Clause 5 Civil work design

Design for the foundation of the PV module is based on the following points:

1) Design standard

Design standard to be applied to this project is essentially as follows:

- ”Design guide on structures for photovoltaic array（JIS C 8955）” for requirements of the civil design
- ”Japanese building code“ for stability analysis
- ”Wind pressure equation from Egyptian Code #201“ for wind load
- ”Regulation for earthquake-resistant design of building in Egypt” for seismic load

2) Loads

According to “Design guide on structures for photovoltaic array (JIS C 8955)” and wind pressure equation from Egyptian Code #201, design loads are as follows:

- Dead load

  Total weight of PV module, mounting structure, and foundation

- Wind load

  Wind pressure for PV module:

  $W=Cw\times q\times Aw$

  Where W :Wind load (N)
  Cw :Wind pressure coefficient
  q :Velocity pressure ($N\cdot m^{-2}$)
  Aw :Windy Area (m^2)

  As a result of discussion with NREA, wind loads for this PV power project are based on Egyptian Code. While wind speed in Egyptian Code is considered with gust of 3 seconds at a height of 10m above ground, maximum average wind speed (26m/s) is adopted for this project. Calculation sheets for wind load of the PV modules are attached in Appendix 3-3-2.

- Seismic load

  Horizontal seismic load for foundation is as follows:

  $K=k\times G$

  where K :Seismic load(N)
  k :Horizontal seismic coefficient
  G :Total weight of mounting foundation (N)

  Hurghada is located along the Gulf of Suez seismic belt, which is known as one of the active seismic zones in Egypt. According to Seismic Activity Zones in Egyptian Seismic Code, Egypt is divided in terms of seismic impact into five zones. Hurghada is in zone 5a and value of k (Horizontal seismic coefficient) is 0.25G.

Seismic loads based on Egyptian regulation for earthquake are calculated and compare to the wind load. Calculation sheets for seismic load of the PV modules are attached in Appendix 3-3-2.

- Snow load

Since it does not snow in winter, snow load is not considered.

- Flowing Water Pressure

Water Pressure for foundation is as follows:

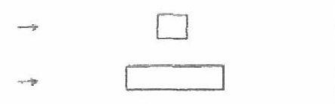
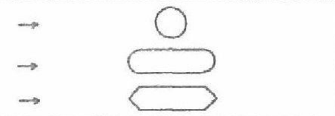
$P=k\times V^2\times A$

where P : Flowing Water Pressure (kN)

k : Coefficient of Bridge Footing Shape as shown below

V : Velocity of Water Flow (m/s)

A : Frontal Projected Area of Foundation(m^2)

Footing Shapes	k
	0.7
	0.4
	0.2

Flowing water pressure based on Japanese Specifications for Highway Bridges is calculated and compare to the wind load. Calculation for the flowing water pressure of the PV modules is attached in Appendix 3-3-2.

3) Stability analysis

Minimum requirements for foundation design are bearing capacity (for compression and uplift), overturning, and sliding.

i) Stability of compression load

The ground has enough bearing capacity against actual load, i.e., dead load and pressure of wind force.

Factor of safety (FS) shall be 1.20.

Calculation method is shown below.

$$\frac{q_a}{\sigma_{c\max}} \geq Fc$$

Where

q_a : Allowable Bearing Capacity (kN/m²)

$\sigma_{c\max}$: Ground Reaction $\sigma_{c\max} = \alpha \times \frac{V_c}{B \times B'}$ (kN/m²)

$$\alpha = 1 + \frac{6 \times e}{B}$$

e : Eccentric Distance $e = \frac{M_c}{V_c}$ (m)

V_c : Vertical Loads $V_c = C_v + W_C + W_G$ (kN)

M_c : Action Moment $M_c = C_H \times h$ (kN·m)

W_c : Weight of Foundation (kN)

W_G : Weight of PV panel and Mounting structure (kN)

B, B' : B=Width, B′=Depth (m)

h : Length of Action Moment (m)

F_c : Factor of Safety (=1.20)

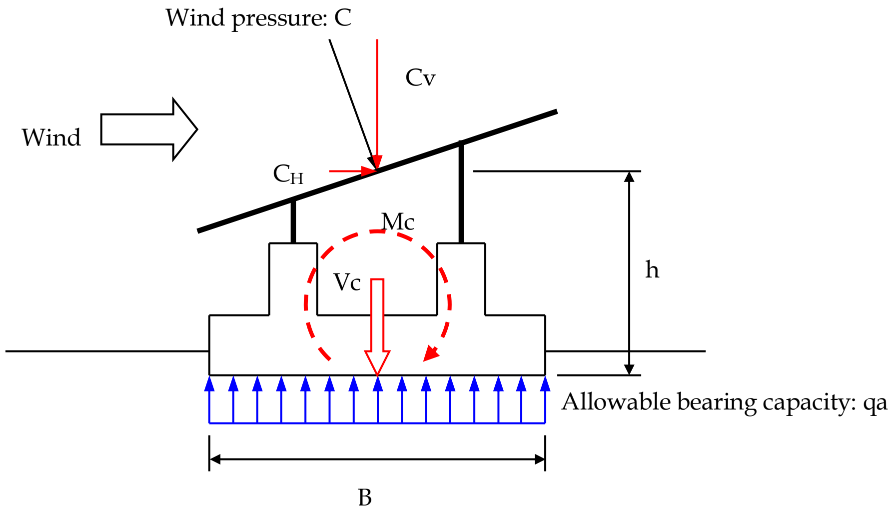


Fig. 3-3-5-1 Compression load for PV foundation

ii) Stability of tension load

The foundation has enough weight against uplifting wind force.

