig. 3-1-1-1 Location of the target site

2) Current situation of the target site

- Hurghada wind farm is located in the northern side of Hurghada city along Hurghada – Ras Gharib road.
- Total capacity of wind farm is nominal 5.4MW. But some of the wind turbines are not in operation, because they are too old to maintain. As a consequence to this matter, the actual capacity of existing wind turbine is 4.2MW. The layout of the wind turbines is shown in Fig. 3-1-1-2.
- Number and type of wind turbine in the wind farm is as follows:
  - ✓ 100kW Wind turbine: in total 24 units including 4 units out of order
  - ✓ 300kW Wind turbine: 6 units
  - ✓ Small wind turbine (5 kW): 3 units (all of them are out of order)
  - ✓ American style (multi blade type) wind turbine: 1 unit (out of order)

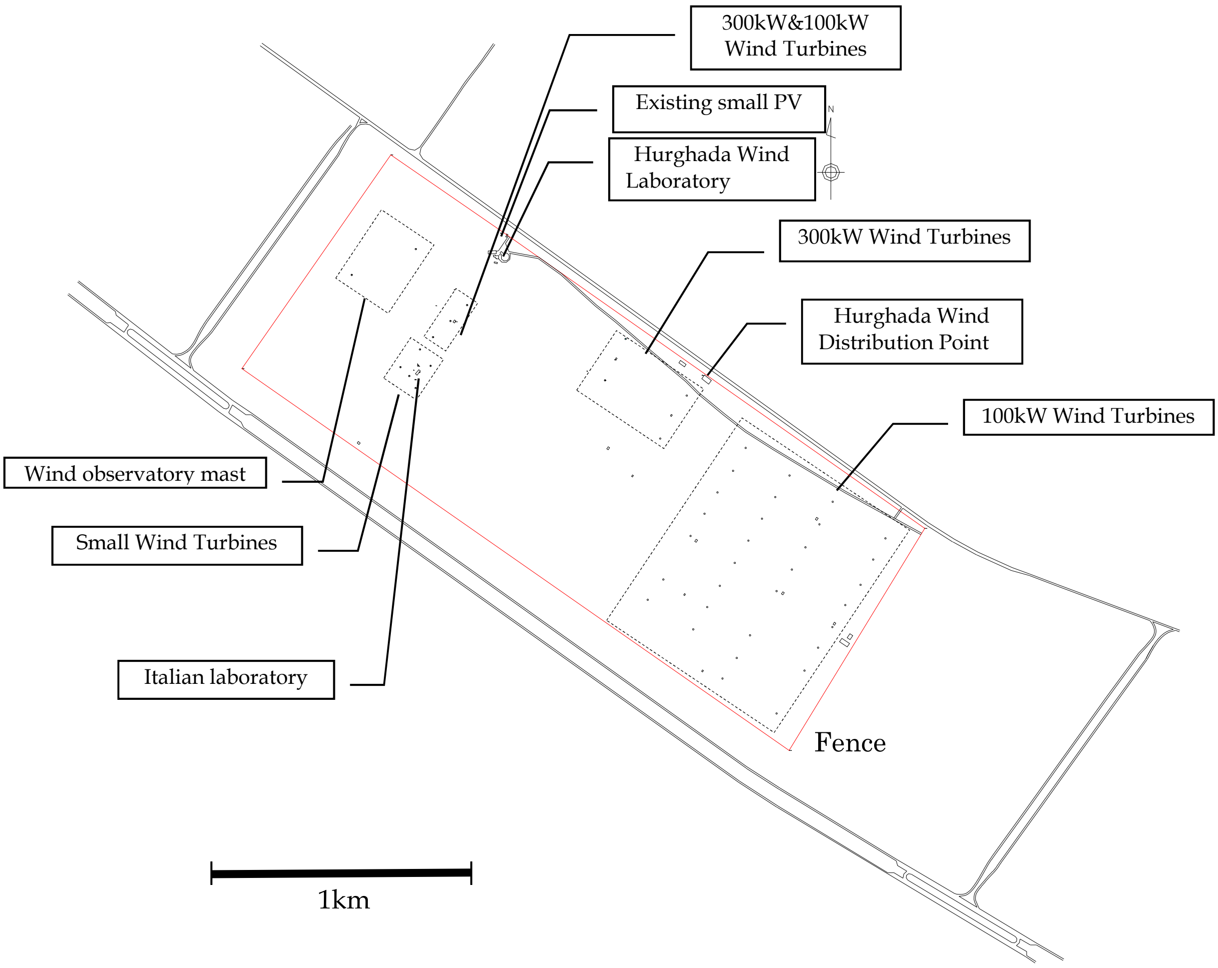


Fig. 3-1-1-2 Current situation of the target site

Photovoltaic (PV) modules shall be installed in available spaces in the wind farm area avoiding the existing wind facilities. There are a lot of wind turbines installed in the southern part of the wind farm area. From northern side to east side of the area, it is vacant for some wind facilities. Accordingly, it will be appropriate for the installation of the PV modules at the vacant area.

The candidate area is relatively inclined from northwest to south west around 30 degree.

There are many resort hotels and residences constructed/under construction surrounding the area of the target site.

Photo 3-1-1-1 Site condition (northern-side)(1)

Photo 3-1-1-2 Site condition (western-side)(2)

Photo 3-1-1-3 300kW and 100kW Wind turbine in the candidate site (3)

Photo 3-1-1-4 Wind observatory mast in the candidate site (4)

Photo 3-1-1-5 Existing small scale PV modules (5)

Photo 3-1-1-6 Existing SCADA for wind (6)

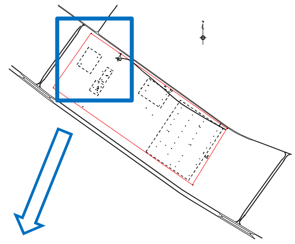
Photo 3-1-1-7 Hurghada Wind Laboratory (7)

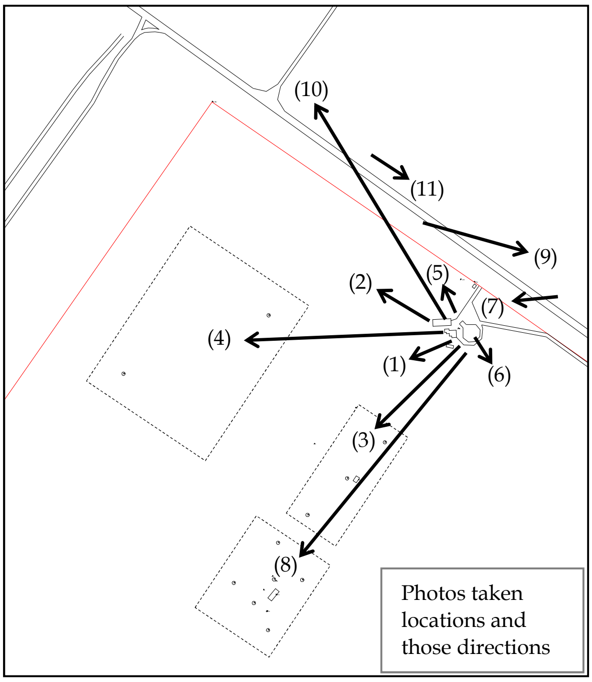
Photo 3-1-1-8 Italian laboratory (8)

Photo 3-1-1-9 Surround situation of the site1 (9)

Photo 3-1-1-10 Surround situation of the site2 (10)

Photo 3-1-1-11 Existing site border fence (11)





Photos taken locations and those directions

Clause 2 Current electricity facilities at Hurghada

1) Electric power network

Current situation of the electric power network in Hurghada is shown in Fig. 3-1-2-1. And the location of each substation and transmission line is as shown in Fig. 3-1-2-2.

Electric power is coming from Qena 220substation via Safaga substation by 220kV EHV transmission line to South Hurghada substation. South Hurghada substation is the biggest substation in Hurghada. Almost the entire Hurghada town is supplied with electricity from this substation.

NREA's Hurghada wind farm is connected by two 11kV distribution lines coming from Central Hurghada substation at the Hurghada wind distribution point located in the Hurghada wind farm. And also the Hurghada wind distribution point has 22kV switchgears. Two 22kV power lines are coming from Central Hurghada substation sending electric power to El-Gouna town. Layout drawing of the distribution point is shown in Fig. 3-1-2-3 and single line diagram of its connection to Central Hurghada substation is shown in Fig. 3-1-2-4.

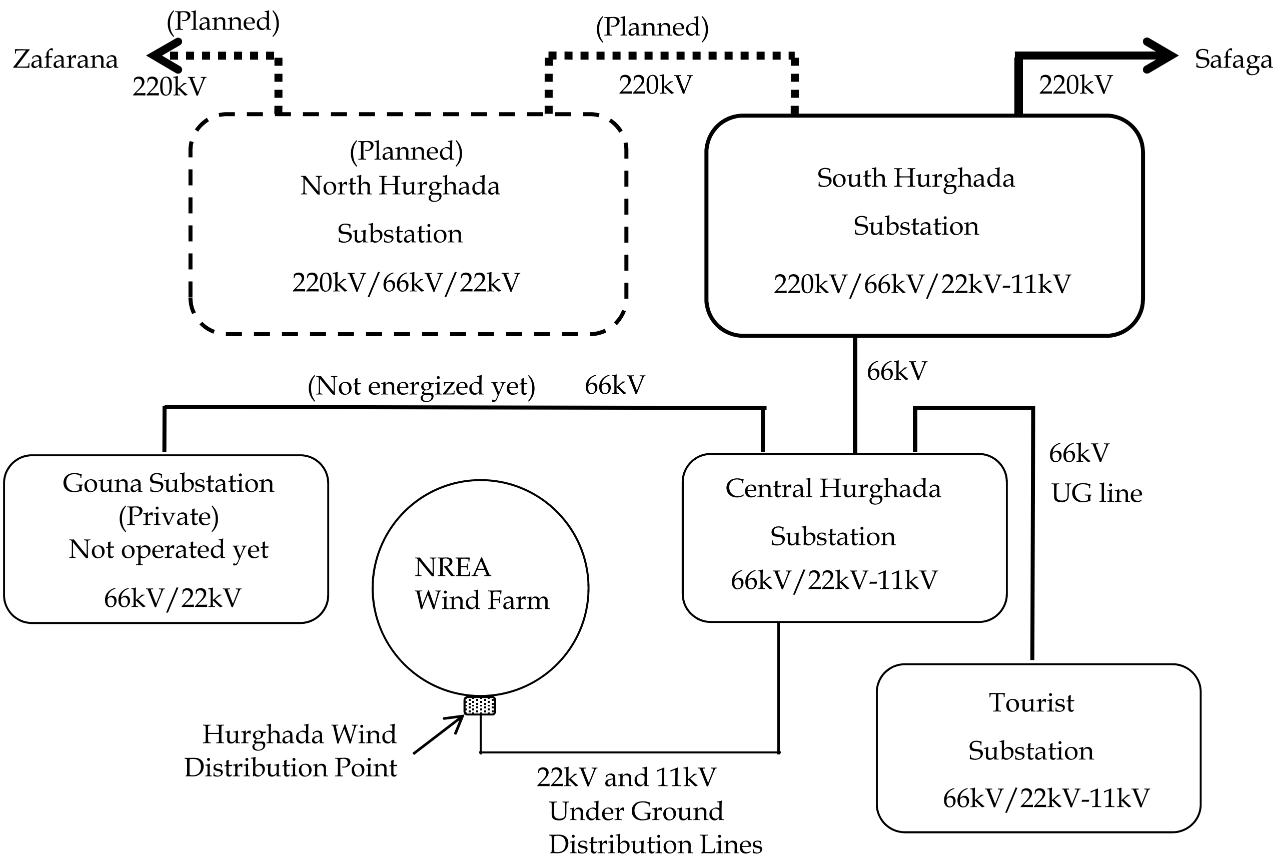


Fig. 3-1-2-1 Electric power transmission Line Network in Hurghada city

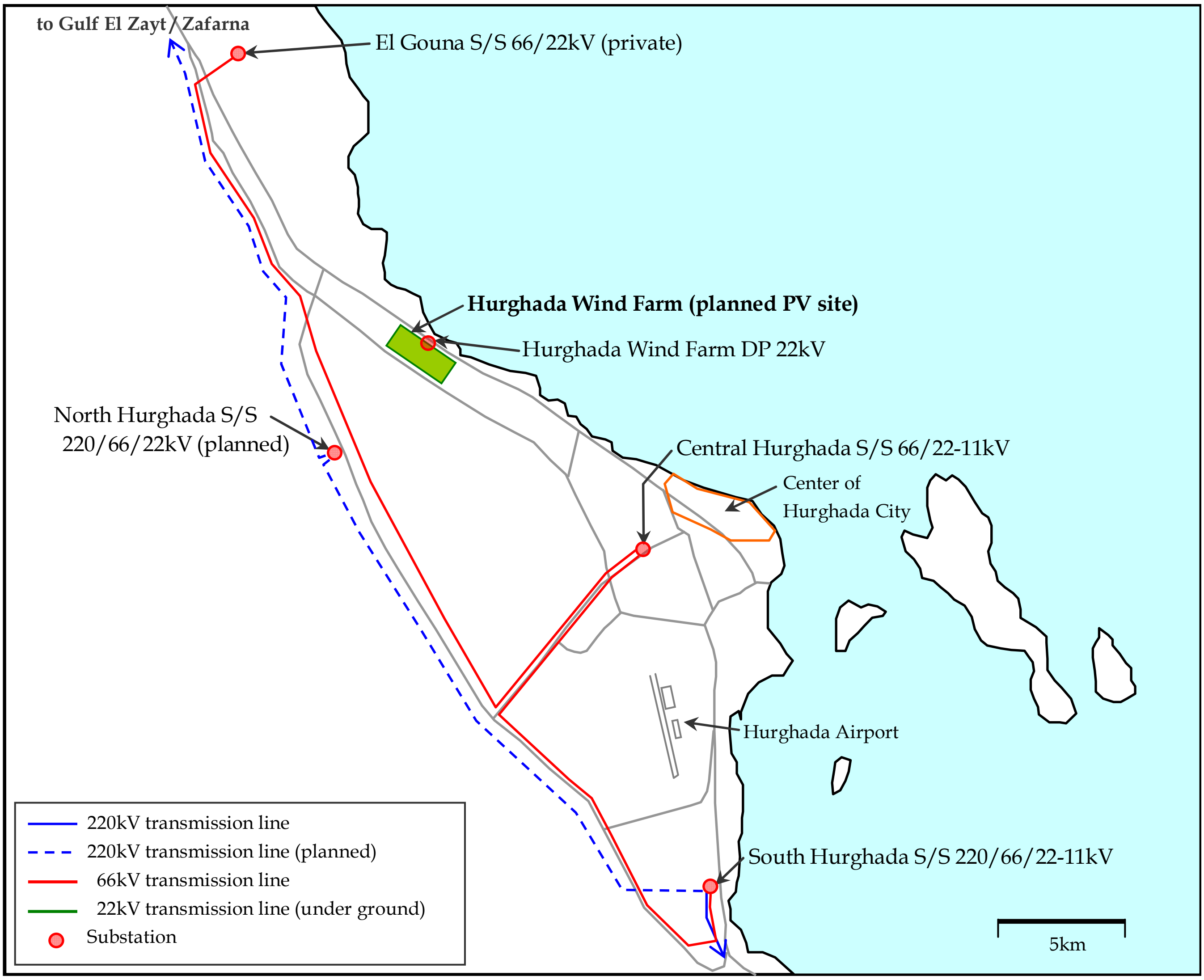


Fig. 3-1-2-2 Location of current electric power facilities

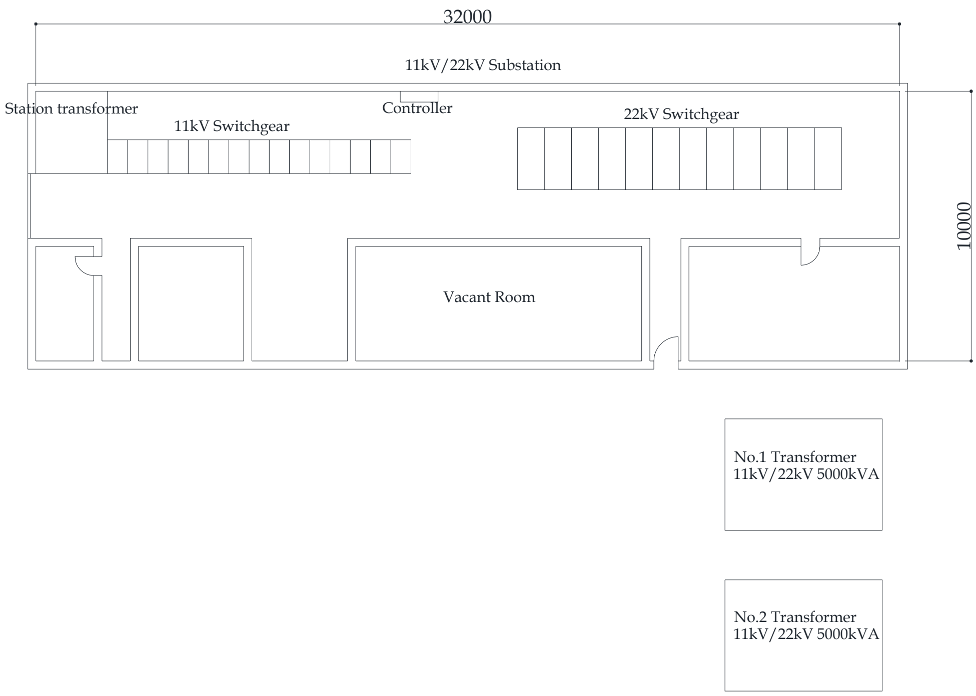
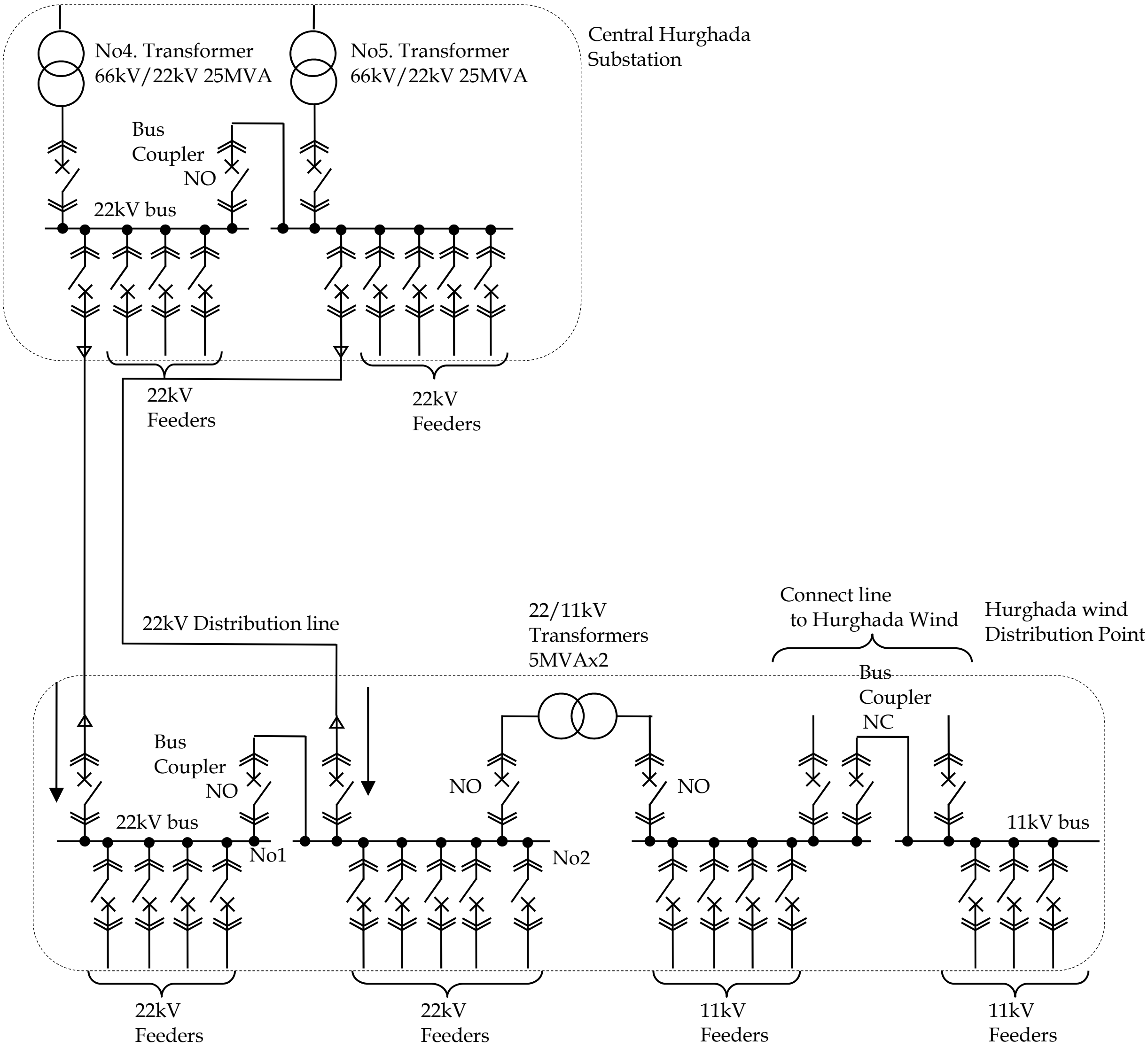


Fig. 3-1-2-3 Layout of existing 11kV/22kV Hurghada wind farm Distribution Point



*NO means Normal Open status, NC means Normal close status

Fig. 3-1-2-4 Current grid connection method between Central Hurghada substation and Hurghada Wind Distribution Point

- The current situations of the substations and transmission lines located around the candidate site is as follows:
  - ✓ 220kV/66kV/22-11kV substation named South Hurghada is located approximately 30km distance southeast of the candidate site.
  - ✓ 66kV/22-11kV Central Hurghada substation is located approximately in distance of 15km southeast from the candidate site.
  - ✓ 66kV transmission line from Central Hurghada to the direction of El-Gouna substation runs through approximately 3km distance south of the candidate site.
  - ✓ EETC has a plan for constructing new 220kV substation named North Hurghada. It will be located along the above 66kV transmission line near

NREA's wind farm. But implementation schedule is not yet decided.

- ✓ 66kV/22kV El-Gouna substation is owned by private company. It has already been constructed, but not yet energized. When it is energized, 22kV existing distribution lines from Central Hurghada substation will be substituted to this substation.
- ✓ There are 22kV and 11kV Distribution Point owned by Canal Distribution Company located in the NREA wind farm area. Existing wind turbines are connected into this 11kV bus bar in the distribution point.
- ✓ NREA and CEDC have made a PPA (Power Purchase Agreement) for generated power from existing Hurghada Wind Farm. This project will be applied of same concept of the existing one.

Existing power cable and electric facilities in Hurghada wind farm is shown in Fig. 3-1-2-5.

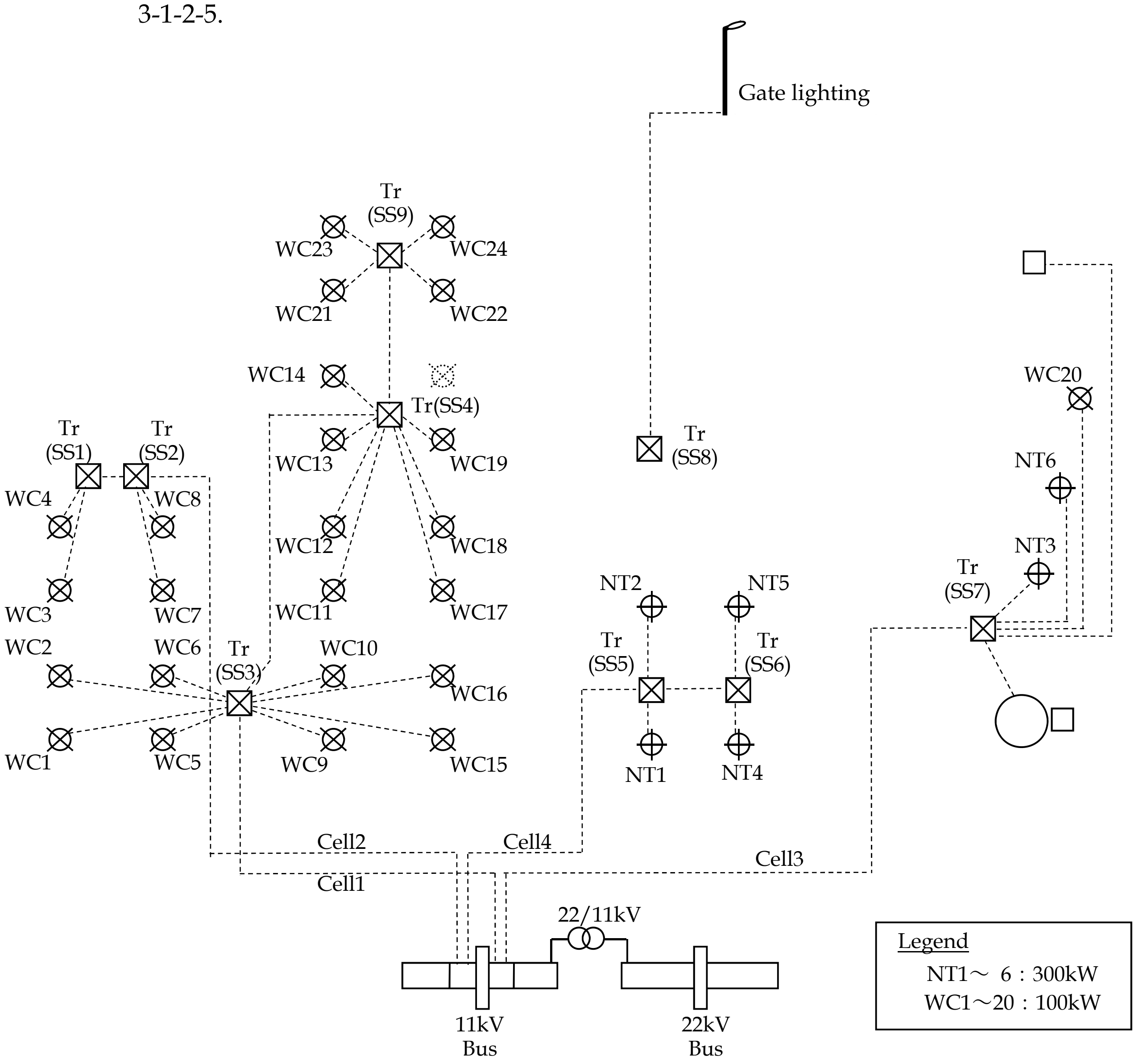


Fig. 3-1-2-5 Existing cable flow and electric power equipment in Hurghada Wind Farm

- All existing wind turbines are connected to 11kV bus of DP in Hurghada Wind Farm.

Photo 3-1-2-1 to 3-1-2-5 shows the situations of the current facilities around the site.

Photo 3-1-2-1 Hurghada wind Distribution Point

Photo 3-1-2-2 22kV switchgear of Hurghada wind Distribution Point

Photo 3-1-2-3 EETC Central Hurghada Substation

Photo 3-1-2-4 El-Gouna substation /Private sector (not energized yet)

Photo 3-1-2-5 Nearest 66kV overhead Transmission line / Central Hurghada to El-Gouna substation (not energized yet)

Clause 3 Meteorological data

(1) Meteorological data of Hurghada Meteorological Observatory (HMO)

The meteorological data provided by the Egyptian Meteorological Authority (EMA) for HMO are as below;

- General meteorological data for 3 years (2007, 2008 and 2009) such as:
  - ✓ Maximum temperature
  - ✓ Minimum temperature
  - ✓ Amount of rainfall
  - ✓ Relative humidity
  - ✓ Average wind speed
- Global Solar Radiation for 4 years (2007 – 2010)
- Diffused Solar Radiation (in some part of this report, "Scattered Solar Radiation" is used as same meaning) for 4 years (2007 – 2010)

Some data of Global and Diffused Solar Radiation were missing because some measurement equipment was not working well due to technical problems. The provided data are shown in the followings pages (Table3-1-3-1 to 3-1-3-3).

Note for Solar Radiation:

- **Global Solar Radiation consists of Direct Solar Radiation and Scattered (Diffused) Solar Radiation.**
- **Direct Solar Radiation is a solar radiation which directly reaches the target.**
- **Scattered Solar Radiation is a solar radiation which indirectly (diffused by air, cloud, reflection from ground) reaches the target.**
- **A solar radiation data which was obtained by JICA's measurement system is Global Solar Radiation since the installed pyrometer is for Global Solar Radiation.**

Table 3-1-3-1 Monthly Data of general meteorological data at Hurghada

Arab Repuplic of Egypt
Egyptian Meteorological Authority
Climate Depart

Date : 31/3 /2011
Req. NO. : 89
File NO. : 35

MONTHLY MEAN FOR SOME METEOROLOGICAL ELEMENTS
PERIOD FROM 1/1/2007 TO 31/12/2009

STATION : (EL HURGHADA)

▼METEOROLOGICAL ELEMENT/ MONTH▶	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MAXIMUM AIR TEMPERATURE (◦C)	23.3	26.1	27.2	29.0	34.2	36.6	37.6	37.3	33.9	31.8	27.4	23.0	2007
MINIMUM AIR TEMPERATURE (◦C)	10.8	12.0	14.9	18.0	23.8	26.5	28.1	27.5	25.0	22.7	16.6	13.5	
AMOUNT OF RAINFALL (MM / MONTH)	0.0	0.0	Trace	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
RELATIVE HUMIDITY (%)	52	46	42	41	35	31	35	39	46	50	47	49	
Wind Speed (knot)	13	10	13	13	11	15	11	14	16	12	11	13	
MAXIMUM AIR TEMPERATURE (◦C)	20.2	22.1	28.7	31.1	33.1	37.1	36.8	37.9	35.7	30.5	27.4	24.2	2008
MINIMUM AIR TEMPERATURE (◦C)	10.8	11.1	16.5	19.6	22.8	26.9	28.0	28.4	26.3	21.5	17.7	13.6	
AMOUNT OF RAINFALL (MM / MONTH)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
RELATIVE HUMIDITY (%)	50	46	39	36	32	28	37	35	40	51	51	55	
Wind Speed (knot	13	12	11	12	13	14	12	13	14	13	10	11	
MAXIMUM AIR TEMPERATURE (◦C)	22.9	23.9	25.0	29.9	32.3	36.7	37.8	36.8	34.7	32.6	27.1	24.5	2009
MINIMUM AIR TEMPERATURE (◦C)	11.3	12.4	14.0	18.9	22.2	26.5	28.3	27.7	25.2	22.1	17.2	13.1	
AMOUNT OF RAINFALL (MM / MONTH)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
RELATIVE HUMIDITY (%)	49	42	44	36	35	31	35	38	44	54	53	51	
Wind Speed (knot	12	12	14	14	15	13	12	14	12	10	12	10	

REMARKS :-

Trace = AMOUNT OF RAINFALL < 0.1 mm .
Knot = 1.85 km / Hour .
This Data Actually from Registers (EL HURGHADA) Station and covering 50 Km. Area .
This Data Provided to (T E P S C O) as Requested on 28/3 / 2011.

PREPARED BY — Ezzat 31-3-2011

HEAD OF DATA — Kamal 31-3-2011

DIRECTOR OF CLIMATE DATA — A.A. Ali 31-3-2011

GENERAL DIRECTOR OF CLIMATE — Amal Nawafy 31/3/2011

Table 3-1-3-2 Monthly data of Global Solar Radiation at Hurghada

Regional Radiation Center
Hurgada - Egypt
Global radiation Mj/m2.day

Month	Monthly Average 2007	Monthly Average 2008	Monthly Average 2009	Monthly Average 2010
Jan	-	14.72	-	15.45
Feb		19.22	-	18.88
Mar		22.56	-	22.42
Apr	25.30	26.28	-	25.91
May	27.62	28.66	26.51	-
Jun	29.57	-	29.28	-
Jul	28.56	-	28.29	27.57
Aug	27.26	-	26.22	25.69
Sep	24.33	-	23.48	23.48
Oct	19.48	*19.08*	18.98	19.15
Nov	16.71	-	16.31	-
Dec	-	14.00	-	14.42

Table 3-1-3-3 Monthly data of Diffused Solar Radiation at Hurghada

Regional Radiation Center
Hurgada – Egypt
Diffuse radiation Mj/m2 .day

Month	Monthly Average 2007	Monthly Average 2008	Monthly Average 2009	Monthly Average 2010
Jan	-	3.98	3.90	3.50
Feb	3.07	4.16		4.44
Mar	4.44	6.28		6.18
Apr	6.56	6.11		6.71
May	6.63	6.77		
Jun	5.95		6.31	
Jul	5.68		5.74	5.84
Aug	5.50		5.56	5.97
Sep	5.17		5.04	4.21
Oct	5.69	4.66	5.25	5.04
Nov	3.29		4.21	
Dec	-	3.50	-	3.34

Hurghada Meteorological Observatory (HMO) is located around 3km southern-east from NREA Hurghada wind farm. Its location is shown in Fig. 3-1-3-1

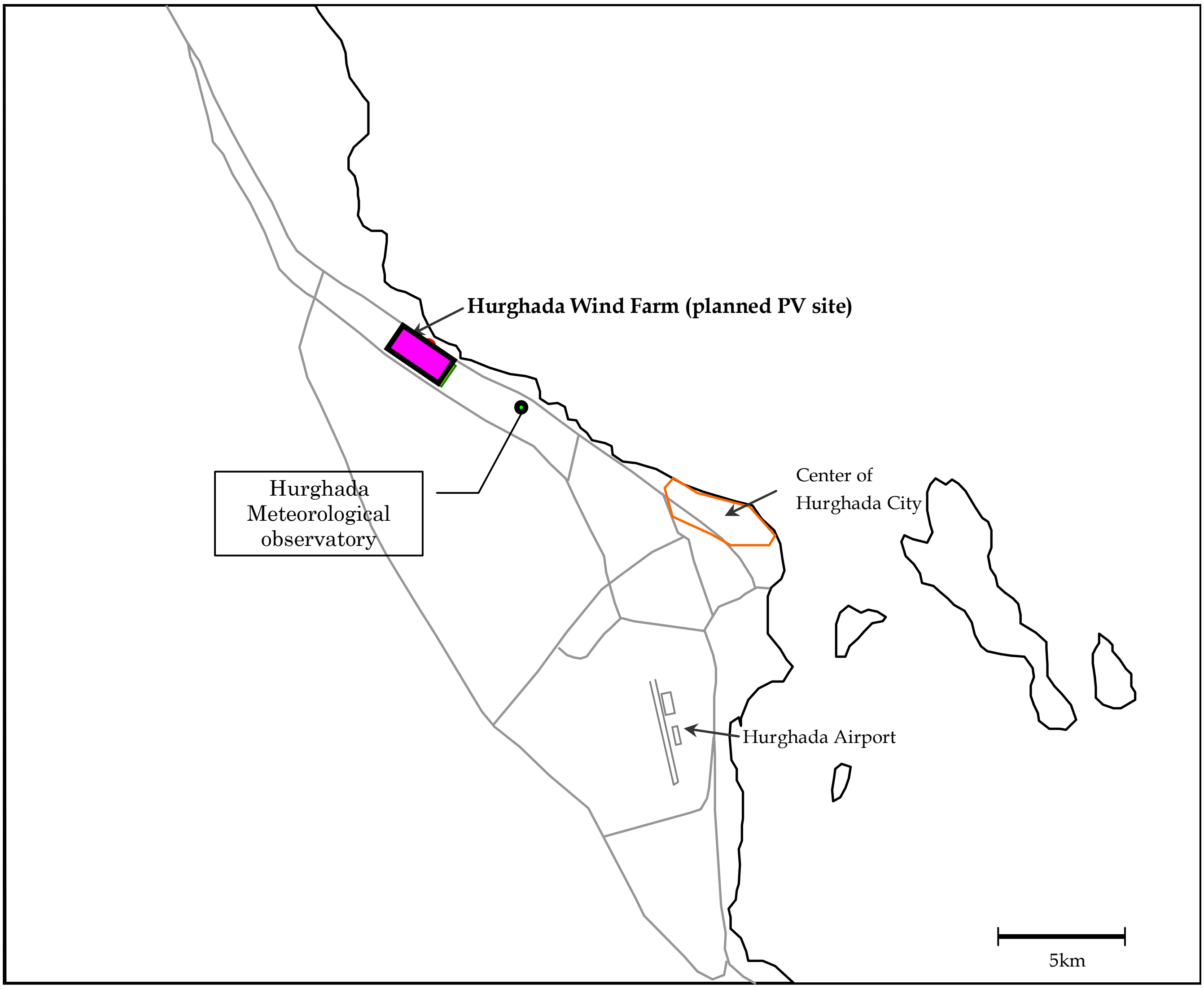


Fig. 3-1-3-1 Location of Hurghada meteorological observatory

Photo 3-1-3-1 View of Hurghada meteorological observatory

Photo 3-1-3-2 Pyranometers set in Hurghada meteorological observatory

Though some part of the data is missing of Global Solar Radiation data, average of each month for 4 years; 2007 to 2010 (data provided period) are calculated as follows. In addition, the unit for Global Solar Radiation is converted from "MJ/m2/day" to "kWh/m2/day" for comparison with other Global Solar Radiation data which has been obtained.

Table 3-1-3-4 Monthly data of Global Solar Radiation at Hurghada (Average)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[MJ/m2/day] ([kWh/m2/day])	15.09 (4.19)	19.05 (5.29)	22.49 (6.25)	25.83 (7.18)	27.60 (7.67)	29.43 (8.18)	28.14 (7.82)	26.39 (7.33)	23.76 (6.6)	19.17 (5.33)	16.51 (4.59)	14.21 (3.95)

Note: 1kWh/m2/day = 3.6MJ/m2/day

(2) Comparison of available meteorological data

The other 2 types of Global Solar Radiation data other than HMO data described above are available for this site. One is solar atlas published by NREA, and the other is NASA's renewable energy resource web site.

The data, for comparing among the three types of the Global Solar Radiation, is shown in Table 3-1-3-5 and Fig. 3-1-3-2. Since these three types of data are very similar and HMO one is moderate, the Team decided to use HMO data for basic design such as "comparison between sun tracking system and fixed system". In addition to the HMO data, measured data obtained by JICA's measuring system was used for energy production from PV modules described in Clause 4 in Section 3 of this Chapter.

Table3-1-3-5 Comparison of Monthly data of Global Solar Radiation

(unit: kWh/m2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
NASA	4.07	4.95	5.99	6.87	7.29	8.07	7.84	7.17	6.19	5.04	4.05	3.61	5.93
Egypt Solar Atlas	4.26	5.36	6.53	7.41	7.88	8.27	8.18	7.75	6.96	5.56	4.48	3.91	6.38
Meteorological Authority	4.19	5.29	6.25	7.18	7.67	8.18	7.82	7.33	6.6	5.33	4.59	3.95	6.20

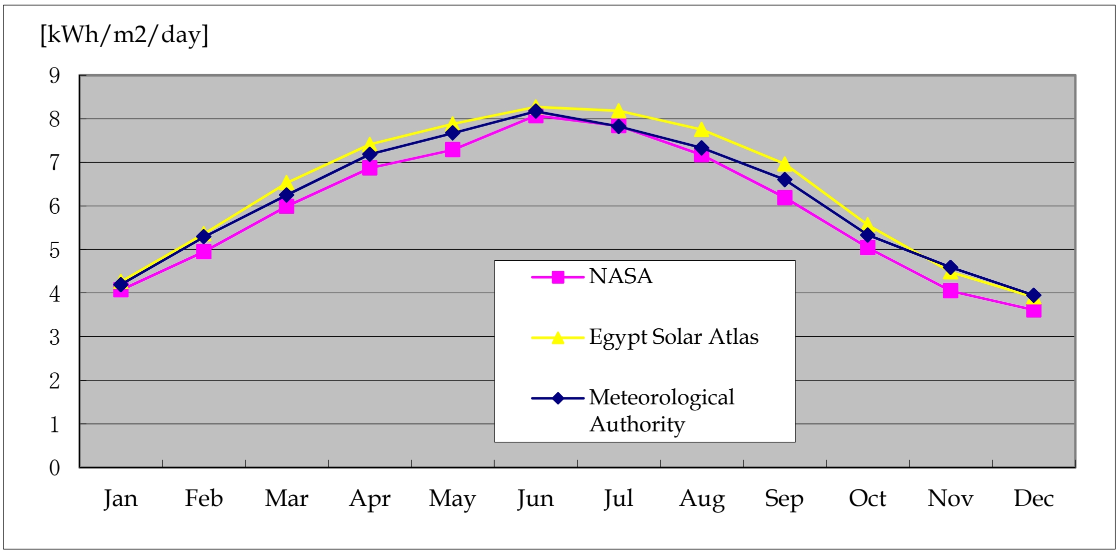


Fig. 3-1-3-2 Comparison of Monthly data of Global Solar Radiation

The average data of general meteorological data for 3 years; 2007 to 2009 is shown in the below Table 3-1-3-6.

Table 3-1-3-6 Average data of General Meteorological Data at Hurghada (for 3 years)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Maximum air temperature [Deg.]	22.1	24.0	27.0	30.0	33.2	36.8	37.4	37.3	34.8	31.6	27.3	23.9	30.5
Minimum air temperature [Deg.]	11.0	11.8	15.1	18.8	22.9	26.6	28.1	27.9	25.5	22.1	17.2	13.4	20.0
Amount of rainfall [mm/month]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Relative humidity[%]	50	45	42	38	34	30	36	37	43	52	50	52	42
Wind speed [m/s]	6.5	5.8	6.5	6.7	6.7	7.2	6.0	7.0	7.2	6.0	5.7	5.8	6.4

Based on the provided data, no rainfall is found. But according to NREA's site engineer, it had a lot of rainfall, several times in the past. Detail is described in Clause 4 of this Section.

Clause 4 Data for civil design

Data and information collected for candidate site related to civil engineering are as the followings:

- Geological condition
  - ✓ NREA maintains past soil investigation data of Hurghada wind farm such as boring log.
  - ✓ Site reconnaissance at Hurghada wind farm has been done in the first

mission.

- Geographical condition
  - ✓ There are no land survey data to check elevation and slope at Hurghada wind farm. Detailed survey of the area should be done before detailed design (for preparing technical specifications) stage.
  - ✓ The broad topographical characteristics are obtained from a field study in the first mission.
- Seismic condition
  - ✓ According to some reports, occasionally, magnitude 7 class earthquakes had occurred along the red sea coast. It needs to be examined according to the actual situation of the seismic conditions. In accordance with Egyptian codes, seismic load has been considered in the basic design.
- Meteorological condition
  - ✓ According to the NREA's site engineer, generally there are very few rainfalls in this site. But there has been 3 times of heavy rainfalls over the past years from 1996.
  - ✓ NREA's Hurghada wind farm have measured wind speed by wind observatory mast from 1990's. According to the data, maximum wind speed at the site is 26 m/s, which occurred 2 years ago, e.g., in 2010.
- Present situation and development plan of land use
  - ✓ There are underground cables from each wind turbine to the substation (Distribution Point) at the site. However, it is unclear where the cables are buried.

Here are the results of site reconnaissance at Hurghada wind farm.

1) Geological condition

There are mostly sand and partially calcareous rocks at Hurghada wind farm. Details of the soil are shown below.

- ■ Sand
  - ✓ Same soil layer is continuing from surface through deep underground level.
  - ✓ Surface of the ground where there is not much traffic is very loose. However, just about 20 or 30cm underground below the surface is medium hard.

Photo 3-1-4-1 Surface ～ 30cm below ground level

Photo 3-1-4-2 Sand layer condition near Hurghada wind farm

- Calcareous rock
  - ✓ Rocks are weathered and easily crashed by hand.
  - ✓ Large rocks that are left around Hurghada wind farm are over 1m diameter.
  - ✓ Depth of Calcareous rock layer is not clear in this investigation.

Photo 3-1-4-3 Surface of the rock

Photo 3-1-4-4 Removed rocks from construction sites

2) Geographical condition

Candidate PV site has almost flat ground except that there are hill area in the corner of the west side. By using handy GPS equipment, height of the hill area is approximate 5 m higher than the flat ground area.

According to observation of several construction sites around Hurghada wind farm, underground water level is 5 meter below surface of the ground. It seems that the underground water level is the same as red sea water level.

Photo 3-1-4-5 Hill area in Hurghada wind farm

Photo 3-1-4-6 Underground water at other construction site

3) Water run-off situation

Heavy rainfall has occurred 3 times in the past as described before. During heavy rainfall, it is intimated that rain water with soil and gravel flew from mountain side to the Red sea side. The Team simulated rain water run-off route by using Google Earth as Fig. 3-1-4-1 for reference then found that hilly area in North West of the project site might be an obstacle to rain water run-off.

These images are shown in Fig. 3-1-4-1.

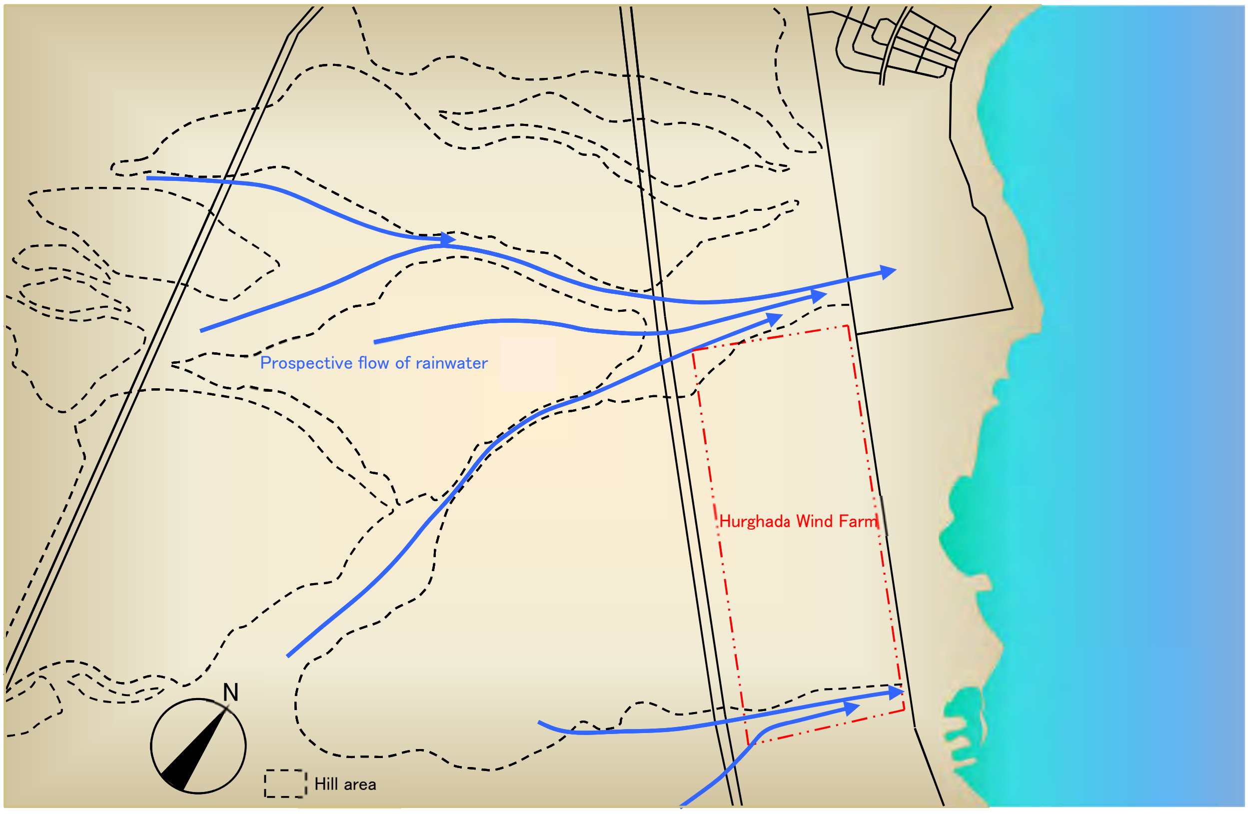


Fig. 3-1-4-1 Prospection flow of rain water run-off at Hurghada wind farm area

Section 2 Measurement for examination of power energy output

Clause 1 Outline of the system

(1) Purpose of measurement

The purpose of the measurement in this project is as follows:

- ✓ Comparison of Global Solar Radiation data

  The data of Global Solar Radiation obtained by the measurement system and the existing data are compared, and the result is reflected in the calculation of power energy output.

- ✓ Examination of dust effect

  From some experiences of installing PV (photovoltaic) modules in desert area, it has been found that generation efficiency of the PV power generation system was decreased by approximately up to 50% by accumulated dust on the PV modules. The dust effect shall be examined at the candidate site by using the measurement system. Two modules were installed for the examination; one module was cleaned up periodically, and the other one was remaining kept as it is for a long period. These data are compared, and the result is reflected on calculation of power energy production.

- ✓ Examination about effect of temperature

  Generation efficiency of PV power generation system is decreased by temperature rises. The effect of temperature on the candidate site is examined, and the result is reflected in the calculation of power energy production.

The measurement system was installed by JICA in October 2011. Since the measurement had been started, the measurement system was cleaned up, and maintained by the Team’s local consultant on weekly basis.

Since this report is taking the measured data for one year, the Team believed that reliability and accuracy of this study is improved, especially the amount of annual power energy production.

(2) Outline of the measured data

Items of the measured data are as follows;

- ✓ Global Solar Radiation
- ✓ Output current of each PV module
- ✓ Temperature of each PV module
- ✓ Outside temperature

In addition to the above, the local consultant developed a data transferring system from the site to the designated location in Cairo or Japan by using 3G router.

The image of the measurement system and the necessary equipment procured by JICA is shown below.

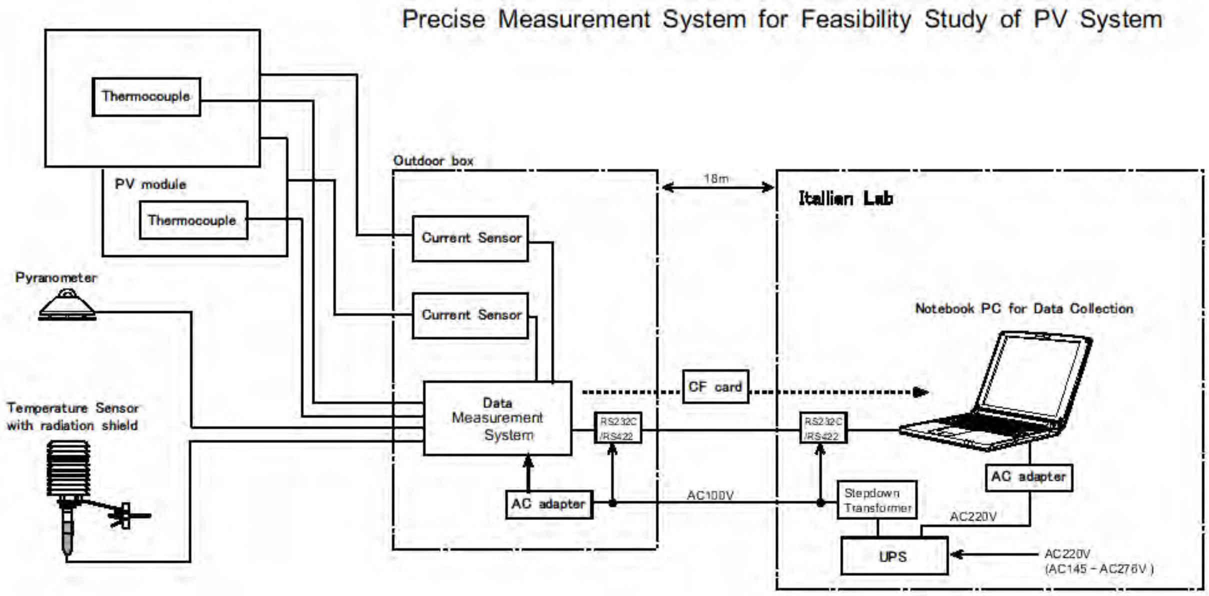


Fig. 3-2-1-1 Image of the Measurement System

Table 3-2-1-1 List of the Main Equipment

Item	Amount
PV module (85W) SF85-A	2
Pyranometer MS-402	1
Thermometer MT-052	1
Current sensor WS-2-003	2
Thermocouple (T-type/Sheath type)	2
Data logger FAST-M8	1
PC for data collection E6420	1
UPS BU1002SW	1
RS232C/485 Converter RC-58X	2
Step-down transformer BS-100	1

(3) Layout for the measurement system

Considering the wind situation, the shade of the ambient structures, the firmness of the ground, and the cable route, the team proposed the installation layout for the measurement system as shown in Fig. 3-2-1-2

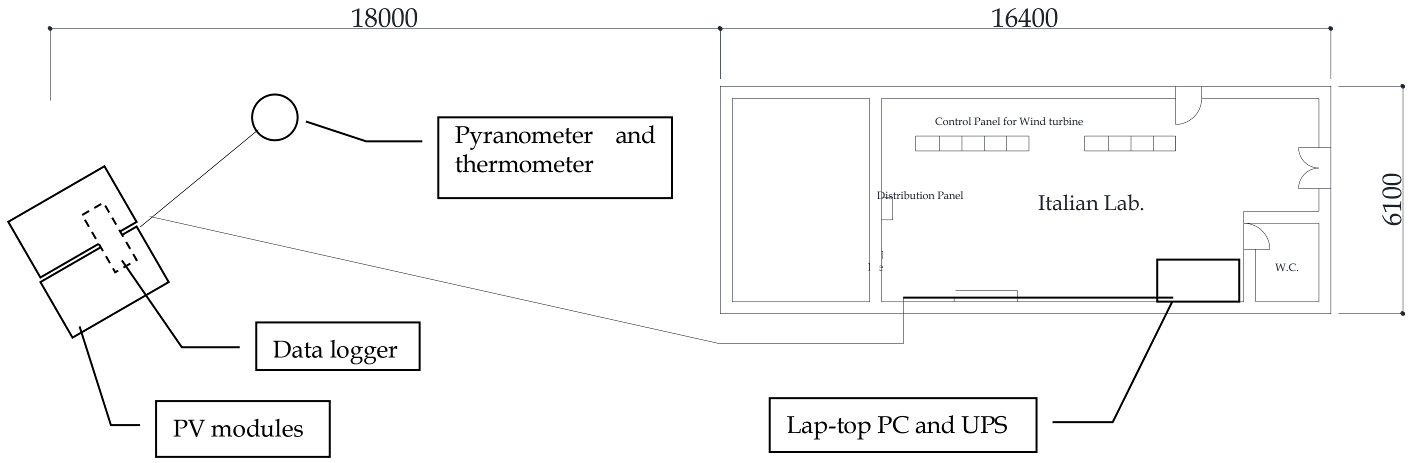


Fig. 3-2-1-2 Layout for the Measurement System

Photo 3-2-1-1 Outside view of Equipment

Photo 3-2-1-2 Inside view of Equipment

Photo 3-2-1-3 PV Module

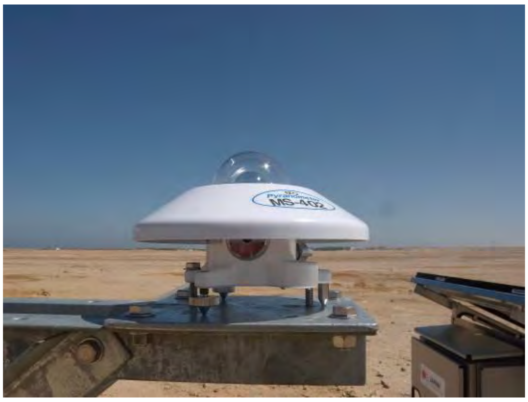


Photo 3-2-1-4 Pyranometer

Photo 3-2-1-5 Thermometer

Photo 3-2-1-6 Outdoor Box
(Data Logger, Current Sensor)

Photo 3-2-1-7 PC for Data Collection

Photo 3-2-1-8 UPS

(4) Schedule of installation and measurement

The Schedule of the installation and the measurement is shown below.

Schedule for Installation of the measuring system

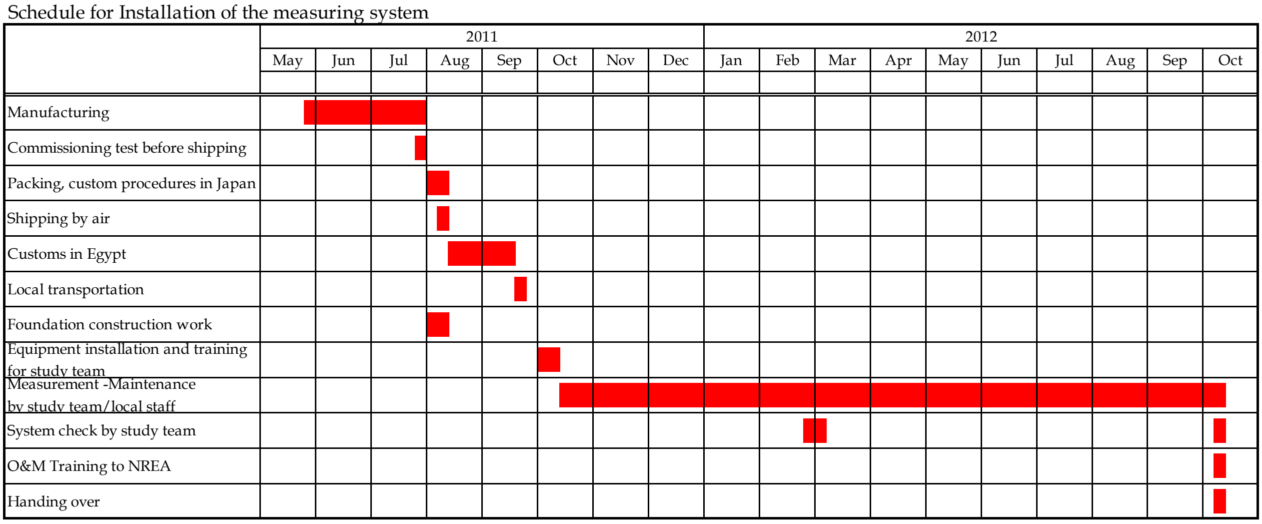


Fig 3-2-1-3 Schedule of Installation and Measuring

(5) Handing over of the measurement system

After the measurement was taken through one year, JICA handed over the measurement system to NREA. The Team conducted O&M training regarding the measurement system for NREA's staff of Hurghada wind farm.

Measurement in Hurghada wind farm will be conducted by NREA continuously. This continued measured data shall be used for energy production at the time of tendering stage as well as project implementation stage in order to have more accurate and reliable energy production estimation.

Photo 3-2-1-9 Handing Over

Photo 3-2-1-10 O&M Training

Clause 2 Result of measurement

Outline and features of the measured data collected by the measurement system between October 2011 and September 2012 is as follows (The actual measurement data is as attached in Appendix 3-2-1):

- ✓ Fig. 3-2-2-1 shows daily transition of output currents of the installed PV modules and Global Solar Radiation. The output current is the base data for estimating the power energy production of the PV module.
- ✓ Module No.1 had been cleaned up its surface periodically. The maintenance period is once a week.
- ✓ Module No.2 had been left as it is for a long period. Its surface gets dirty by sand dust.
- ✓ Difference of the output current between two modules indicates difference of the energy output power. This can show the dust effect.

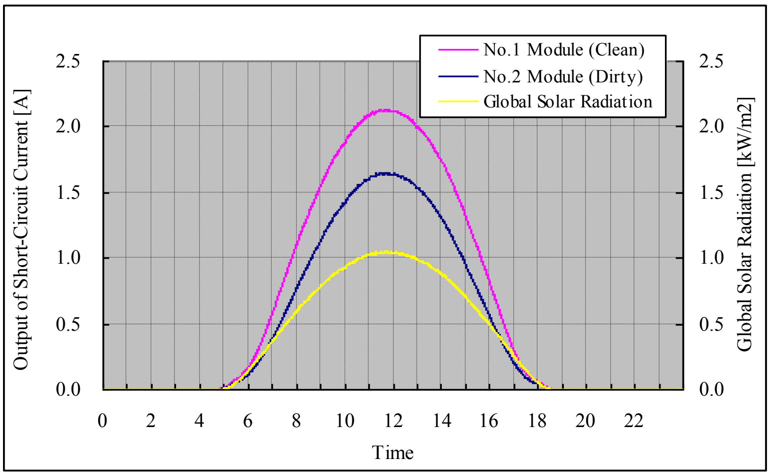


Fig. 3-2-2-1 Output Current and Global Solar Radiation (20th May. 2012)

- ✓ Fig. 3-2-2-2 shows temperature of the two modules and outside air temperature.
- ✓ Difference between the module temperature and the outside air temperature is related to Global Solar Radiation in daytime. Increment of the module temperature causes reduction of output power of PV module.

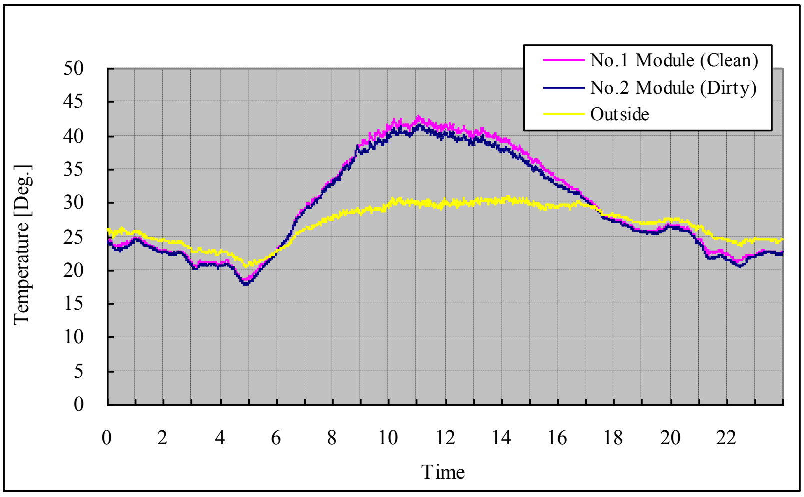


Fig. 3-2-2-2 Temperature of PV Modules and Outside Temperature (20th May 2012)

Clause 3 Comparison between collected data and measured data

Comparison between the measured data collected by the measurement system installed by JICA and meteorological data provided by the Egyptian Meteorological Authority (EMA) at Hurghada Methodological Observatory (HMO) is as follows:

- ✓ These measured data, particularly Global Solar Radiation data, are almost the same as the data provided by EMA.
- ✓ Therefore, these average data including measured data can be used for the design.

(Data of the year 2011 and 2012 described in the below figures are actual measured data by JICA system and those of 2007, 2008 and 2009 are data provided from EMA)

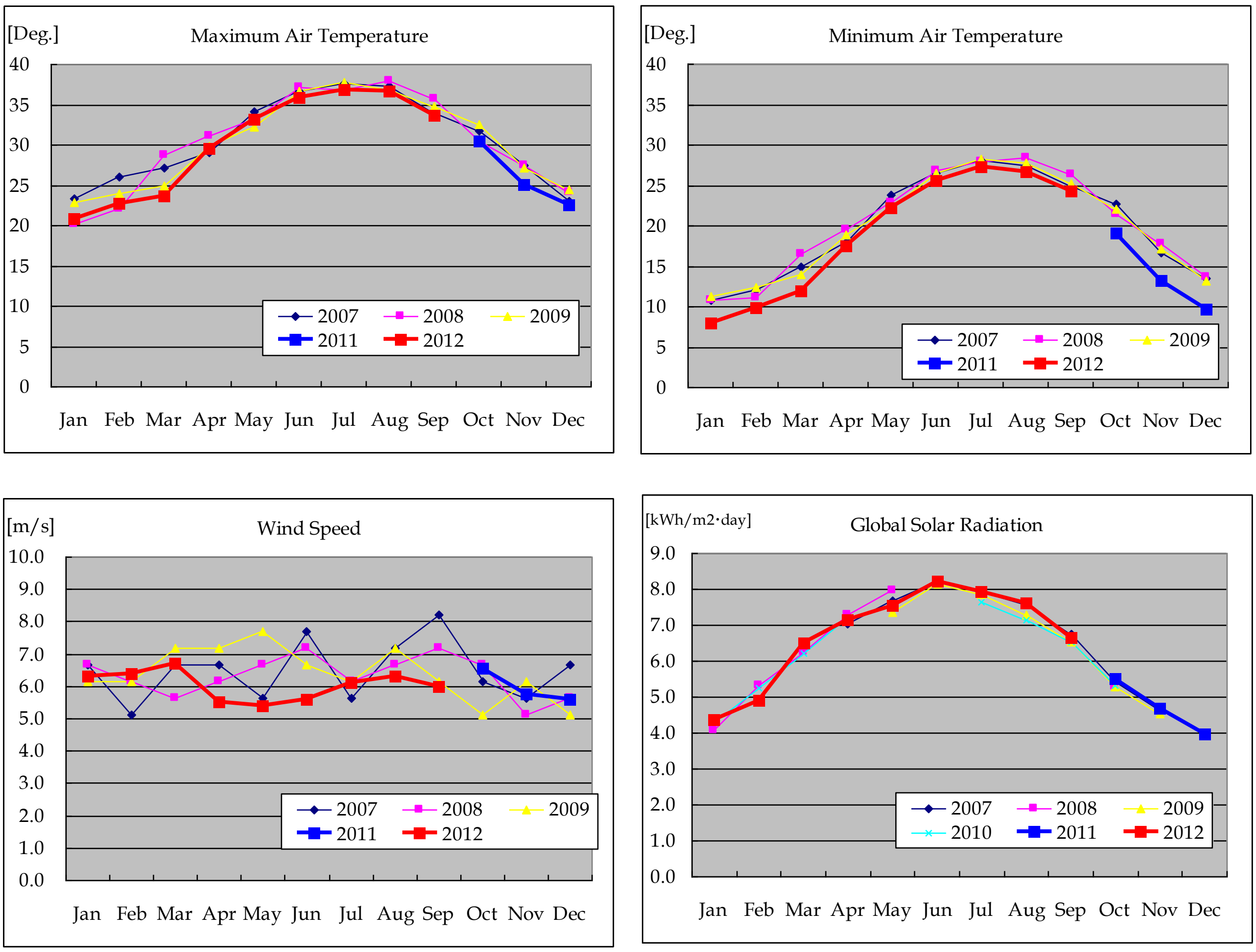


Fig. 3-2-3-1 Comparison between the Measured Data and the Meteorological Data

Clause 4 Measured data of monthly PV module temperature

Increment of the PV module temperature causes reduction of power energy output of PV module. Transition of maximum air temperature and PV module temperature (see Appendix 3-2-2 for details) is shown in Table 3-2-4-1 and Fig. 3-2-4-1.

Table 3-2-4-1 Transition of maximum air temperature and PV module temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Note
Maximum air temp. [Deg.]	20.8	22.7	23.7	29.6	33.1	35.8	36.8	36.7	33.7	30.4	25.1	22.6	Measured by JICA system
PV module temp.[Deg.]	30.0	32.4	33.0	39.8	42.5	44.9	45.6	46.8	43.2	38.3	34.6	31.5	ditto
Difference [Deg.]	9.2	9.7	9.3	10.2	9.4	9.1	8.8	10.1	9.5	7.9	9.5	8.9	

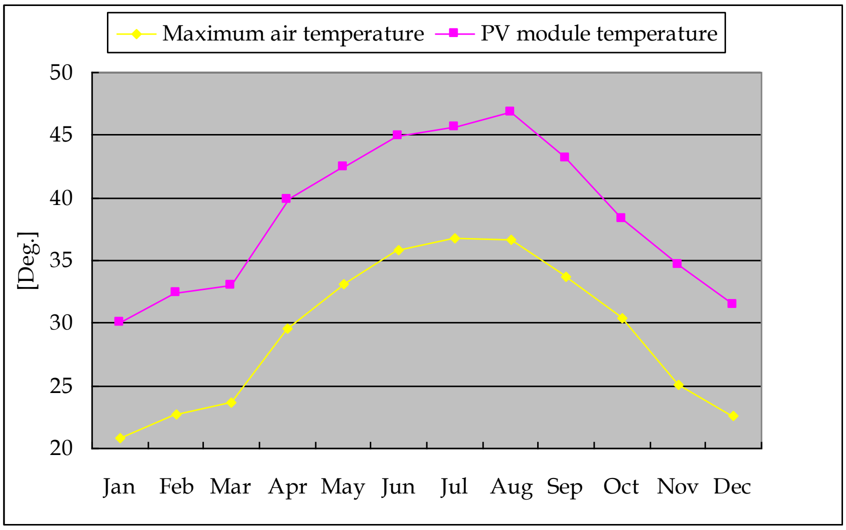


Fig. 3-2-4-1 Transition of maximum air temperature and PV module temperature

Clause 5 Dirt condition of the PV module

The Team examined the transition of output current ratio affected by sand dust (dirty/clean) for 3 times in total:

- ✓ The 1st examination was conducted from October 2011 to February 2012.
- ✓ The 2nd examination was conducted from March 2012 to May 2012.
- ✓ The 3rd examination was conducted from June 2012 to September 2012.

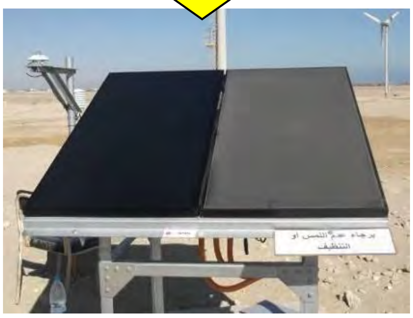
At the beginning of each examination, both of the PV modules were cleaned up.
The module on the left side was cleaned in weekly basis, and the one to the right side was left as it is.

The 1st examination	The 2nd examination	The 3rd examination

3rd Nov. 2011 (After 1 month)

6th Apr. 2012 (After 1 month)

6th Jul. 2012 (After 1 month)



8th Dec. 2011 (After 2 months)

4th May. 2012 (After 2 months)

3rd Aug. 2012 (After 2 month)

22nd Dec. 2011 (After 3 months)

25th May. 2012 (After 3 months)

7th Sep. 2012 (After 3 months)

2nd Feb. 2012 (After 4 months)

Photo 3-2-5-1 Transition of dirty condition on the surface of the PV module

Photos on left side: October 2011-February 2012

Photos on middle side: March 2012-May 2012

Photos on right side: June 2012-September 2012

Transition of the output current ratio affected by sand dust is as follows.

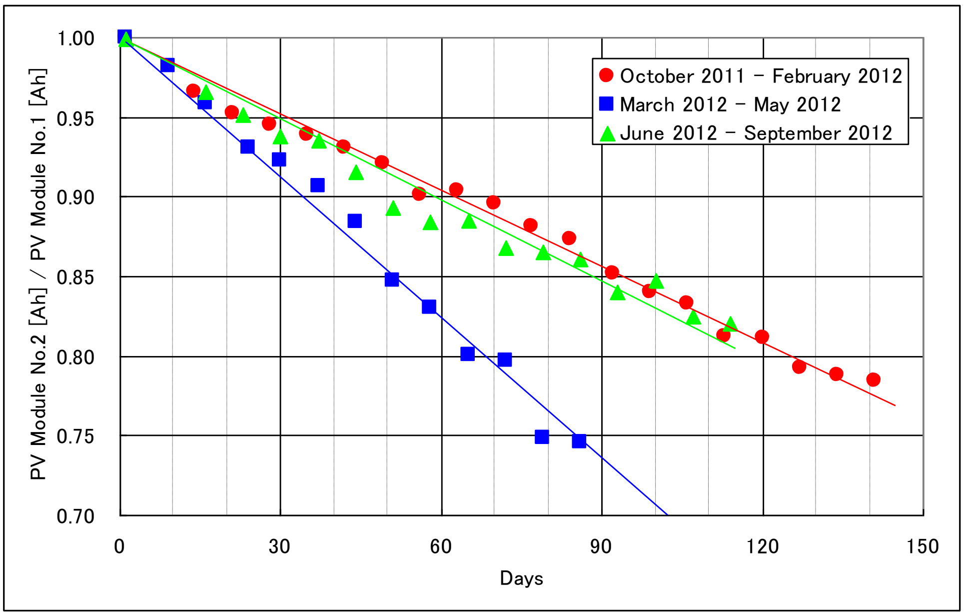


Fig 3-2-5-1 Transition of Output Current Ratio (Dirty/Clean)

The output current ratio was decreased continuously in each examination. Especially, the output current ratio in the 2nd examination (March 2012 – May 2012) significantly decreased about 25% for 3 months. Other two examinations had almost the same reduction ratio of about 15% for 3 months. One of the reasons might be an influence of sandstorm which frequently occurs between March and May every year.

Average of output current reduction ratio in each examination is approximately 3.3% for 2 weeks, and approximately 6.6% for 1 month.

Reduction of output current is related to reduction of power energy production. Therefore, this data should be referred to for the estimation of annual energy production.

Moreover, periodic maintenance work such as cleaning up the modules is indispensable in order to avoid decreasing power energy output. Maintenance period should be determined taking into account the expected reduction of energy output.

Detailed examination of maintenance work such as period and cleaning up method and so on is described in Chapter 5.

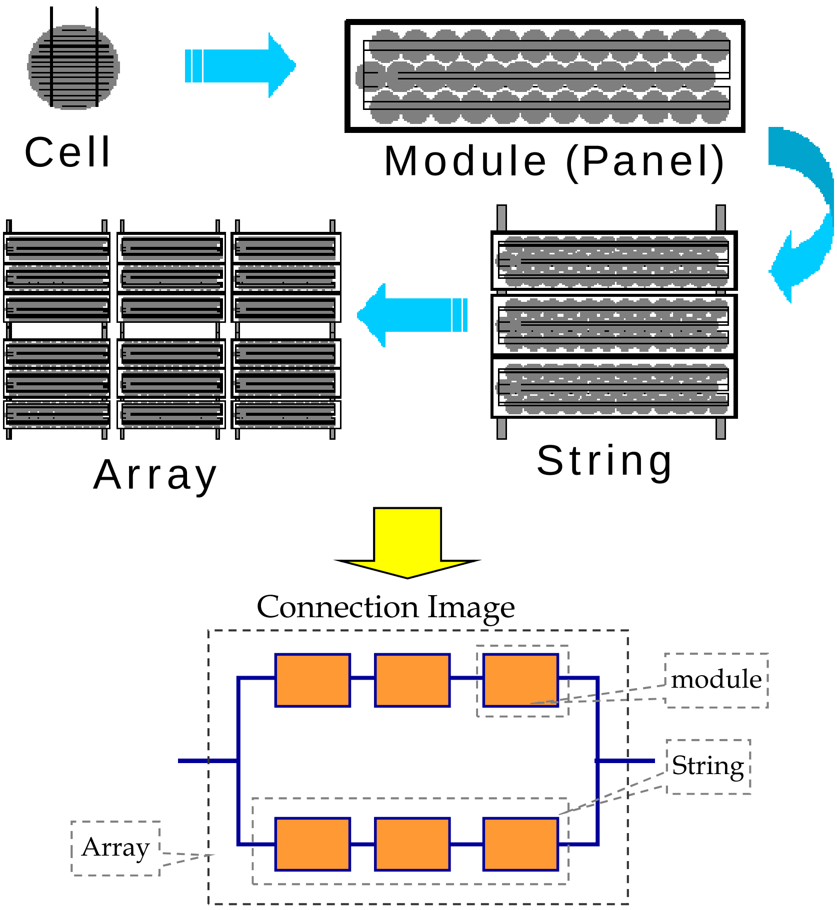
Section 3 Basic Design

Clause 1 Selection of appropriate type of PV module

1) Component of Photovoltaic System

Photovoltaic (PV) system mainly composes the following devices but these components will be varied depending on technical requirements and so on.

- Cell: Minimum unit of PV generating power from sun light
- Module (Panel): Rows of wired cells connected in series which can produce practicable voltage (Practicable minimum size)
- String: Modules connected in series meeting the optimal input voltage of inverter
- Array: Aggregated strings connected in parallel



Source: JICA Study Team

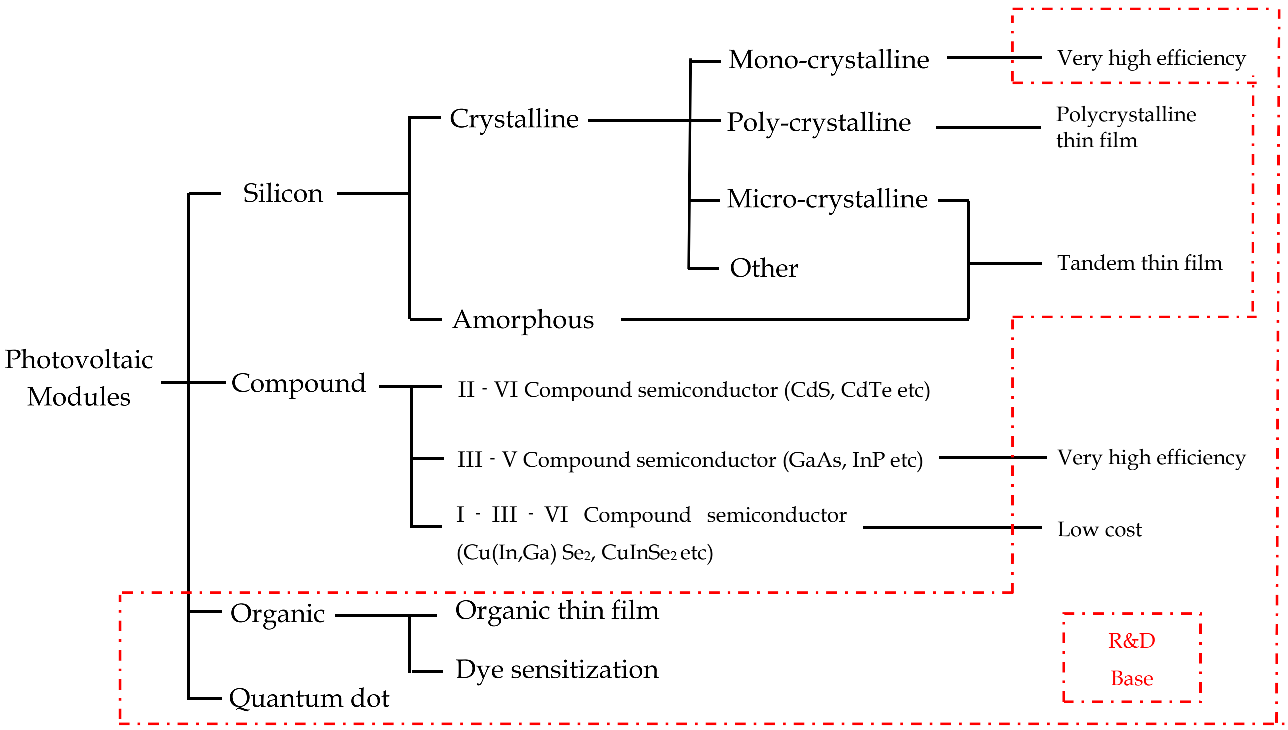
Fig. 3-3-1-1 Component of Photovoltaic System

2) Available types of PV module

Types of PV module can be classified by the following 4 types:

- Silicon Type
- Compound Type
- Organic Type
- Quantum Dot Type

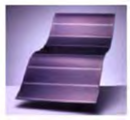
General classification of the types of PV module is shown in the Fig. 3-3-1-2 and the feature and characteristic of each type of PV module is shown in the Table 3-3-1-1.
In Fig. 3-3-1-1, some materials marked with red dotted lines means that these modules are under research and development stage now.



Source: Japanese Manufacturer

Fig. 3-3-1-2 Types of PV modules

Table 3-3-1-1 Features and characteristics of each PV modules

Type				Characteristics		Module Conversion Efficiency
Silicon Type	Crystal Type	Mono Crystalline		Material	Thin Film Mono poly Crystal	~20%
				Conversion Efficiency	High	
				Others	Price is high	
		Poly Crystalline		Material	Poly Crystal collecting relatively small crystal	~15%
				Conversion Efficiency	Lower than Mono Crystal	
				Others	Price is lower than Mono Crystal	
	Thin Film Type	Amorphous Silicon		Material	Amorphous Silicon	~9%
				Conversion Efficiency	Lower than the other types of module	
		Multi-Layer Thin Film		Material	Forming Thin Films of Amorphous Silicon and Crystal Silicon	~11%
				Conversion Efficiency	Lower than Crystal Silicon	
Compound Type	CIS Type			Material	Thin Film Type made from Copper/Indium/Selenium, etc.	~12%
				Others	Produced in large numbers and high functionality are expected.	
	CdTe Type			Material	Thin Film Type made from Cadmium/Tellurium	~11%
				Others	Produced in large numbers and low cost can be realized	
	Light Condensing Type			Material	Integration of light condensing technology and compound elements	~42%
				Others	High functionality and High Price	
Organic Type	Dye Sensitization Type			Material	Using light absorption of oxidized titanium	~11% (Assumption)
				Others	R&D process at present	
	Organic Thin Film Type			Material	Using organic semiconductor	~8% (Assumption)
				Others	R&D process at present	

Source: NEDO[1] White Paper on Renewable Energy Technology

The overview and the present situation of typical types of PV modules in Table 3-3-1-1 are described in the followings.

[1] New Energy and Industrial Technology Development Organization in Japan

(1) Silicon Type

i) Mono Crystalline Type, Poly Crystalline Type

- ✓ High efficiency in commercial level and require less space to obtain same power energy output comparing with other types.
- ✓ Energy reduction is relatively higher at high temperature than other types.
- ✓ Production cost is much expensive than other types and the possibilities of reduction in future will be lower than other types, although its popularity in the market at present may still contribute to reducing the costs of these types.
- ✓ The productions of Japanese manufactures have excellent efficiency comparing with the others, which means that the Japanese products require less space.
- ✓ Recent trend in the world market, majority of this type of PV modules are produced by Chinese and Taiwan manufacturers since their cost of PV modules are much cheaper.

(2) Thin Film Silicon Type

i) Amorphous Type

- ✓ Easy production and has a possibility of reducing its production cost. But the production cost at present is not so low in the commercial level.
- ✓ Lower conversion efficiency comparing with the crystalline types and requires more space.
- ✓ Energy reduction is relatively lower at high temperature than other types.
- ✓ Many manufacturers in China and Taiwan, etc. are producing this type.
- ✓ When this type is used under strong sunshine, there might be some cases of accelerating deterioration of the material, because this type has a characteristic of decreasing electrical conductivity of the silicon by the Staebler – Wronski effect.

ii) Multi-Layer Thin Film type

- ✓ This type has a multi-layer of combining with micro crystallized silicon and amorphous silicon, which have different characteristics of available wavelengths absorbance.
- ✓ It has higher power generation efficiency than only amorphous type, and also has, lower output reduction under high temperature than crystalline type.
- ✓ Many Japanese manufacturers produce this type.
- ✓ This type is expected to obtain more power generation efficiency and more cost reduction in near future.
- ✓ Many mega-solar projects apply this type, because of its cost and efficiency.

(3) Compound Type

i) Cd-Te Type

- ✓ Large numbers of this type has already been adopted in USA.
- ✓ The price is relatively low and the power generation efficiency is high.
- ✓ The volume of its annual production was the top in the world in 2010.
- ✓ This type contains some cadmium then environmental problem caused by the cadmium might be occurred. Quantity of contained cadmium is very small; therefore, it is not covered by the Restriction of Hazardous Substances (RoHS) instruction at present.
- ✓ Environmental control including total recycling system is necessary in the case of utilizing this type.

ii) CIS type

- ✓ This type has the same level of the high efficiency as the poly crystalline type in laboratory test. The efficiency is expected to be higher in commercial level soon.
- ✓ Also with lower output reduction rate under high temperature like the Thin Film Silicon Type.
- ✓ It has a self-mending function (Annealing Effect) which repairs its deterioration condition under high temperature.
- ✓ It is expected that the production volume of this type will be expanded and its production cost is expected to reduce.
- ✓ It has "Light Soaking Effects[2]" which can generate 5-10% more power than nominal capacity.
- ✓ This type have already installed into the mega-scale photovoltaic power plant in Japan, Saudi Arabia and Thailand.
- ✓ Effect of shadow is relatively low for thin-film type module. Because thin-film type module does not have cells like crystalline types. So the entire surface of the module works as an electrode.

The following points are recommended to be considered for selection of appropriate type of PV module based on the conditions of the PV sites:

- ✓ Cost

  Moderate unit price of PV modules is one of the important factors for PV power plant since PV module cost normally occupies a large portion of the total project cost, then power generation cost of the PV power plant is affected.

[2] The Light Soaking Effect represents an additional output effect that is initiated as soon as modules are exposed to solar irradiation. The buffer layer between the PV-active CIS – layer and the transparent conducting oxide (TCO) is the mainly responsible part for the light soaking effect. The Light Soaking Effect is immediately started after the module's exposure to sunlight.

- ✓ Efficiency

  Depending of efficiency of PV modules, required land area for the PV power plant is varied in case same generation capacity is granted.

- ✓ Temperature Characteristic

  It is desirable to select the PV module with a good temperature characteristic, which is expected to obtain higher amount of annual power energy output, because the module will be utilized under high temperature through the year in Egypt.

- ✓ Life Time

  PV modules generally secure their life time which is more than 20 years.

  According to a report, some silicon crystal type of PV module has more than 30 year's life time.

  Additionally, some manufacturers warrant that the life time of the photovoltaic module is 20-25 years.

  Apart from the life time itself, it is better to examine output energy drop (deterioration) of PV modules during its life time.

- ✓ Environmental consideration

  It is better to examine whether the PV module contains environmentally harmful material or not. In case there is some, treatment after life time and at the time of damage of PV module shall be confirmed with its manufacturer in advance.

- ✓ Effect of Shade

  It is better to examine the effect of shade, because there are some photovoltaic module types which reduce its power energy output drastically by the effect of shade.

Based on the above-mentioned points for selecting appropriate PV module, the evaluation result was done by the Team and it is shown in Table 3-3-1-2.

Taking into account the results, basic design is carried out based on Poly Crystalline type, Multi-Layer Thin Film (MLTF) type and CIS type in the following Sections.

However, the followings are recommended to be taken into consideration for selecting the PV module in future:

- ■ Development of large scale PV power plant has just started these few years in the world. Thus technology and cost of the PV module are renovating year by year.
- ■ Adoption of mixture of different types of PV module under this project can be one option for verification of characteristics of each PV module under the Egyptian climate conditions.

Table 3-3-1-2 Evaluation Result for each Photovoltaic Module

	Silicon crystallized		Silicon Thin film		Compound thin film	
	Mono Crystalline	Poly Crystalline	Amorphous Silicon	MLTF	Cd-Te	CIS
Cost	High	Low	Middle	Low	Low	Low
	NG	G	F	G	G	G
Efficiency	Excellent	High	Low	Middle	Middle	Middle
	Ex	G	NG	F	F	F
Temperature Characteristic	Middle	Middle	Excellent	Excellent	Good	Good
	F	F	Ex	Ex	G	G
Life time	Good	Good	Middle	Good	Good	Good
	G	G	F	G	G	G
Environmental consideration	Safe	Safe	Safe Energy efficiency for product	Safe Energy efficiency for product	Caution induce Cd	Caution some products include small amount of Cd
	G	G	Ex	Ex	NG	F
Effect of shade	Middle	Middle	Middle	Middle	Middle	Good
	F	F	F	F	F	G
Total	High cost Weakness to high temperature	Good Efficiency Weakness to high temperature	Low efficiency and require huge space	Adequate	Require environmental consideration - Recycling	Adequate
	NG	G	NG	G	NG	G

<Note> Ex: Excellent, G: Good, F: Fair, NG: Not Good
Source： JICA Study Team

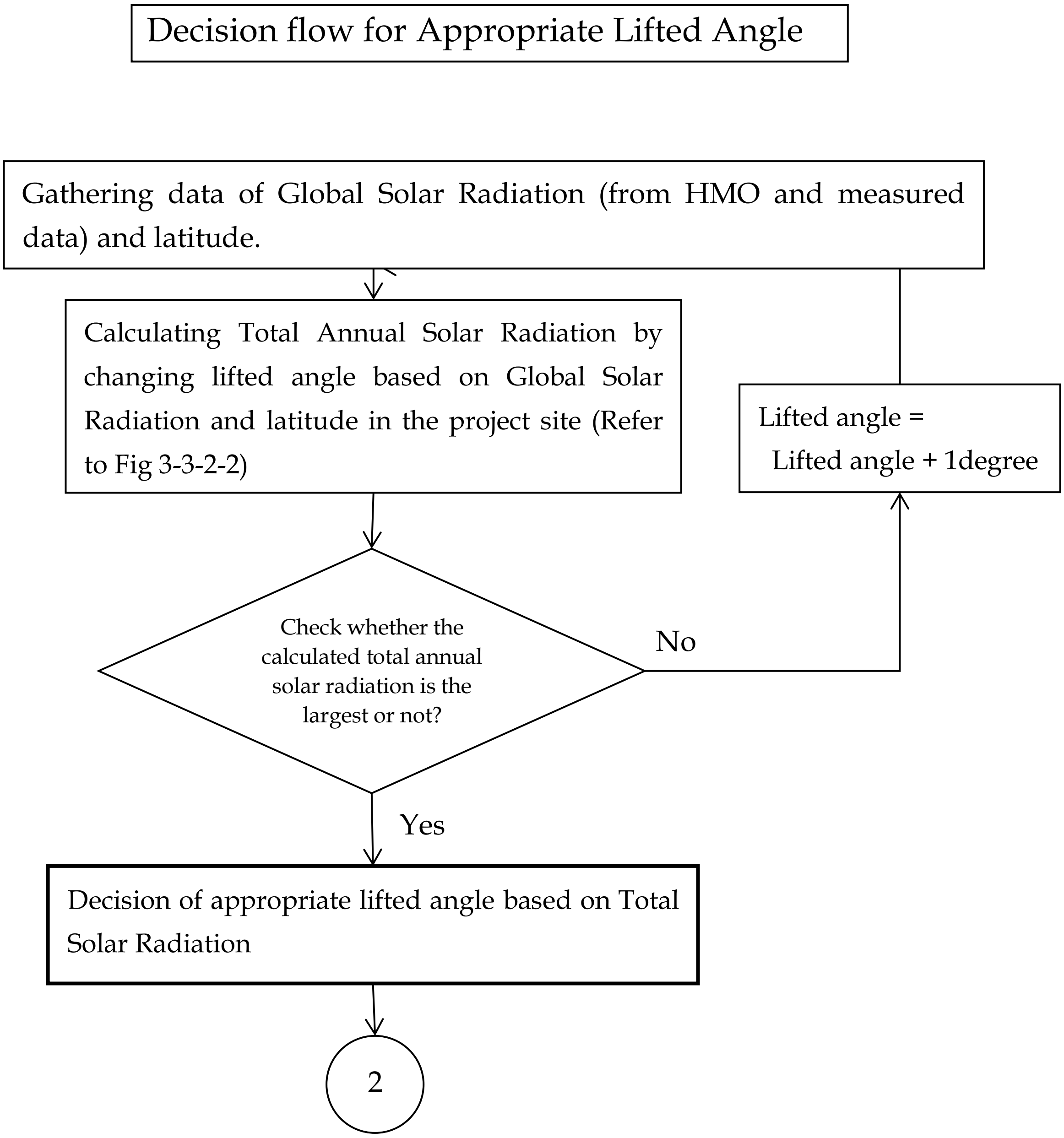
Clause 2 Effect of appropriate lifted angle and shade

1) Appropriate lifted angle

The lifted angle of PV module shall be determined by considering maximized Total Annual Solar Radiation[1] on the surface (called "appropriate lifted angle"), because the power energy output of the PV power generation system depends on the Total Solar Radiation on the surface of the PV modules regardless of the types of the PV modules. In order to decide the appropriate lifted angle, the Total Annual Solar Radiation based on the latitude and Global Solar Radiation in the project site shall be considered in the first step. Then, in order to determine the final appropriate lifted angle, the least cost per energy (USD/kWh/year) which is calculated by the power energy output based on the Total Annual Solar Radiation and project cost considering varied costs such as the frame cost and the foundation cost related to the lifted angle shall be considered.

Flowchart of deciding the lifted angle is shown in the following page.

[1] The Total Annual Solar Radiation on the surface of PV module can be calculated by multiplying Daily Average Solar Radiation on Lifted Surface in each month by the number of days in each month and summing them up. Refer to Table 3-3-2-2.

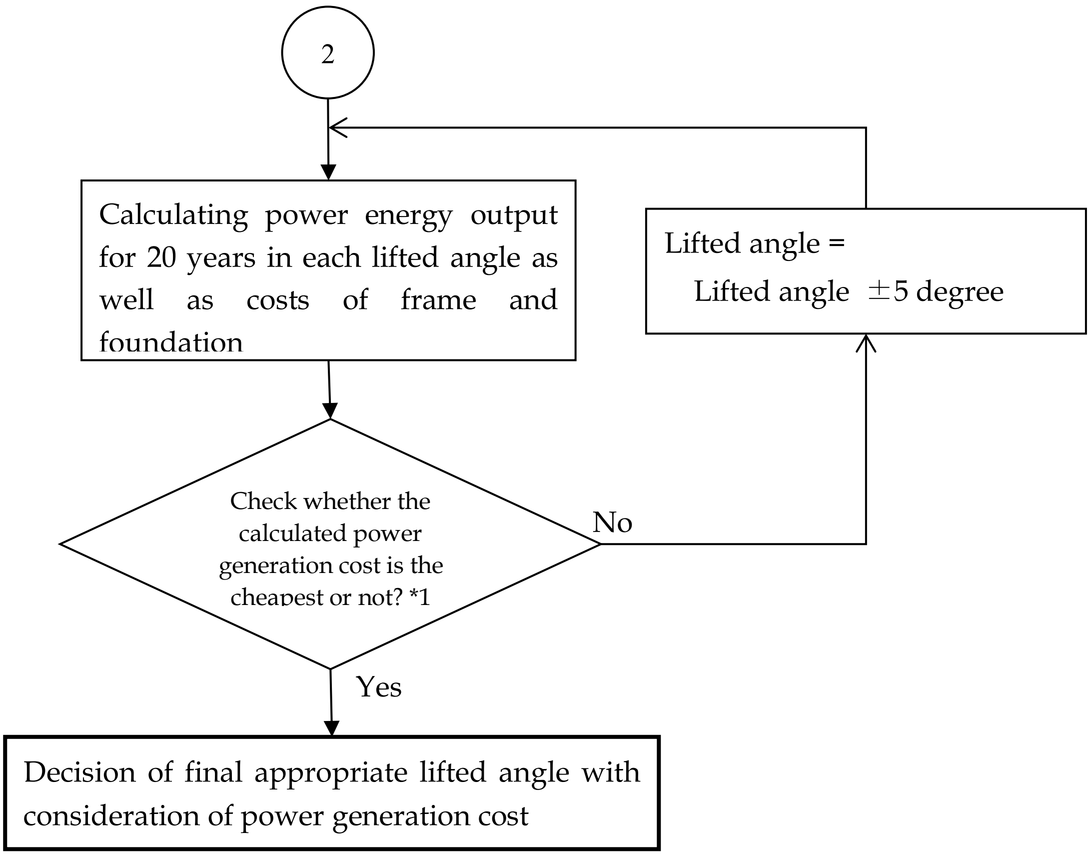


Source: JICA Study Team

Fig 3-3-2-1A Decision Flow for Appropriate Lifted Angle

Decision flow for Final Appropriate lifted angle

In order to find the least cost per energy by changing the lifted angle based on the appropriate lifted angle described in previous figure, cost and energy production comparison is made with varying the lifted angle from lower side to higher side.
Varied cost is assumed only for the frame cost and foundation cost for this purpose since other cost is almost the same in any case.



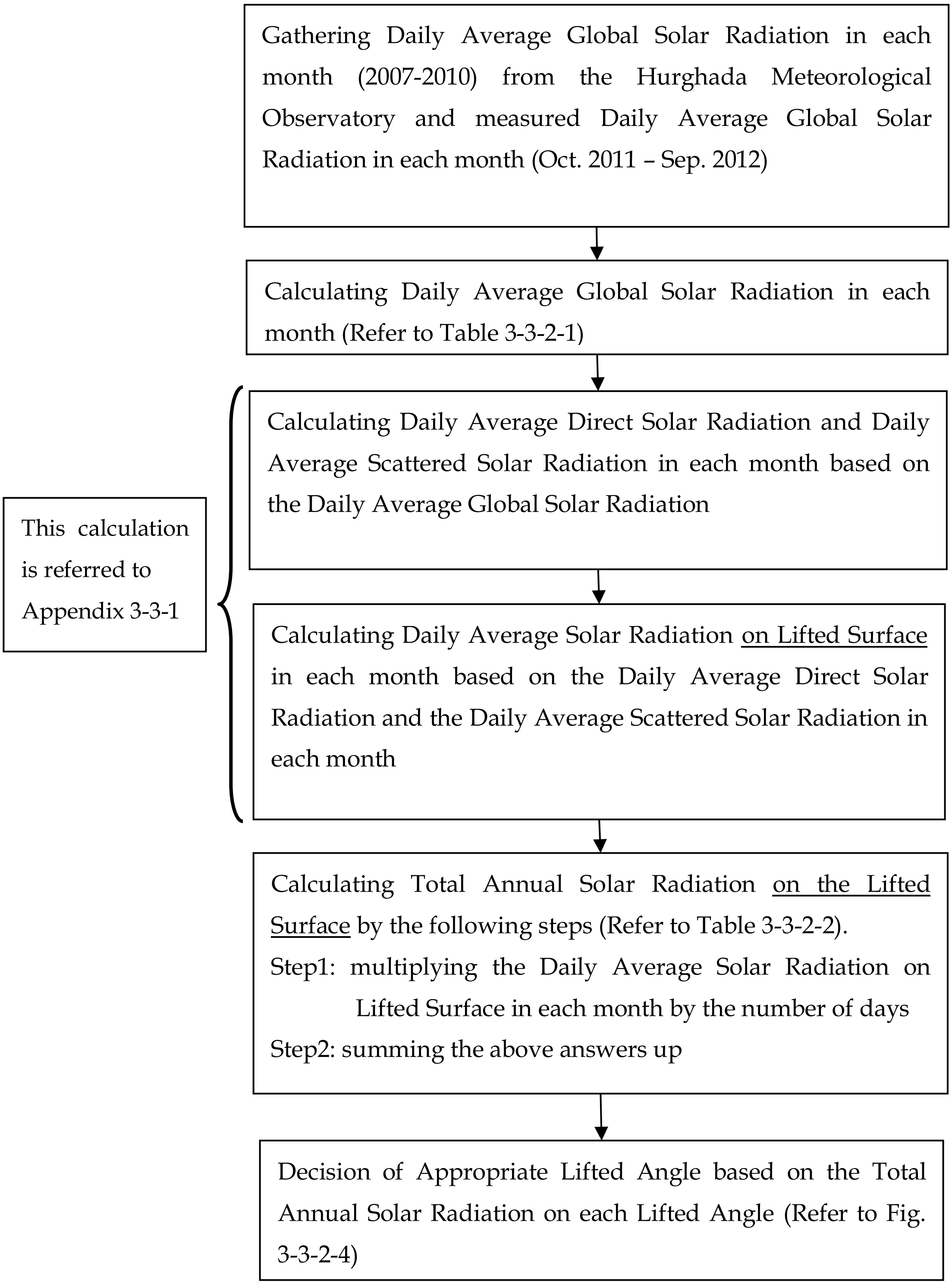
*1 Power Generation Cost = $\dfrac{\text{Cost of [Frame+Foundation]}}{\text{Total Power Energy Output for 20 year in each lifted angle}}$

Source: JICA Study Team

Fig 3-3-2-1B Decision Flow for Final Appropriate Lifted Angle

2) Calculation of Total Annual Solar Radiation in each Lifted Angle

Calculation flow of the Total Annual Solar radiation in each lifted angle based on provided data from Hurghada Meteorological Observatory and measured data from JICA measurement system is shown in Fig.3-3-2-2.



Source : JICA Study Team

Fig. 3-3-2-2 Flow of Total Annual Solar Radiation and Appropriate Lifted Angle

3) Solar Radiation to be used

Based on provided Global Solar Radiation [kWh/m² · day] from Hurghada Methodological Observatory and the measured date from JICA measurement system, the Total Annual Solar Radiation shall be estimated. Global Solar radiation provided and those measured are summarized in Table 3-3-2-1. These values are converted from MJ/m²/day to kWh/m²/day in the unit from the Table 3-1-3-2.

Table 3-3-2-1 Daily Average Global Solar Radiation in each month for calculating Total Annual Solar Radiation

[kWh/m²·day]

	Hurghada Meteorological Observatory					Measured Data						For Basic Design
Month	Monthly Average (A)				Average of 2007 - 2010	Monthly Average (B)		Maximum Measured Data		Minimum Measured Data		Monthly Average of (A) & (B)
	2007	2008	2009	2010		2011	2012	2011	2012	2012	2012	
Jan		4.09		4.29	4.19		4.36		4.93		2.34	4.25
Feb		5.34		5.24	5.29		4.89		6.04		1.80	5.16
Mar		6.27		6.23	6.25		6.49		7.11		5.01	6.33
Apr	7.03	7.30		7.20	7.18		7.15		8.21		4.49	7.17
May	7.67	7.96	7.36		7.66		7.55		8.39		4.22	7.64
Jun	8.21		8.13		8.17		8.22		8.57		7.62	8.19
Jul	7.93		7.86	7.66	7.82		7.94		8.51		7.07	7.85
Aug	7.57		7.28	7.14	7.33		7.62		8.06		7.01	7.40
Sep	6.76		6.52	6.52	6.60		6.63		7.51		5.08	6.61
Oct	5.41	5.30	5.27	5.32	5.33	5.49		6.18		4.85		5.36
Nov	4.64		4.53		4.59	4.68		5.24		4.05		4.62
Dec		3.89		4.01	3.95	3.95		4.35		1.51		3.95
Total average	6.32					6.25		The highest data: 8.57		The lowest data: 1.51		6.21

Source : Hurghada Meteorological Observatory and Measured Data in the Site

4) Each Total Annual Solar Radiation in Each Lifted Angle

Each Daily Average Solar Radiation on the lifted surface is shown in Table 3-3-2-2 which is calculated by changing lifted angle from 0 to 30 degrees based on the daily average Global Solar Radiation shown in Table 3-3-2-1 (The rightmost values in Table 3-3-2-1 is the values in 0 degrees) (refer to Appendix 3-3-1). The Total Annual Solar Radiation on the lifted surface is calculated by multiplying the daily average solar radiation on the lifted surface in each month by each number of days and summing them up.

Table 3-3-2-2 Total Annual Solar Radiation and Daily Average Solar Radiation in each Month in each Lifted Angle

Lifted Angle (degree)	Total Annual Solar Radiation on Lifted Surface (kWh/y) (ΣSolar Radiation x days)	Daily Average Solar Radiation on Lifted Surface (Hβ) (kWh/day)											
		Jun (31days)	Feb (28days)	Mar (31days)	Apr (30days)	May (31days)	Jun (30days)	Jul (31days)	Aug (31days)	Sep (30days)	Oct (31days)	Nov (30days)	Dec (31days)
0	2267.65	4.25	5.16	6.33	7.17	7.64	8.19	7.85	7.40	6.61	5.36	4.62	3.95
2	2294.45	4.40	5.30	6.42	7.21	7.62	8.14	7.82	7.42	6.69	5.48	4.78	4.11
4	2319.20	4.56	5.45	6.51	7.23	7.60	8.09	7.78	7.43	6.76	5.59	4.94	4.27
6	2341.86	4.71	5.58	6.60	7.26	7.57	8.03	7.73	7.43	6.83	5.70	5.10	4.43
8	2362.39	4.85	5.72	6.68	7.27	7.53	7.97	7.68	7.42	6.89	5.81	5.25	4.58
10	2380.76	4.99	5.84	6.75	7.28	7.49	7.89	7.62	7.41	6.94	5.90	5.40	4.73
12	2396.94	5.13	5.96	6.81	7.28	7.44	7.82	7.56	7.40	6.99	6.00	5.54	4.87
14	2410.92	5.26	6.08	6.87	7.28	7.39	7.73	7.49	7.37	7.03	6.08	5.67	5.00
16	2422.67	5.38	6.18	6.92	7.27	7.33	7.64	7.41	7.34	7.06	6.17	5.80	5.14
18	2432.17	5.50	6.29	6.97	7.25	7.26	7.55	7.33	7.30	7.08	6.24	5.92	5.26
20	2439.41	5.62	6.38	7.01	7.23	7.19	7.45	7.24	7.26	7.10	6.31	6.04	5.39
22	2444.38	5.73	6.47	7.04	7.20	7.11	7.34	7.15	7.21	7.11	6.37	6.15	5.50
24	2447.07	5.83	6.55	7.07	7.16	7.02	7.22	7.05	7.15	7.12	6.43	6.25	5.61
25	2447.56	5.88	6.59	7.08	7.14	6.98	7.17	7.00	7.12	7.12	6.46	6.30	5.67
26	2447.48	5.93	6.63	7.08	7.12	6.93	7.11	6.94	7.08	7.11	6.48	6.35	5.72
28	2445.60	6.02	6.70	7.10	7.07	6.84	6.98	6.83	7.01	7.10	6.52	6.44	5.82
30	2441.45	6.10	6.76	7.10	7.01	6.74	6.85	6.72	6.94	7.09	6.56	6.53	5.91

Source: JICA Study Team

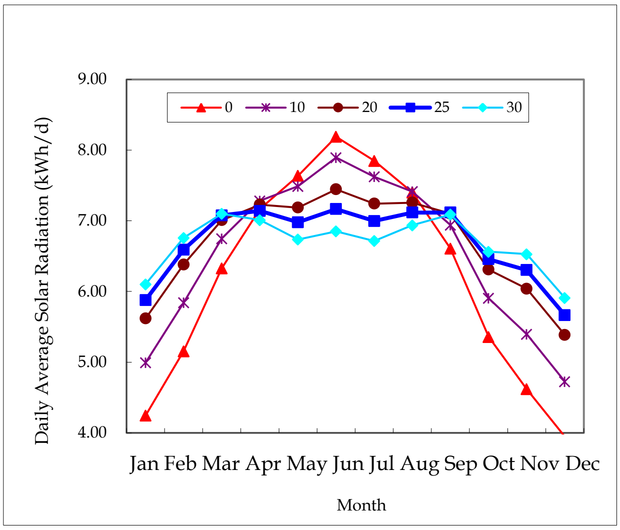


Fig. 3-3-2-3 Daily Average Global Solar Radiation in each Lifted Angle

Source: JICA Study Team

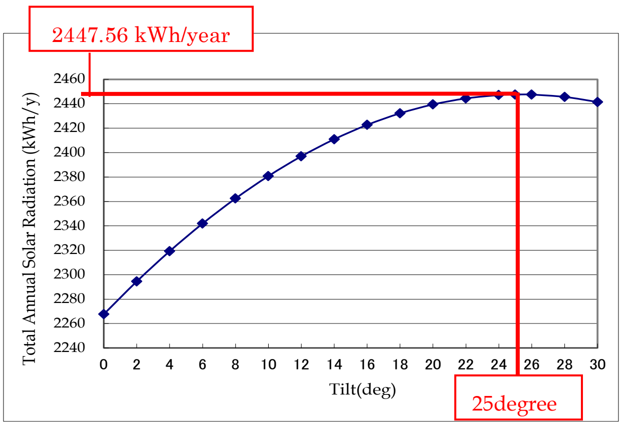


Fig. 3-3-2-4 Total Annual Solar Radiation in each Lifted Angle

Source: JICA Study Team

Based on the results of the above, the appropriate lifted angle can be considered as 25 degree, because the total annual solar radiation is the maximum at this angle as shown in Fig. 3-3-2-4.

In this study for deciding the appropriate lifted angle, types of PV module is not relevant, it is only related to the largest Total Solar Radiation, therefore this method can be used for each type of PV module as a common method.

5) Final Appropriate Lifted Angle in consideration with construction cost

Although appropriate lifted angle which can be obtained by the maximum Total Annual Solar Radiation is at 25 degree, the final appropriate lifted angle shall be determined based on the least project cost per energy. In case of changing lifted angle, frame and foundation cost should also be changed.

In general, as mentioned in the Fig. 3-3-2-1B, the least cost per energy can be estimated by the following factors:

- ✓ Frame cost for each lifted angle
- ✓ Foundation cost for each lifted angle
- ✓ Annual energy produced from each lifted angle
- ✓ Total energy production for lifetime of PV power plant

Comparison between lifted angles from 10 to 25 degree in each type of the PV module based on the above is shown in the Table 3-3-2-3.

From the results, lifted angle of 20 degree is the best cost performance regardless of the types of the PV modules (Poly Crystalline, CIS and MLTF). The reason of this result is as follows:

- ✓ Although impact of the wind gets stronger when the PV module is installed in a larger lifted angle, foundation volume is the same in case of 20 degree or 25 degree.
- ✓ Frame cost will decrease in lower lifted angles, because length of frame post decreases.

The power energy output is larger in the 25 degree lifted angle than that of 20 degree as described as appropriate lifted angle. However, the difference of cost for[Frame + Foundation]between 20 and 25 degree lifted angle can not be compensated by difference of energy production of 20 years life time.

Table 3-3-2-3 Comparison for identifying Final Lifted Angle

Comparison of frame and foundation cost and PV Energy Production

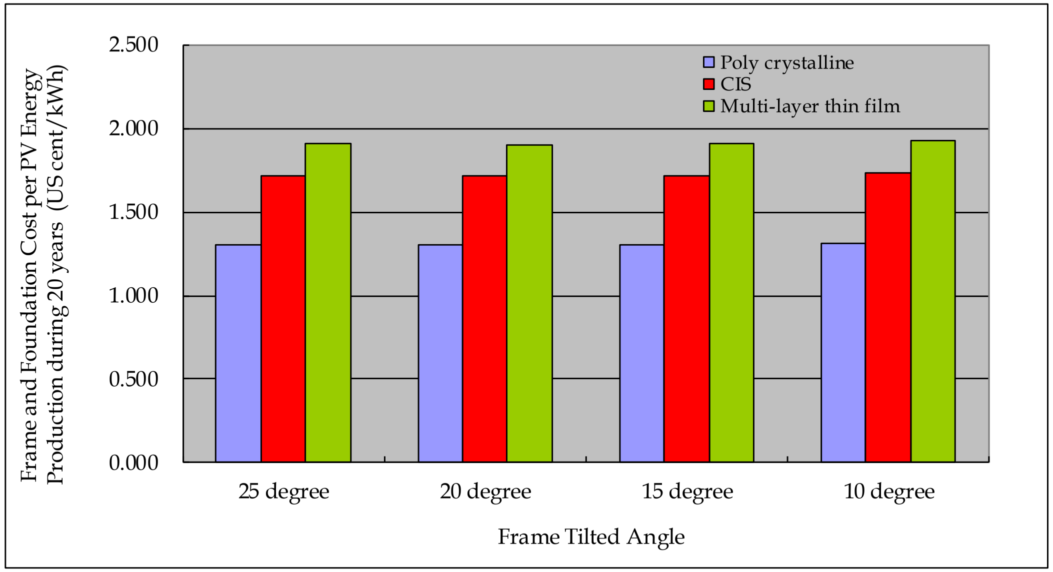
	Tilted Angle (Degree)	Frame cost (US$)	Foundation (US$)	Sub total (US$)	Annual PV Energy production (MWh)	PV Energy production during Lifetime years(MWh)	Cost per Energy during 20years (US cent/kWh)	Difference from 25degree (US cent/kWh)
Poly crystalline	25	7,029,500	2,072,217	9,101,717	34,903	698,054	1.304	0.000
	20	6,965,000	2,072,217	9,037,217	34,760	695,200	1.300	0.004
	15	6,900,500	2,072,217	8,972,717	34,414	688,281	1.304	0.000
	10	6,842,250	2,072,217	8,914,467	33,869	677,381	1.316	-0.012
CIS	25	9,708,250	2,370,021	12,078,271	35,148	702,965	1.718	0.000
	20	9,634,500	2,370,021	12,004,521	35,013	700,260	1.714	0.004
	15	9,561,000	2,370,021	11,931,021	34,675	693,493	1.720	-0.002
	10	9,494,500	2,370,021	11,864,521	34,135	682,703	1.738	-0.020
Multi-layer thin film	25	11,131,500	2,605,782	13,737,282	36,044	720,878	1.906	0.000
	20	11,050,500	2,605,782	13,656,282	35,910	718,200	1.901	0.004
	15	10,969,500	2,605,782	13,575,282	35,567	711,336	1.908	-0.003
	10	10,896,500	2,605,782	13,502,282	35,018	700,357	1.928	-0.022

Life time= 20 years

Frame and Foundation Cost per PV Energy Production during 20 years (US cent/kWh)

	Poly crystalline	CIS	Multi-layer thin film
25 degree	1.304	1.718	1.906
20 degree	1.300	1.714	1.901
15 degree	1.304	1.720	1.908
10 degree	1.316	1.738	1.928

*Time Deterioration is not considered here, because there is no comparison between photovoltaic module types.



6) Effect of shade

The following 2 steps shall be considered in this clause with「Poly crystalline type」,「MLTF type」 and「CIS type」.

- ✓ Consideration of Direction and the Number of PV modules to be installed
- ✓ Consideration of Distance between the PV Arrays

Table 3-3-2-4 Specifications of PV Modules

Type	Poly crystalline	MLTF	CIS
Long Side (mm)	1,662	1,402	1,257
Short Side（mm）	990	1,001	977
Thickness (mm)	46	24	35
Area (m^2)	1.645	1.403	1.228
Weight (kg)	21.0	26.0	20.0
Capacity (W)	240	128	140

Source : JICA Study Team based on the results of the interview with the manufacturers

(1) Consideration of Direction and the Number of PV modules to be installed

In consideration of “effect of shade”, “Workability of installation and maintenance” and “Workability of Cleaning for PV Modules” described below, the following 2 points for the PV module shall be decided.

- ✓ Direction of the installation of module (Long Side or Short Side)
- ✓ Number of column of modules

■ Effect of the shade

Many arrays shall line not only east-west direction, but also north-south direction; therefore shadow of the front arrays is affecting the layout of arrays. If height of the module is too high, required space between modules, north-south direction, is required to be wider.

■ Workability of installation and maintenance

If number of column of the module is too much, the highest position of the module is too high to approach. It is difficult for installation work and maintenance. And also it will require cranes for installation; therefore it requires more space for setting the cranes.

■ Workability of Cleaning for Photovoltaic Modules

It is necessary to clean the surface of the PV module periodically in order to minimize the reduction of the power energy production, because the candidate site is in the desert and based on the measurement, the reduction of the power energy production by the dust is expected. Additionally, automated cleaning for the PV modules is not applicable due to its high cost.

The arrangement of the PV modules is taking into consideration that cleaning will be done by maintenance staffs as well. Therefore, appropriate number of columns should be limited.

(2) Condition of Arrangement of PV Modules

The clearance between the ground surface and the PV modules shall be 1m due to the followings:

- Avoiding increasing temperature of the PV modules by the heat reflected from the ground. If temperature of the PV module rises up, output energy of the PV module is going down, because of its temperature specification. According to some experiences of installation PV modules in the desert area, it is recommended to keep 1m or more between the ground and the PV modules.
- Avoiding the possibility that PV modules might get wet during the flood. In the past, there were heavy rain fall and though risk is very low, some flood might be expected. Therefore as precaution, it is recommended to set the PV module with appropriate clearance, e.g., more than 0.5m above the ground.

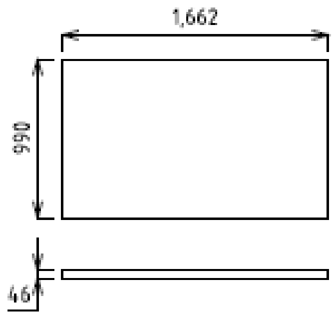
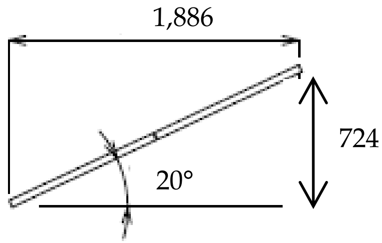
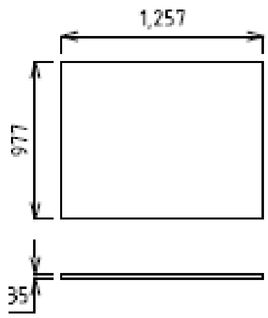
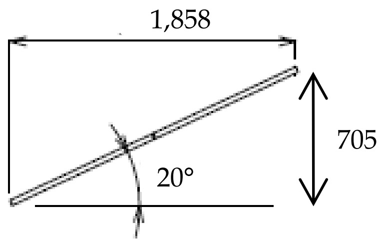
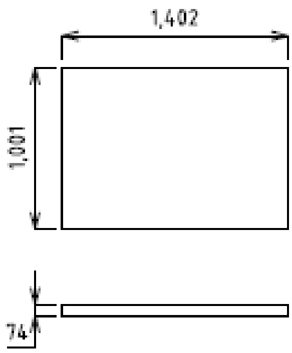
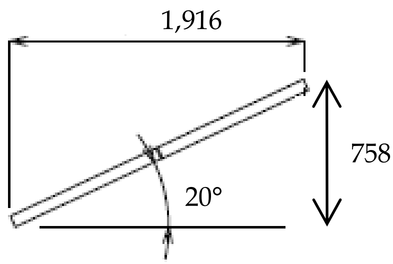
The length of the lifted surface of the PV modules shall be limited to approximately 2 m considering that the cleaning of the PV modules will be carried out by general cleaning tools such as a mop and so on in case the PV modules will be set in the east-west direction in parallel.

The height of the PV module at the northern side end shall be limited to approximate 2 m considering the maintenance of the cables and terminal boxes located in the backside of the PV modules.

The best arrangement of the PV modules to be installed in this project is:

- PV module is fixed in two parallel rows

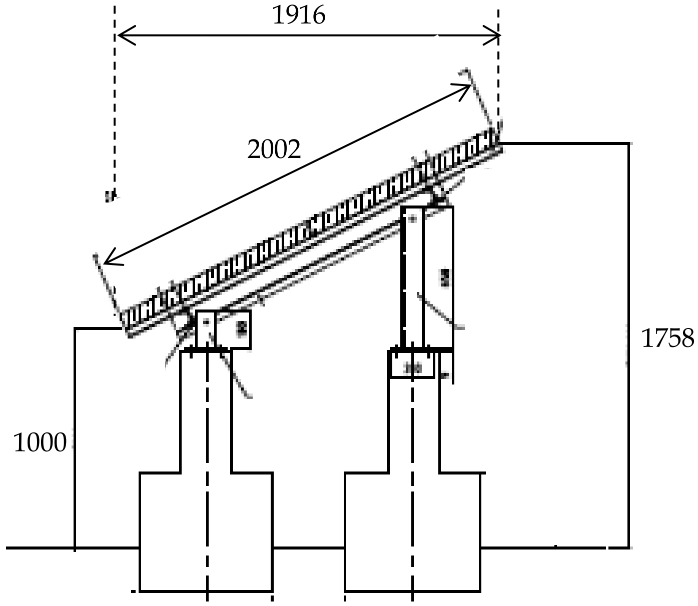
Fig. 3-3-2-5 shows the size of PV module and arrangement of PV modulus of short side on each PV module.

	Size of PV Module	Side View Short Side PV Modules
Poly Crystalline		
CIS		
MLTF		

Unit: mm

Source : JICA Study Team creates based on the results of the interview with the manufacturers

Fig. 3-3-2-5 Size of PV module and arrangement of PV modules of short side



Source : JICA Study Team

Fig. 3-3-2-6 One Example of Short Side and 2 Photovoltaic Modules Installation including Frame and Foundation (MLTF type)

(3) Consideration of Distance between PV Arrays

Based on the result of '(1) Consideration of Direction and the Number', the distance between the PV arrays is decided by considering the effect of shade of the nearby PV array.

As for the effect of shade, this consideration is conducted on the winter solstice in general, because the sun elevation is the lowest through a year on that day, therefore the consideration in this section is conducted on the winter solstice as well.

In Table 3-3-2-5, in the case of installing 1 m pole and becoming the highest altitude of the Sun at noon, the length of the shade in each time is described by the scale comparing with the length of the 1 m pole. Additionally, the hatched portion in the table shows the length of the north-facing shade and these values in the hatched portion are utilized for this consideration, because the most suitable direction for installing the photovoltaic modules is south in this project.

Table 3-3-2-5 Scale of Shade Length in each time on the winter solstice in the Hurghada

(unit : degree)

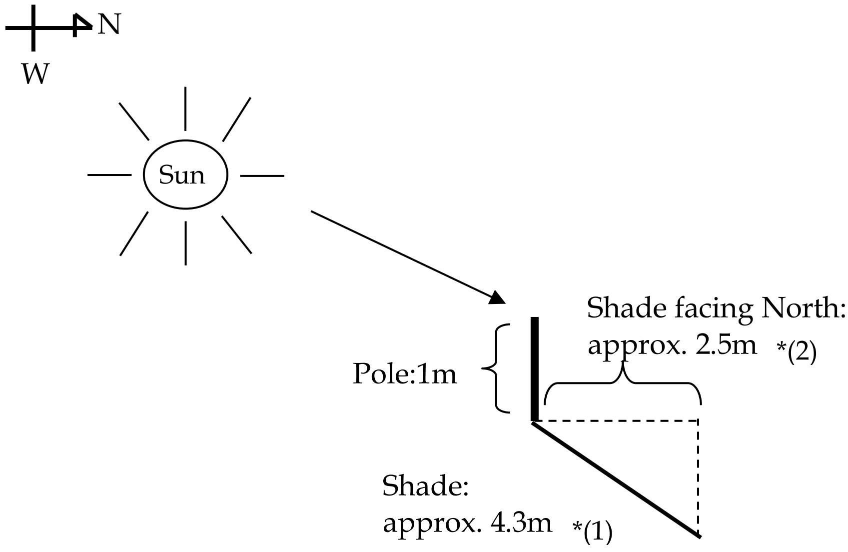
Considerable Time Zone (8:00 – 16:00)

Time	Sun Elevation	Sun Azimuth Direction	Shade Length	Shade Coodinate in North&South	Shade Coodinate in East&West
7:00	2.0	117.6	28.4	13.1	-25.1
7:15	4.8	119.4	11.9	5.8	-10.4
7:30	7.6	121.3	7.5	3.9	-6.4
7:45	10.4	123.3	5.4	3.0	-4.5
8:00	13.2	125.4	4.3 *(1)	2.5 *(2)	-3.5
8:15	15.8	127.6	3.5	2.2	-2.8
8:30	18.4	129.9	3.0	1.9	-2.3
8:45	20.9	132.4	2.6	1.8	-1.9
9:00	23.3	135.1	2.3	1.6	-1.6
9:15	25.6	137.9	2.1	1.5	-1.4
9:30	27.8	140.9	1.9	1.5	-1.2
9:45	29.8	144.1	1.7	1.4	-1.0
10:00	31.7	147.4	1.6	1.4	-0.9
10:15	33.4	151.0	1.5	1.3	-0.7
10:30	34.9	154.7	1.4	1.3	-0.6
10:45	36.3	158.6	1.4	1.3	-0.5
11:00	37.4	162.6	1.3	1.3	-0.4
11:15	38.2	166.9	1.3	1.2	-0.3
11:30	38.9	171.2	1.2	1.2	-0.2
11:45	39.3	175.6	1.2	1.2	-0.1
12:00	39.4	180.0	1.2	1.2	0.0
12:15	39.3	184.5	1.2	1.2	0.1
12:30	38.9	188.9	1.2	1.2	0.2
12:45	38.2	193.2	1.3	1.2	0.3
13:00	37.4	197.4	1.3	1.3	0.4
13:15	36.2	201.5	1.4	1.3	0.5
13:30	34.9	205.4	1.4	1.3	0.6
13:45	33.4	209.1	1.5	1.3	0.7
14:00	31.7	212.6	1.6	1.4	0.9
14:15	29.8	216.0	1.7	1.4	1.0
14:30	27.8	219.1	1.9	1.5	1.2
14:45	25.6	222.1	2.1	1.5	1.4
15:00	23.3	224.9	2.3	1.6	1.6
15:15	20.9	227.6	2.6	1.8	1.9
15:30	18.4	230.1	3.0	1.9	2.3
15:45	15.8	232.4	3.5	2.2	2.8
16:00	13.2	234.7	4.3 *(1)	2.5 *(2)	3.5
16:15	10.4	236.8	5.4	3.0	4.6
16:30	7.6	238.8	7.5	3.9	6.4
16:45	4.8	240.6	11.9	5.8	10.4
17:00	2.0	242.4	28.6	13.2	25.4

Source: JICA Study Team

(+:North / −:South)　(+:East / −:West)

An image to understand Table 3-3-2-5 is shown in Fig. 3-3-2-7.



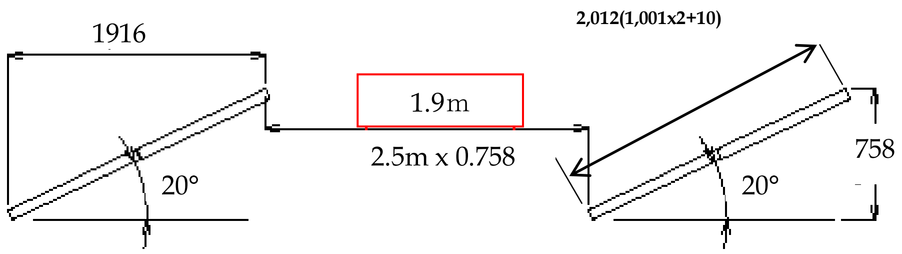
(1) and (2) shown in the above is referred to Table 3-3-2-5.

Fig. 3-3-2-7 Shade Length at 8 am on the winter solstice

In case of calculating power energy output, 9 am to 3 pm is utilized as the considerable time zone in Japan in general because of limitation of land acquisition. However, 8 am to 4 pm can be considered as the considerable time zone for the distance between the PV arrays and the power energy output in this project, because the required area of the PV installation based on 8 am to 4 pm can be covered by the allocated one taking into consideration the distance between the PV arrays and those effect of the shade.

Accordingly, the distance between the nearby PV arrays is calculated based on the length of the shade at 8 am or 4 pm in the considerable time zone, because each length of the shade at 8 am or 4 pm in the considerable time zone is the longest in a day.

Additionally, Fig. 3-3-2-8 shows the result of the distance between the PV arrays in the MLTF type having the longest length since MLTF is the longest among the three types as shown in Fig. 3-3-2-5. As a conclusion, there is no effect by the shade of the nearby PV arrays from 8 am to 4 pm in the case of securing approximate 1.9 m of the distance between the PV arrays. In case 1.9 m of the distance between the PV arrays is secured, no effect by the shade of the nearby PV arrays are expected regardless the PV module type since MLTF type has the longest of the short side among the three types. Also, this 1.9m distance will allow a light truck with approximately 1.5m width carrying a PV washing machine (as example, refer to Photo 2-2-14) size of 1m * 0.5m * 0.5m to go through the arrays.



Source : JICA Study Team

Fig. 3-3-2-8 Consideration Result of Distance between Photovoltaic Arrays in MLTF type and 20 degree of Lifted Angle

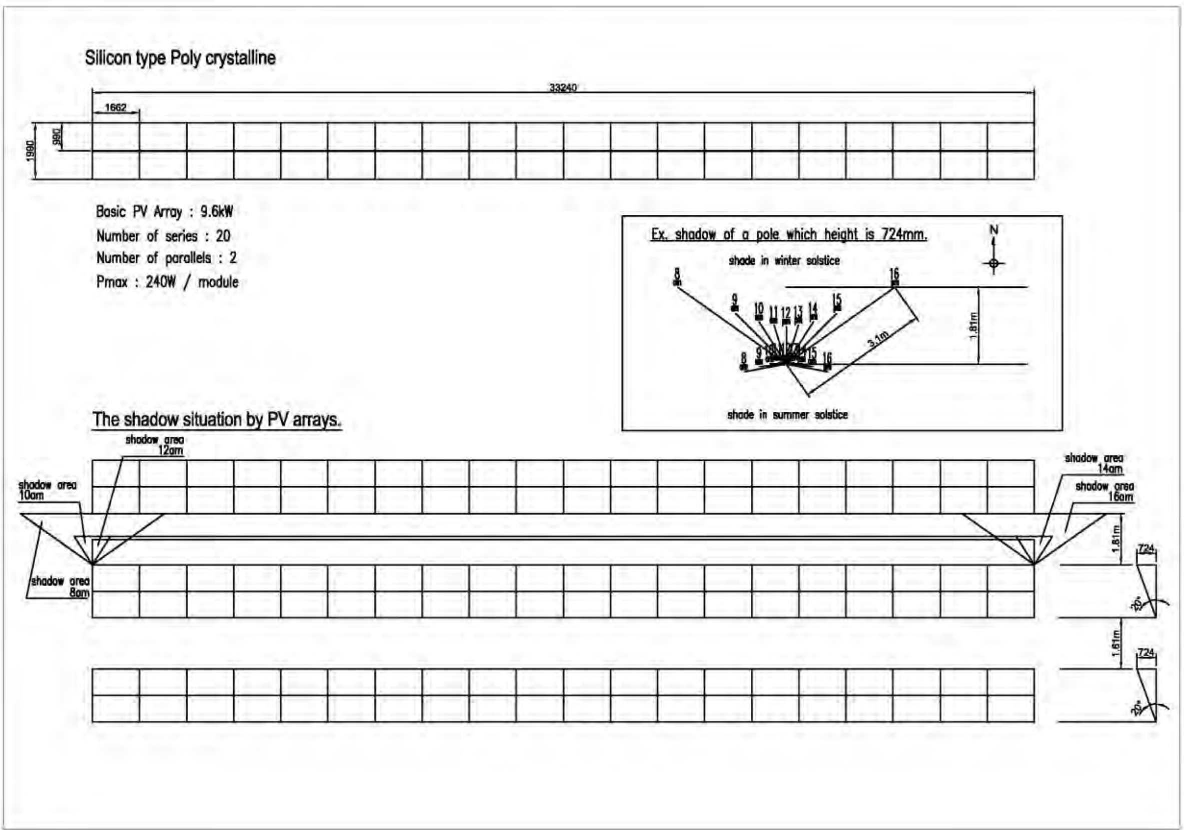


Fig. 3-3-2-9 PV array arrangement considering shadow effect for Poly Crystalline type

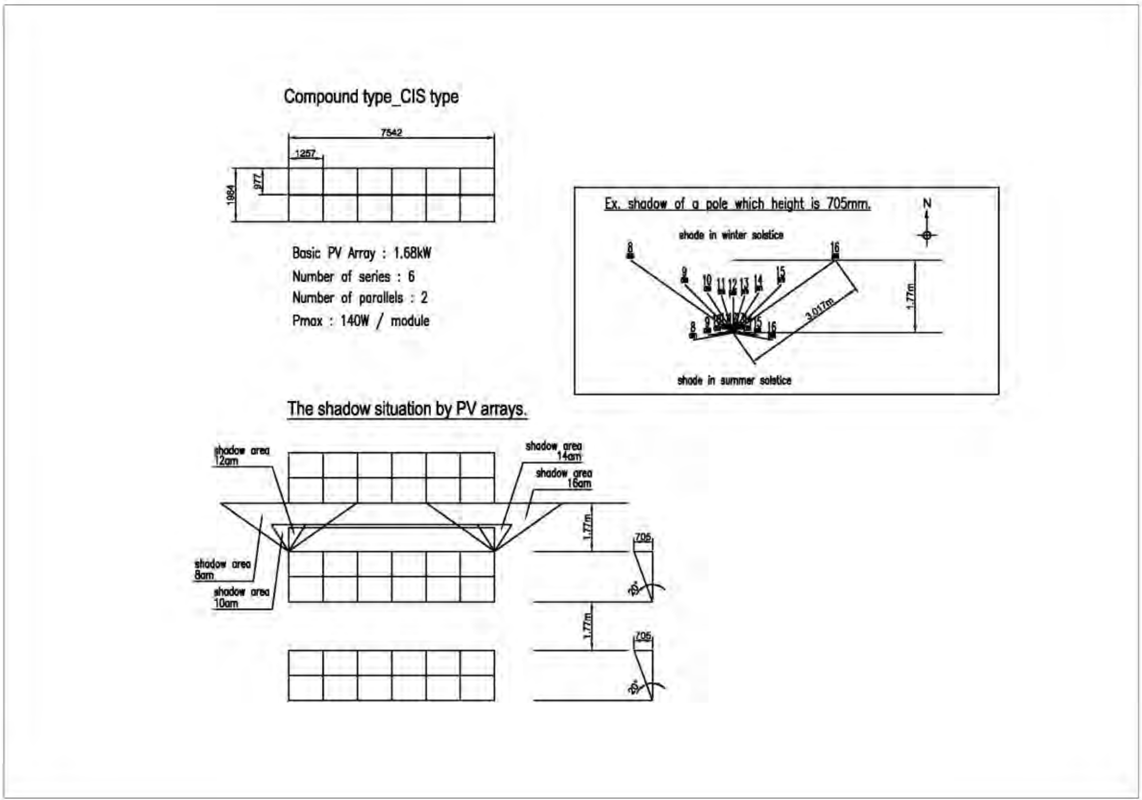


Fig. 3-3-2-10 PV array arrangement considering shadow effect for CIS type

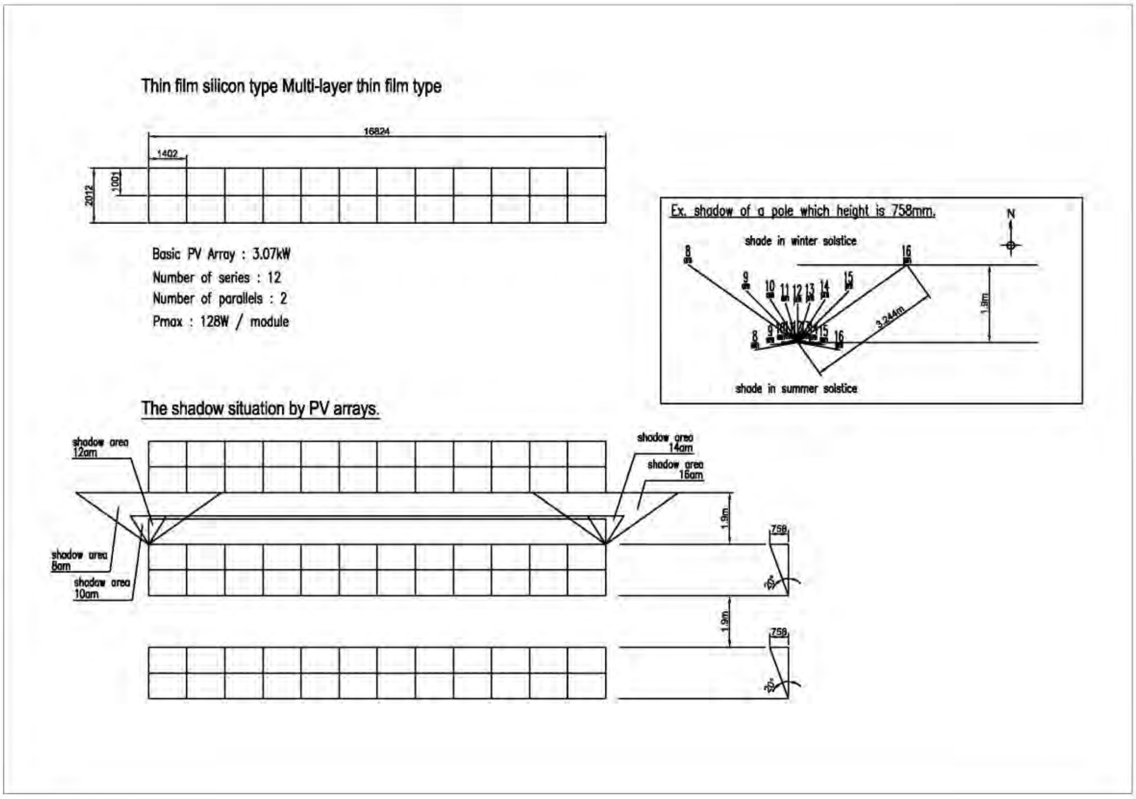


Fig. 3-3-2-11 PV array arrangement considering shadow effect for MLTF type

7) Consideration of existing wind turbines

To carry out layout design for PV arrays, it is required to consider existing wind turbines and wind measuring masts. The PV modules shall be arranged with avoiding shade of existing towers. Example for shade of towers is shown in Fig.3-3-2-12.

Length of the shade depends on height of towers.

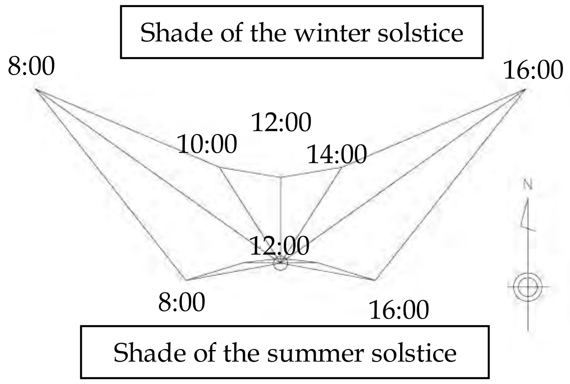


Fig. 3-3-2-12 Example for shade of existing wind turbine

Considering with location and height of existing towers, the result of the shade of towers is shown in Fig.3-3-2-13. According to this study, NREA decided to remove the two towers (currently not operated) located in the North-west side (see Fig. 3-2-2-13) in order to secure appropriate space for PV modules installation.

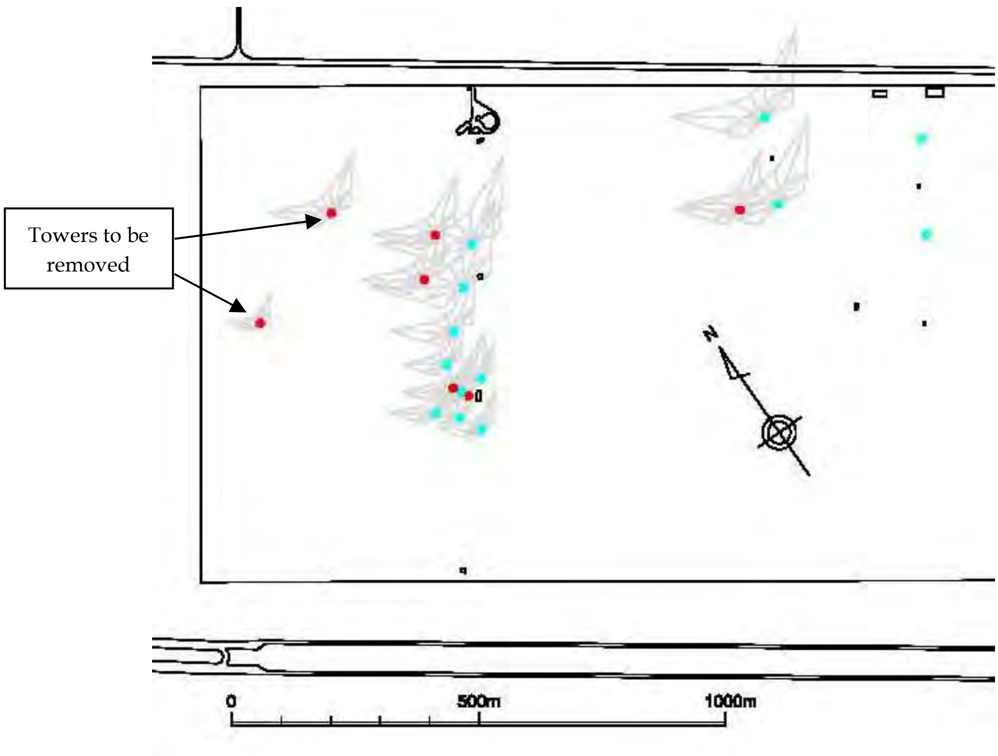


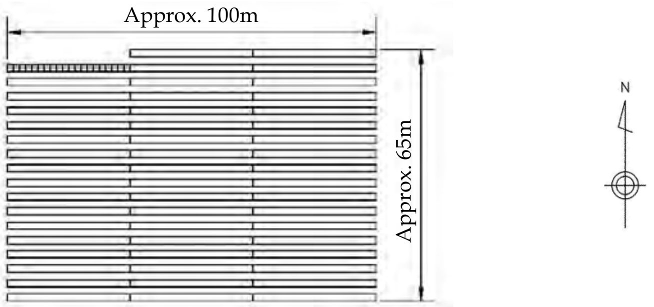
Fig. 3-3-2-13 Shade effect of the existing wind turbines

Clause 3 Comparison of sun tracking system and fixed system

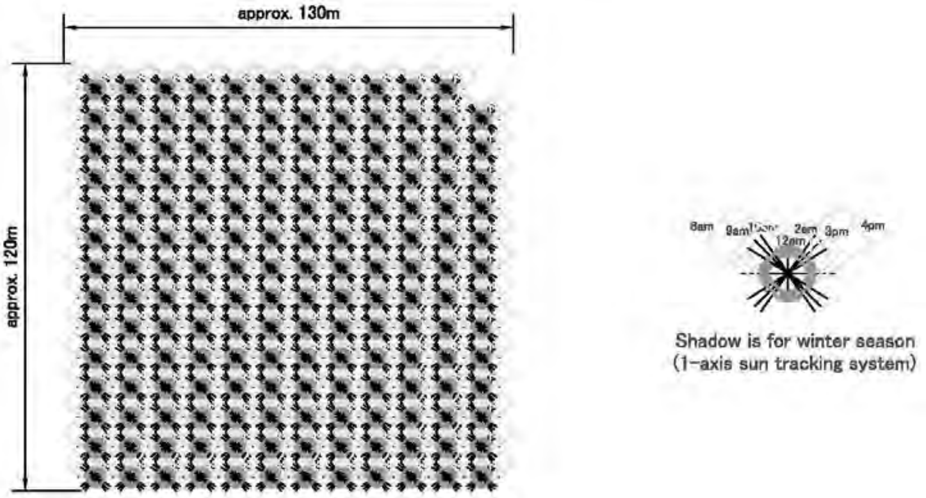
PV (photovoltaic) modules with fixed system is generally set fixed lifted angle, and faced fixed direction particularly south in the northern hemisphere. The lifted angle of the PV module in the PV power generation system is set at the lifted angle which can be obtained the maximum annual power energy output in general.

On the other hand, the PV power generation system with a sun tracking system is more effective than the fixed system in view of increasing power energy output. One of the characteristics of the sun tracking system is that the PV modules can follow the sun automatically to receive radiation to the modules vertically in order to generate power as much as possible. The sun tracking system is equipped with mounts moving device which can be shift from east to west and change the lifted angle of the PV modules, etc. Therefore, in case the height of the sun is low, length of the shade of the PV modules is longer, because the surfaces of the PV modules follow the sun as much as possible. Thus, the sun tracking system is required to have enough (wider than the fixed type) distance between the arrays in order to avoid shades of PV modules in front. Accordingly, the sun tracking system requires large size of land in total than the fixed one. For example, the required land area of the sun tracking system (1-axis system: moving from east to west, 2-axis system: moving from east to west and moving the lifted angle of the PV module) is approximately 3 times than the required area of the fixed system under the same conditions (in case of considering Poly crystalline type, Energy production time: 8AM to 4PM).

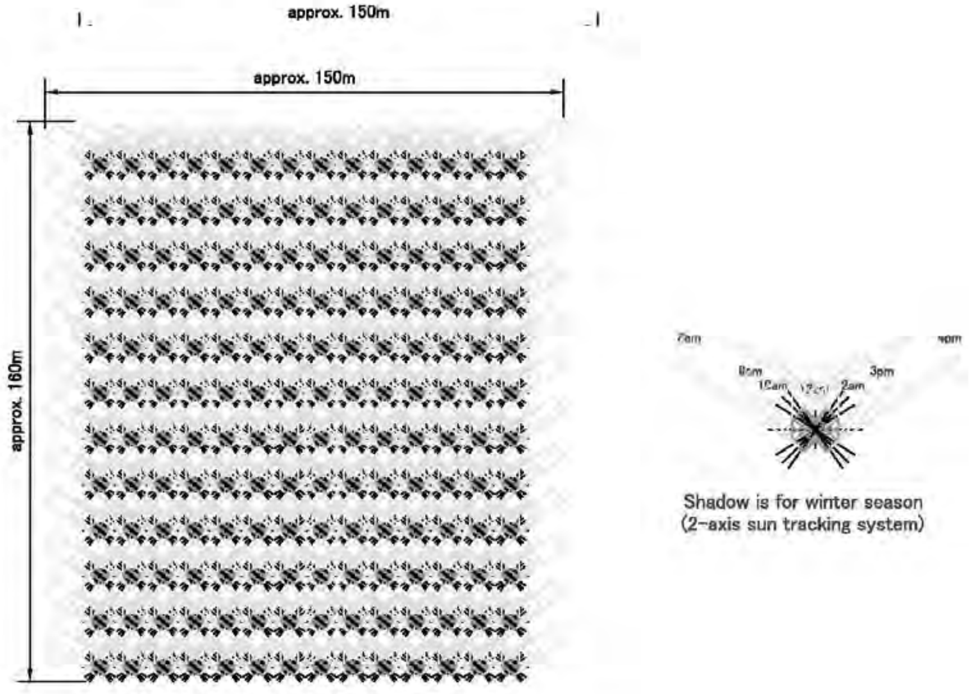
Required land area considering shadow effect of tracking system for 1-axis and 2-axis tracking system type, which unit has a capacity of 3kW as well as the fixed type is shown in Fig. 3-3-3-1. Layout drawings of total capacity of 20MW with 1-axis and 2-axis tracking systems are shown in Fig.3-3-3-2 and Fig.3-3-3-3 respectively.



Fixed frame system (for reference)
9.6kW x 53 = 509kW



1-axis sun tracking system
3kW module x 167 = 501kW



2-axis sun tracking system
3kW module x 167 = 501kW

Fig. 3-3-3-1 500kW group of arrays layout for Sun Tracking System and Fixed System with Poly Crystalline

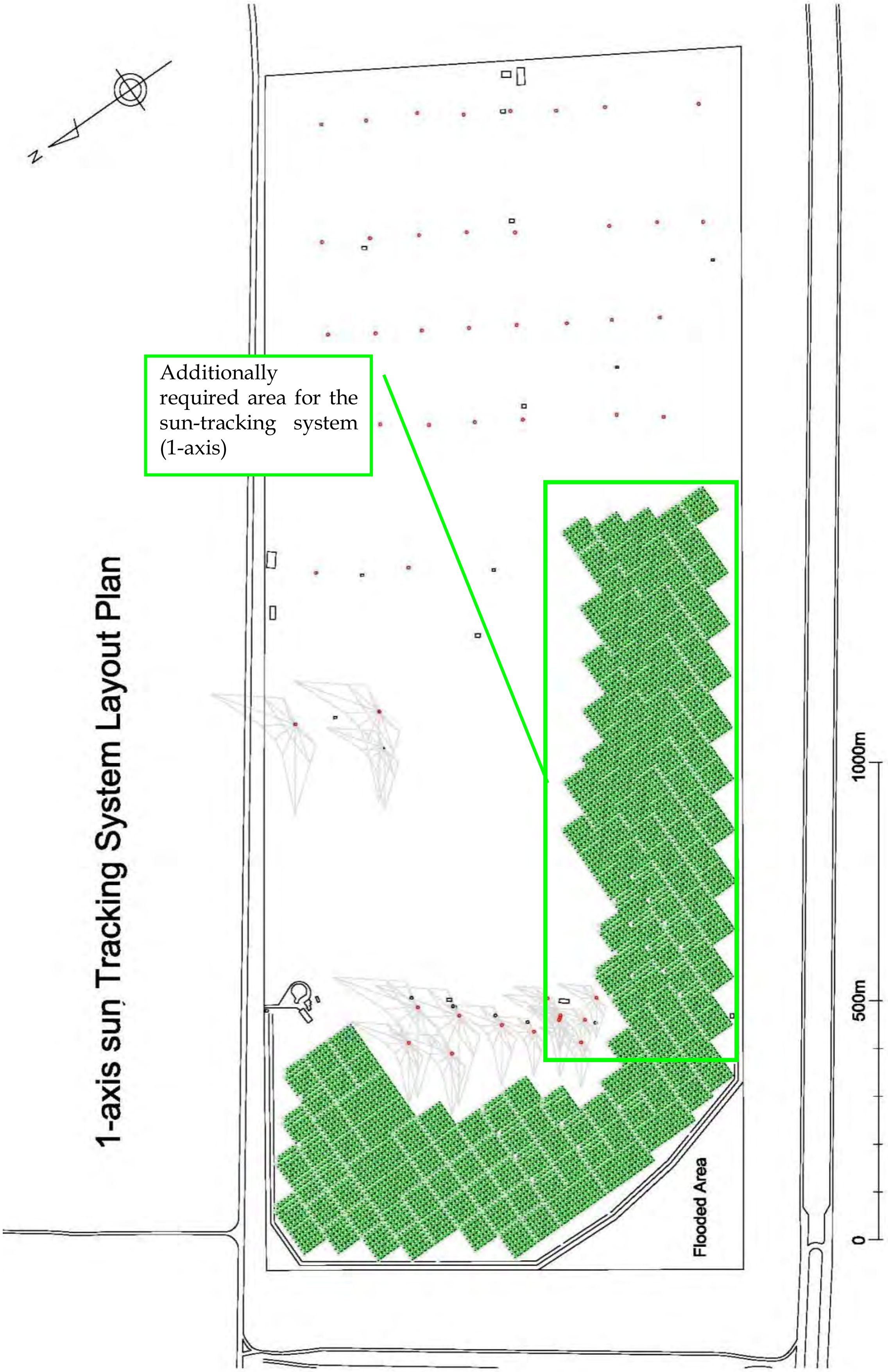


Fig. 3-3-3-2 Example of Arrangement of 1-axis Sun Tracking System with Poly Crystalline

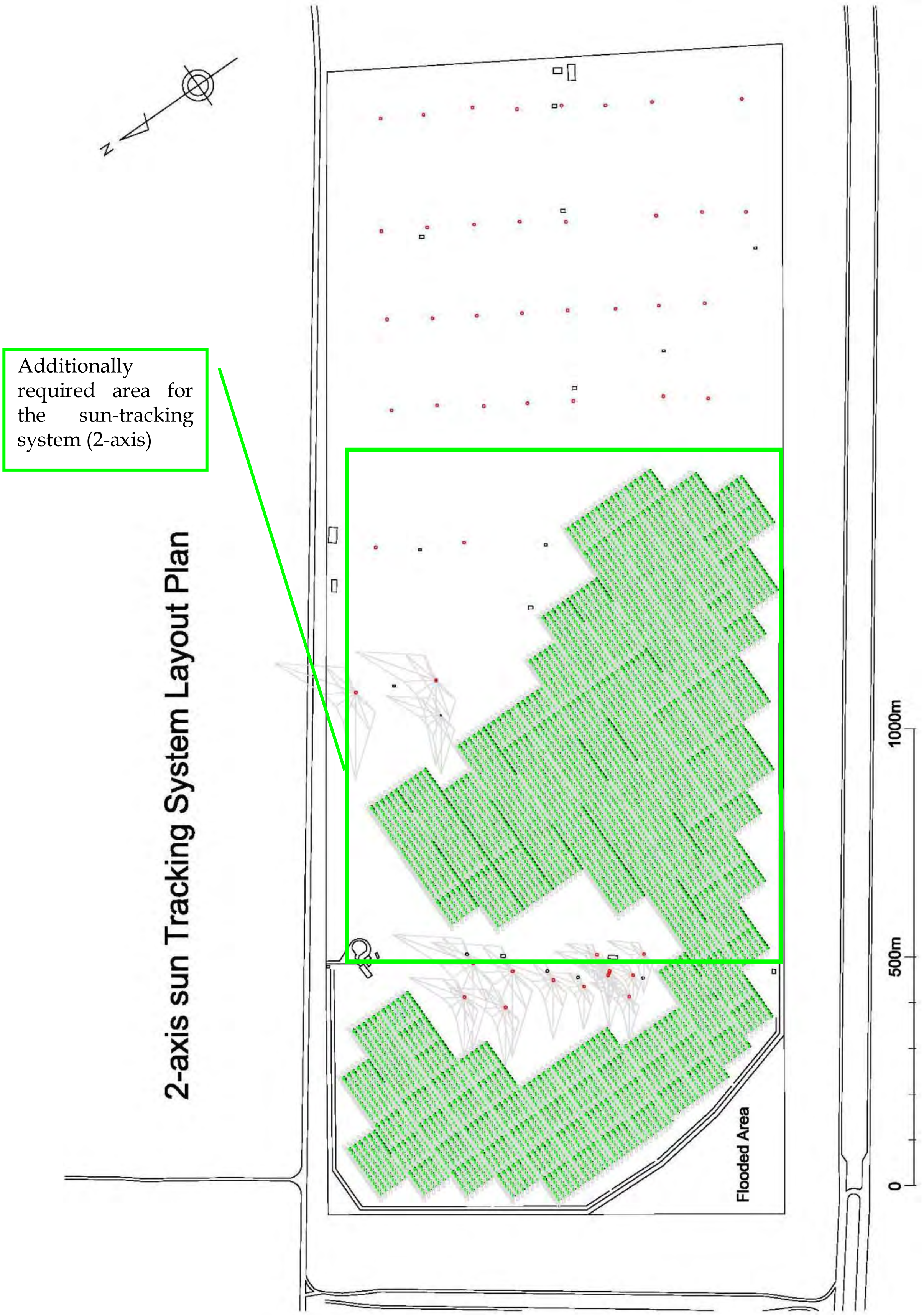


Fig. 3-3-3-3 Example of Arrangement of 2-axis Sun Tracking System with Poly Crystalline

Estimation of monthly and annual Total Solar Radiation is shown as follows:

- ✓ 1-axis system can obtain 15% more of Annual Total Solar Radiation than the fixed type.
- ✓ 2-axis system can obtain 20% more of Annual Total Solar Radiation than the fixed type.

Table 3-3-3-1 Comparison of monthly and annual Total Solar Radiation

unit: kWh/m2/day

	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Incremental Ratio
Total Solar Radiation by fixed angle 20 degree	5.62	6.38	7.01	7.23	7.19	7.45	7.24	7.26	7.10	6.31	6.04	5.39	2,439.41	-
Total Solar Radiation by 1 axis tracking of Direction	5.94	6.86	7.84	8.41	8.50	9.38	9.30	8.61	8.27	7.07	6.47	5.81	2,823.77	15.8%
Total Solar Radiation by tracking of Lifted Angle	6.03	6.65	7.10	7.43	7.64	8.13	7.86	7.50	7.14	6.51	6.40	6.00	2,567.08	4.5%
Total Solar Radiation by 2 axis tracking	6.35	7.14	7.93	8.60	8.95	10.07	9.91	8.85	8.31	7.27	6.83	6.42	2,940.58	20.5%

(note)
Since this comparison is made in initial study stage, data of the above is only considering EMA data, not considering the measured data.

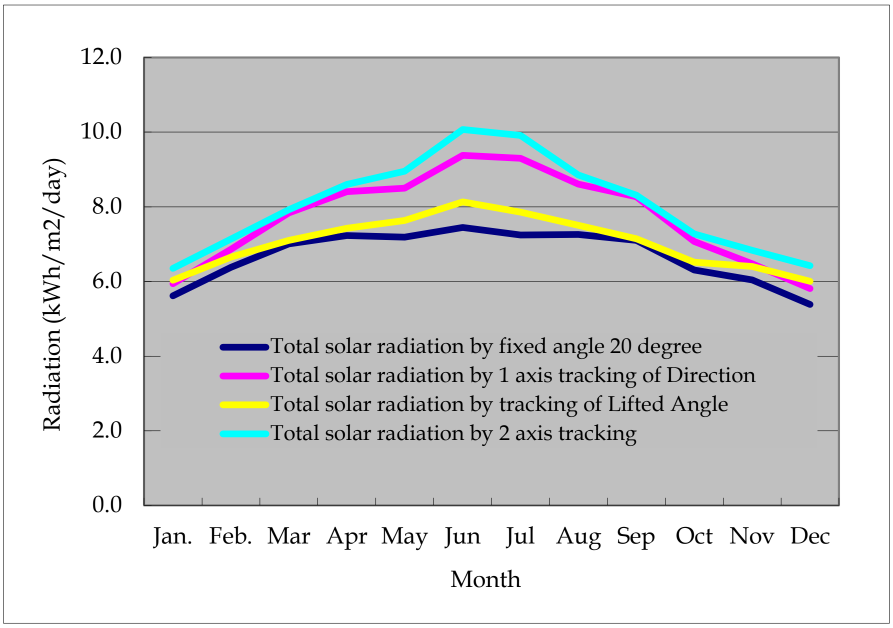


Fig. 3-3-3-4 Comparison of monthly Total Solar Radiation

As O&M point of view, the followings shall be noted:

- ■ The PV power generation with fixed system is generally maintenance free with low running cost.
- ■ Since the sun tracking system has many moving parts, proper and timely maintenance for the moving parts is required and O&M cost is much higher than that of the fixed system.

- Additionally, the sun tracking system requires high accuracy control of sun tracking movement, thus sand dust may be the reason of some defects or problems for the moving devices. Accordingly, high technology of the maintenance is required to the sun tracking system.

Comparison results between fixed and sun tracking system with 1-axis and 2-axis are shown in the Table 3-3-3-2 to Table 3-3-3-4 for Poly Crystalline type, CIS type and MLTF type, respectively.

Table 3-3-3-2 Comparison of Cost and Power Energy Output (Poly Crystalline type)

Poly Crystalline	Fixed System	Tracking System	
	(Lifted Angle: 20 deg.)	2-axis	1-axis
(1) Frame ($/kW)	348	2,820	1,204
(2) Foundation ($/kW)	104	745	
(3) Total Cost =(1)+(2)($/kW)	452	3,565	1,204
(4) Cost rate to Fixed System	1.00	7.89	2.66
(5) Annual power output rate to Fixed System	1.00	1.20	1.15
Cost Effectiveness =(4)/(5)	1.00	6.57	2.32

Source: JICA Study Team

Table 3-3-3-3 Comparison of Cost and Power Energy Output (CIS type)

CIS	Fixed System	Tracking System	
	(Lifted Angle:20deg)	2-axis	1-axis
(1)Frame ($/kW)	482	4,835	1,415
(2)Foundation ($/kW)	119	745	
(3)Total Cost =(1)+(2)($/kW)	601	5,580	1,415
(4)Cost rate to Fixed system	1.00	9.28	2.35
(5)Annual power output rate to Fixed system	1.00	1.20	1.15
Cost Effectiveness=(4)/(5)	1.00	7.74	2.05

Source: JICA Study Team

Table 3-3-3-4 Comparison of Cost and Power Energy Output (MLTF type)

Multi Layer Thin Film	Fixed System	Tracking System	
	(Lifted Angle:20deg)	2-axis	1-axis
(1)Frame ($/kW)	553	5,288	1,501
(2)Foundation ($/kW)	130	745	
(3)Total Cost =(1)+(2)($/kW)	683	6,033	1,501
(4)Cost rate to Fixed system	1.00	8.83	2.20
(5)Annual power output rate to Fixed system	1.00	1.20	1.15
Cost Effectiveness=(4)/(5)	1.00	7.36	1.91

Source: JICA Study Team

As shown in Table 3-3-3-2 to Table 3-3-3-4, although 1-axis system has a more cost effectiveness than 2-axis system, it is difficult to obtain more benefit than the fixed system. The reason is explained as follows;

- Example case 1 : Poly Crystalline 1-axis type
  - (a) Additionally required cost for installing 1-axis tracking system against the fixed system
    - Additionally required cost : (1,204 ($/kW) – 452 ($/kW)) X 20,000kW =$15,040,000
  - (b) Additional cost for providing PV modules with 1-axis type for getting 15% more annual energy output.
    - Photovoltaic Module Cost: 48,826,600US$/20,000kW (refer to the Appendix 3-4-1)
    - Additional cost =$48,826,600 ∗ 0.15 = $7,323,990

From the above, (a)" Additionally required cost for installing 1-axis tracking system" is higher than (b) "Additional cost for providing PV modules for getting 15% more annual energy output", then it can be concluded that 1-axis tracking system has less merit cost wisely than the fixed type.

- Example case 2 : Poly Crystalline 2-axis type
  - (a) Additionally required cost for installing 2-axis tracking system against the fixed system
    - Additionally required cost : (3,565 ($/kW) - 452 ($/kW)) * 20,000kW = $62,260,000

(b) Additional cost for providing PV modules with 2-axis type for getting 20% more annual energy output.

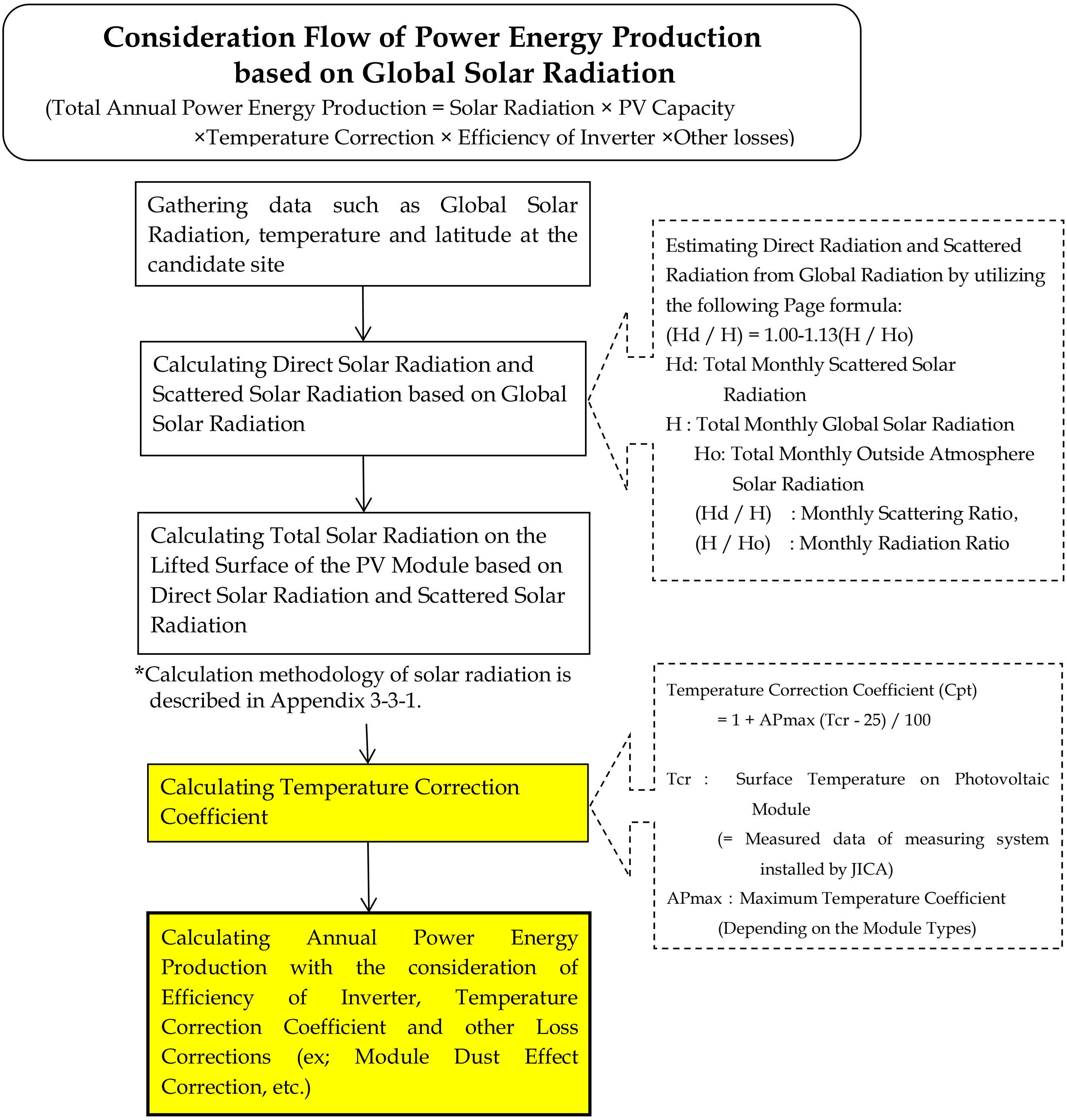
- Additional cost : $48,826,600 * 0.2 = $9,765,320

From the above, (a)"Additionally required cost for installing 2-axis tracking system" is higher than (b)"Additional cost for providing PV modules to get 20% more annual energy output", then it can be concluded that 2-axis tracking system has less merit cost wisely than the fixed type.

In consideration to the above matter, the Team concluded that tracking system is not recommendable to be used in this project.

Clause 4 Estimation of annual energy production

The consideration flow from the Global Solar Radiation to the Annual Power Energy production is shown in Fig. 3-3-4-1 and calculation methodology of Solar Radiations are described in Appendix 3-3-1.



Source : JICA Study Team

Fig. 3-3-4-1 Consideration Flow for Annual Power Energy Output

(1) Temperature of Photovoltaic module Surface

The Team has obtained climate data from the measuring system installed by JICA from October 2011 to September 2012. As explained before, the temperature of the installed PV module surface and air temperature are part of measuring items of this system. Those data are shown in following table.

Table 3-3-4-1 PV module temperature

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Note
Meteorological Authority Data	Average Maximum Temperature °C	22.1	24.0	27.0	30.0	33.2	36.8	37.4	37.3	34.8	31.6	27.3	23.9	2007-2009 average
Measured Data	Maximum Temperature °C	20.8	22.7	23.7	29.6	33.1	35.8	36.8	36.7	33.7	30.4	25.1	22.6	Oct.2011-Sep.2012
	PV module temperature °C	30.0	32.4	33.0	39.8	42.5	44.9	45.6	46.8	43.2	38.3	34.6	31.5	Oct.2011-Sep.2012

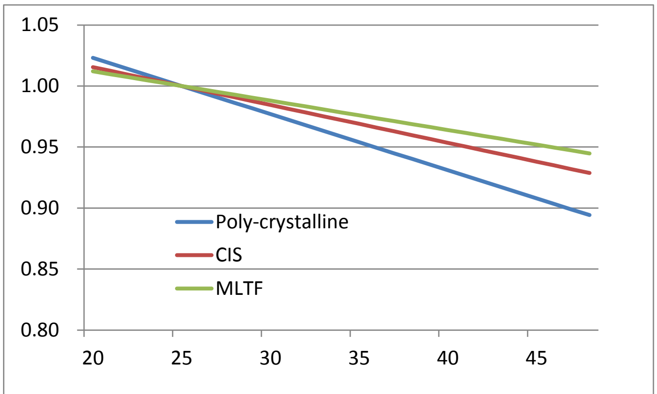


Fig. 3-3-4-2 Temperature coefficient of PV module

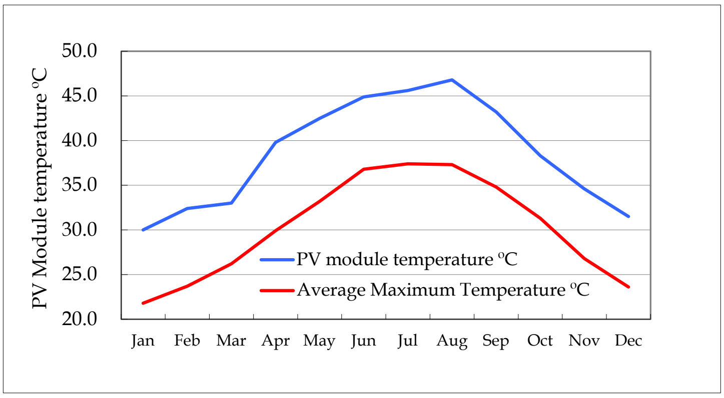


Fig. 3-3-4-3 PV module temperature

(2) Temperature Correction Coefficient

Based on the information provided from typical PV manufacturers, the Team decided to apply the following formula for estimating the temperature correction coefficient to this project. Additionally, the calculating result of the temperature correction coefficient in each month is shown in Table 3-3-4-2.

Temperature Correction Coefficient (Cpt) = 1 + APmax (Tcr – 25) / 100

Tcr: Surface Temperature on PV Module
(=Measured Data of Measuring System installed by JICA)
APmax: Maximum Temperature Coefficient (Depending on the module types)

Table 3-3-4-2 Temperature correction coefficient

Month		Jun	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Maximum Temperature Coefficient (AP max) %/℃
PV module temperature ℃		30.0	32.4	33.0	39.8	42.5	44.9	45.6	46.8	43.2	38.3	34.6	31.5	
Temperature Correction Coefficient	Poly Crystalline	0.977	0.966	0.963	0.932	0.920	0.908	0.905	0.900	0.916	0.939	0.956	0.970	-0.46
	CIS	0.985	0.977	0.975	0.954	0.946	0.938	0.936	0.932	0.944	0.959	0.970	0.980	-0.31
	MLTF	0.988	0.982	0.981	0.964	0.958	0.952	0.951	0.948	0.956	0.968	0.977	0.984	-0.24

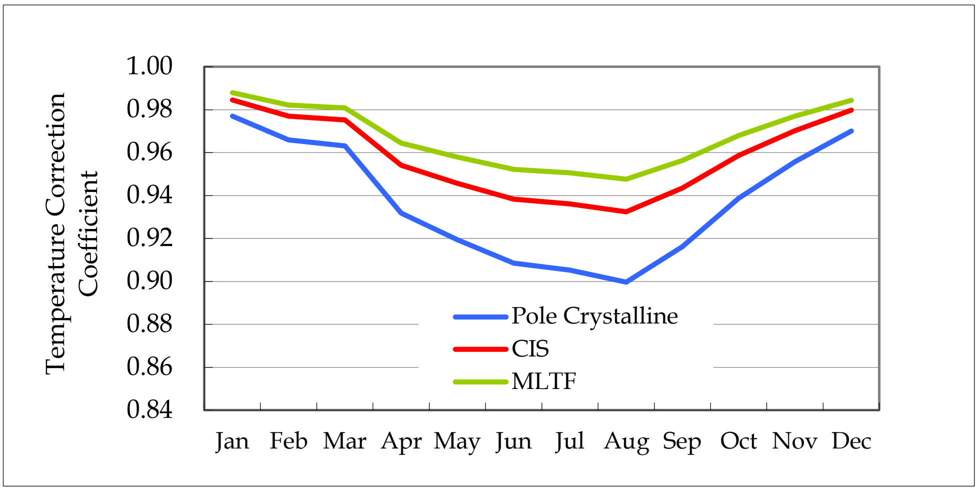


Fig. 3-3-4-4 Temperature correction coefficient

(3) Dust effect on surface of PV module

The PV module installed by JICA has been checked for the dust effect of the PV module surface.

One PV module has been cleaned once a week, the other one was left as it is being accumulated by sand dust.

Short circuit current of each PV module has been measured to confirm deterioration of output energy caused by the dust effect.

Short circuit current is in proportion to solar radiation which is blocked by sand dust. Energy output is also in proportion to solar radiation. As a result, ratio of the short circuit current between two modules is as same as the ratio of energy output.

The dust effect is analyzed based on deteriorate ratio of output energy between the cleaned module (PV module No.2) and the left (without cleaning) module (PV module No.1) and the result is shown in Table 3-3-4-5.

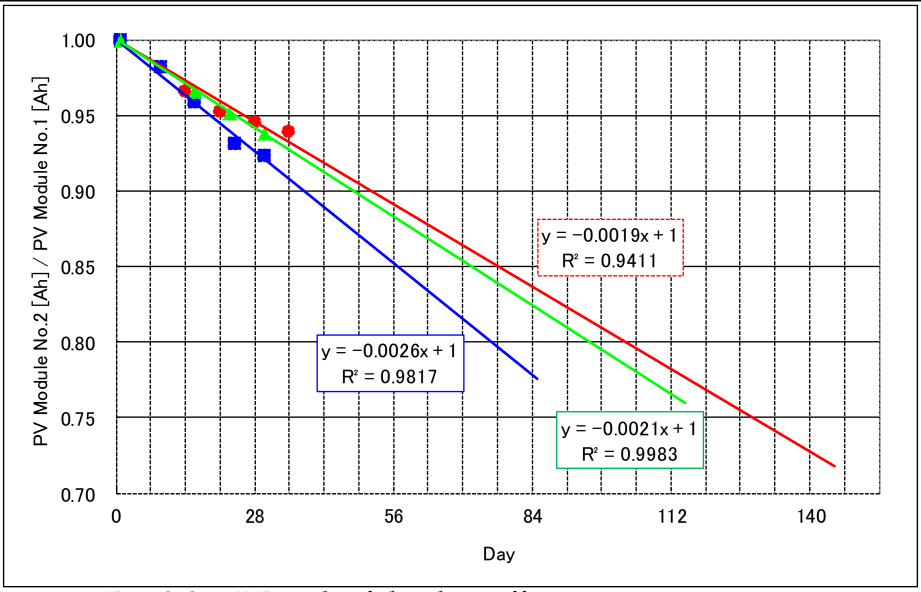


Fig. 3-3-4-5 Result of the dust effect

Red line: from Oct/2011 - Feb/2012
Blue-line: from Mar/2012 - May/2012
Green-line: from Jun/2012 - Sep/2012

The Team has tried to obtain dust effect data three times since the PV module was installed. The first period was measured from October 2011 to February 2012, the second period was from March 2012 to May 2012 and the third one was from June 2012 to September 2012.

Average deterioration ratio of the energy output by dust effect is shown in Table 3-3-4-3.

Table 3-3-4-3 Result of dust effect on average deterioration ratio

Interval	From Oct./2011 to Feb./2012	From Mar./2012 to May/2012	From Jun./2012 to Sep./2012	Average
2 weeks	−3.2%	−3.8%	−2.9%	−3.3%
1 month	−5.7%	−7.8%	−6.3%	−6.6%

The deterioration ratio by the dust effect is around 3% in 2 weeks, and around 7% in 1 month. Considering the number of PV modules at the site, effort for the cleaning works and the deterioration ratio condition, cleaning interval is recommended to be at least once a month. Thus, the dust effect is assumed to be 7% for estimation of annual energy production in this project.

(4) Other Necessary Coefficients for Calculating Power Energy Output

The other parameters shown in Table3-3-4-4a are necessary items to be considered in calculating the power energy production other than the above-mentioned parameters under this project.

Energy production from the PV module is usually decreased year by year. Deterioration ratio is depending on the type and characteristic of PV modules. Therefore this coefficient is separately explained in Table 3-3-4-7, not in Table3-3-4-4b.

Table 3-3-4-4a Other Necessary Coefficients for Calculating Power Energy Production

Total Output of PV System	C_AS	kW	20,000	
Actual Fluctuation Correction Coefficient of Solar Radiation	C_HD	-	0.97	This coefficient shows statistical fluctuation of solar radiation
Aging Variation Correction Coefficient	C_PD	-	See Table 3-3-4-4b (below)	Dust Effect Correction, Time Deterioration Correction, Spectral Response Deviation factor, Nonlinear Response Fluctuation Correction
Array Circuit Correction Coefficient	C_PA	-	0.97	This coefficient corrects Wiring Resistance Loss and Reversed Flow Fluctuation Correction, Nonlinear Response Fluctuation Correction
Array Load Matching Correction Coefficient	C_PM	-	0.94	This coefficient shows the difference between optimum operating point of PV array and actual operating point of PV array decided according to load
Inverter Effective Efficiency	C_INO	-	0.95	
Basic Design Coefficient	C'	-	See Table 3-3-4-5	C'=C_HD*C_PD*C_PM*C_PA*C_INO; The ratio of active Solar Radiation for power generation in actual Solar Radiation

Table 3-3-4-4b Variety of Aging variation Coefficient (C_PD)

Module Type	Dust Effect Correction	Time Deterioration Correction	Spectral Response Deviation factor	Nonlinear Response Fluctuation Correction	Variety of Aging variation Coefficient without Deterioration Correction
Poly crystalline	0.93	See Table 3-3-4-7	1.005	0.97	0.91
CIS			0.99		0.89
Multi-layer thin film			1.005		0.91

(5) Basic Design Coefficient (C’)

As explained in Table 3-3-4-4a, the basic design coefficient was calculated as shown in Table 3-3-4-5 as the total design coefficient of each type of PV for calculating the power energy production under this project. However these coefficients do not include Time Deterioration Correction coefficient. This coefficient is considered after calculating the annual energy production of its first year.

Table 3-3-4-5 Basic Design Coefficient without Time Deterioration Correction Coefficient

	Basic Design Coefficient without Time Deterioration Correction Coefficient
Poly Crystalline	0.76
CIS	0.75
MLTF	0.76

(6) Annual Power Energy Production for the first year

The annual power energy production for the first year is calculated based on the above-mentioned coefficients and the following formula.

As explained in Clause 2, Section 3 of this chapter, the lifted angle was used as 20 degree.

Monthly energy production is estimated as the following formula;

$$E_{pm} = C \times P_{AS} \times H_{AM}/G_s$$

Where

E_{pm} : Monthly energy production (kWh)

C : Monthly Basic design Coefficient

P_{AS} : Regulated output of modules under normal testing condition (kW)

H_{AM} : Monthly summation of solar radiation (kWh/m^2/month)

G_s : Regulated solar radiation for normal testing condition (kWh/m^2)

$$C = C' \times C_{pt}$$

Where

C' : Basic design Coefficient

C_{pt} : Temperature Correction Coefficient for each month (Table 3-3-4-2)

Annual energy production for the first year at 20 degree lifted angle is calculated from summation of each monthly energy production as shown in Table 3-3-4-6 and Fig. 3-3-4-6.

Table 3-3-4-6 Energy Production of PV plant for each types of module for first year

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Anuual total
Monthly Energy Production (MWh)	Poly Crystalline	2,593	2,629	3,188	3,079	3,121	3,091	3,097	3,084	2,974	2,798	2,638	2,468	34,760
	CIS	2,573	2,620	3,180	3,105	3,162	3,145	3,154	3,148	3,017	2,815	2,638	2,455	35,013
	MLTF	2,622	2,674	3,247	3,187	3,252	3,240	3,252	3,248	3,104	2,885	2,696	2,504	35,910

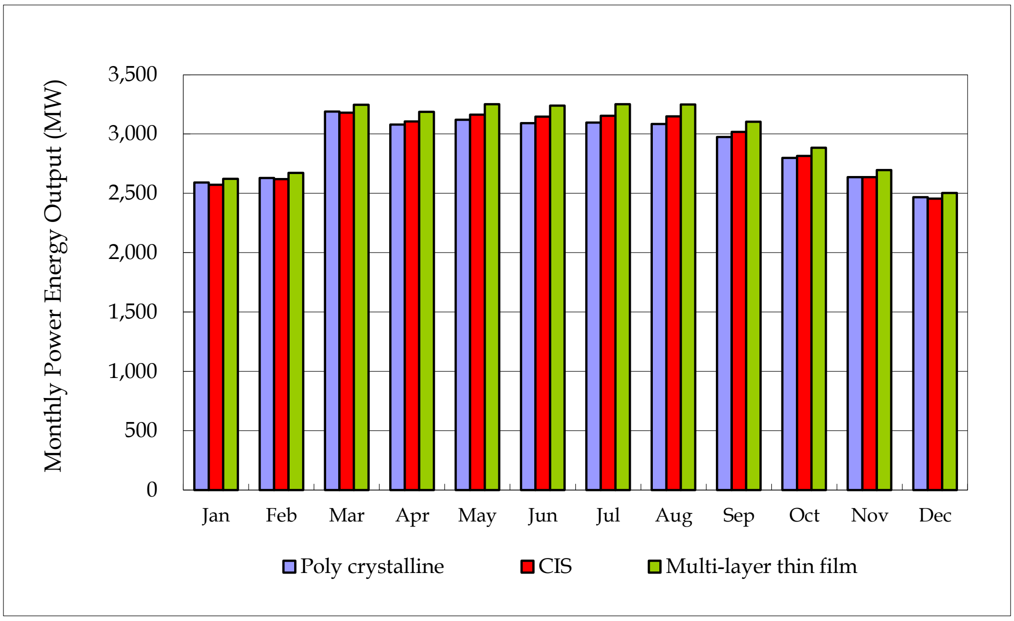


Fig. 3-3-4-6 Energy Production of PV plant for each type of modules for the first year

(7) Time deterioration correction coefficient

Time deterioration correction coefficient is depending on the type and the characteristic of each PV module. The Team obtained these data from major PV manufacturers in Japan with considering their warranty condition and summarized in Table 3-3-4-7.

Table 3-3-4-7 Time deterioration ratio of each type of modules

Type	Time deterioration
Poly Crystalline	1.0% /year
CIS	0.5% /year
MLTF	1.5% /year (～10years)
	0.0% /year (11～20years)

Lifetime of PV module is assumed to be approximately 20 years in general.

Therefore, power energy output of each type of PV modules during the life time is estimated based on the energy production of the first year and the PV module's time deterioration correction coefficient.

The energy production of each PV module during its life time is shown in Table 3-3-4-8 and Fig. 3-3-4-7.

Table 3-3-4-8 Energy Production for 20years

year	Poly Crystalline [MWh/year]	CIS [MWh/year]	MLTF [MWh/year]
1	34,760	35,013	35,910
2	34,412	34,838	35,371
3	34,064	34,663	34,832
4	33,716	34,488	34,293
5	33,368	34,313	33,754
6	33,020	34,138	33,215
7	32,672	33,963	32,676
8	32,324	33,788	32,137
9	31,976	33,613	31,598
10	31,628	33,438	31,059
11	31,280	33,263	31,059
12	30,932	33,088	31,059
13	30,584	32,913	31,059
14	30,236	32,738	31,059
15	29,888	32,563	31,059
16	29,540	32,388	31,059
17	29,192	32,213	31,059
18	28,844	32,038	31,059
19	28,496	31,863	31,059
20	28,148	31,688	31,059
Total	629,080	667,010	645,435
Average	31,454	33,351	32,272

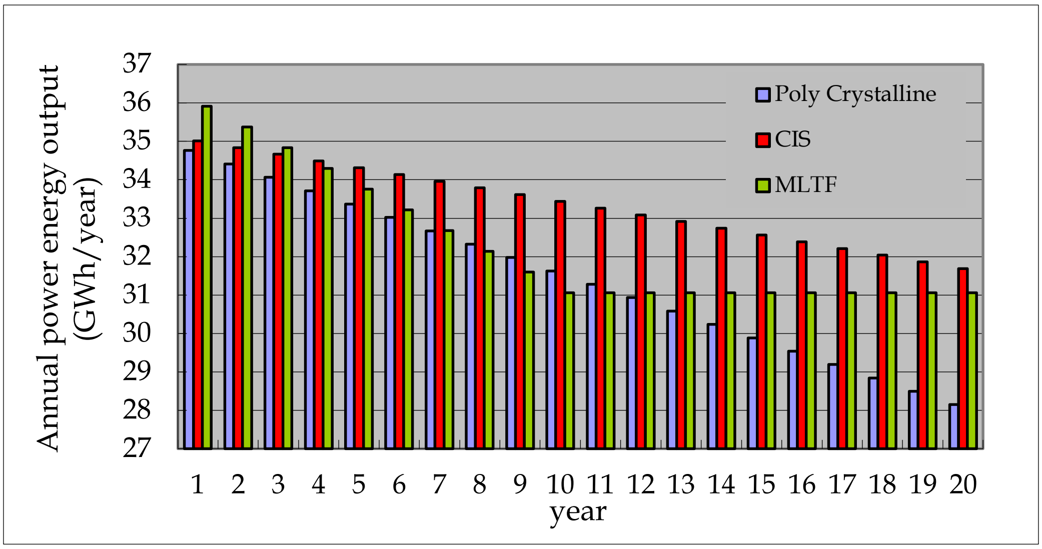


Fig. 3-3-4-7 Energy Production for 20years