Factor of safety (FS) shall be 1.20.

Calculation method is shown below.

$$\frac{V_T}{Tv} \geq Ft$$

Where

V_T : Self Weight of PV Unit $V_T = W_C + W_G$ (kN)

T_V : Vertical Component of Wind Pressure $T_V = T \times \cos\theta$ (kN)

W_c : Weight of Foundation (kN)

W_G : Weight of PV panel and Mounting structure (kN)

θ : Inclination Angle of PV Panel (°)

F_t : Factor of Safety (=1.20)

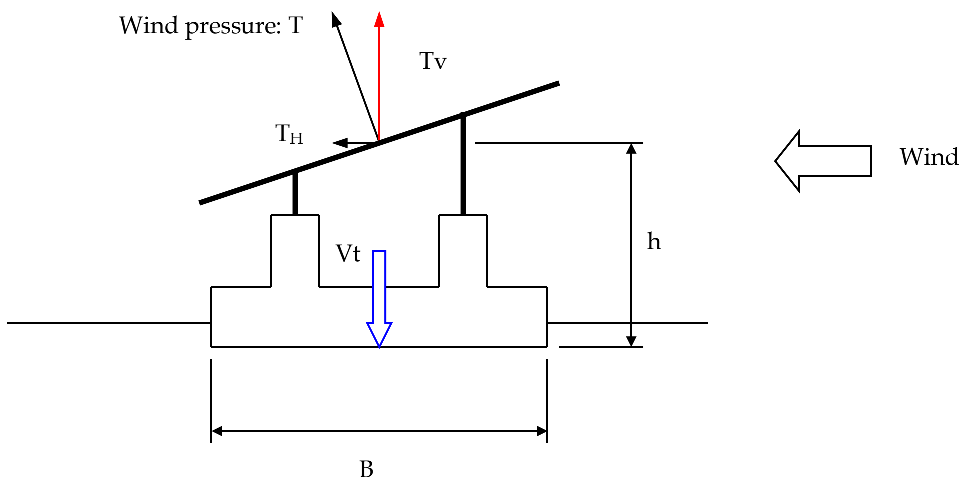


Fig. 3-3-5-2 Tension load for PV foundation

iii) Stability for overturning

Moment of resistance should be larger than overturning moment by maximum lateral force. Basically, this stability check is critical to determine the size of foundations.

Factor of safety (FS) shall be 1.50.

Calculation method is shown below.

$$e \le \frac{B}{3}$$

Where

e : Eccentric Distance $e = \frac{M_o}{V_t}$ (m)

$$M_o \le \frac{M_r}{F_o} = \frac{V_t \times (B/2)}{1.5}$$

$$\frac{M_o}{V_t} \le \frac{B}{3}$$

M_o : Overturning Moment $M_o = T_H \times h$ (kN·m)

M_r : Moment of Resistance $M_r = V_t \times (B/2)$ (kN·m)

V_t : Vertical Loads $V_t = W_C + W_G - T_v$ (kN)

W_c : Weight of Foundation (kN)

W_G : Weight of PV panel and Mounting structure (kN)

B : B=Width (m)

h : Length of Overturning Moment (m)

F_o : Factor of Safety (=1.50)

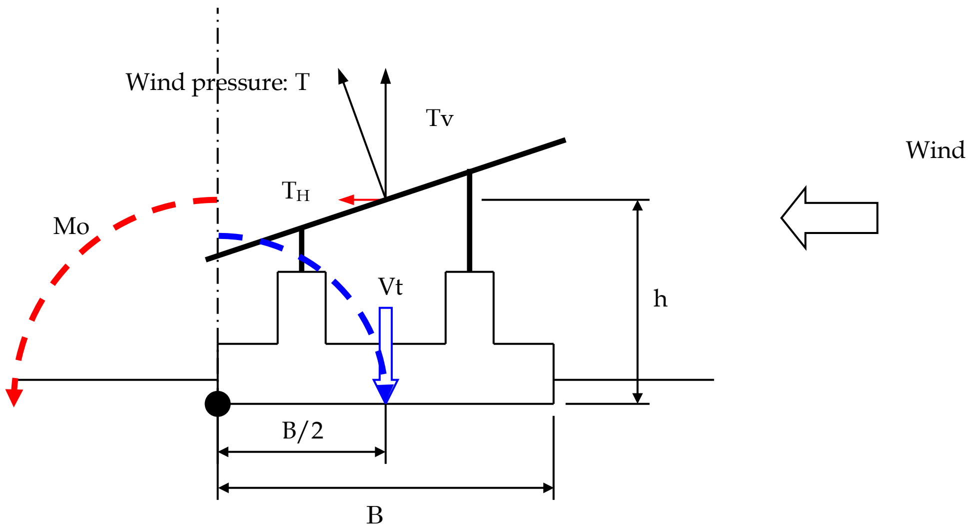


Fig. 3-3-5-3 Over turning for PV foundation

iv) Stability for sliding

Passive earth pressure should be larger than maximum lateral force.

Factor of safety (FS) shall be 1.20.

Calculation method is shown below.

$$\frac{P_p}{Q} \geq F_H$$

Where

P_p : Passive Earth Pressure $P_p = K_p \times \gamma \times t \times B$ (kN)

K_p : Coefficient of Passive Earth Pressure

$$K_p = \tan^2\left(45° + \frac{\phi}{2}\right)$$

γ : Unit Weight of Supporting Soil (kN/m^3)

t : Embedded Length (m)

B : Width (m)

ϕ : Internal Friction Angle (°)

Q : Horizontal Load =TH (kN)

F_H : Factor of Safety (=1.20)

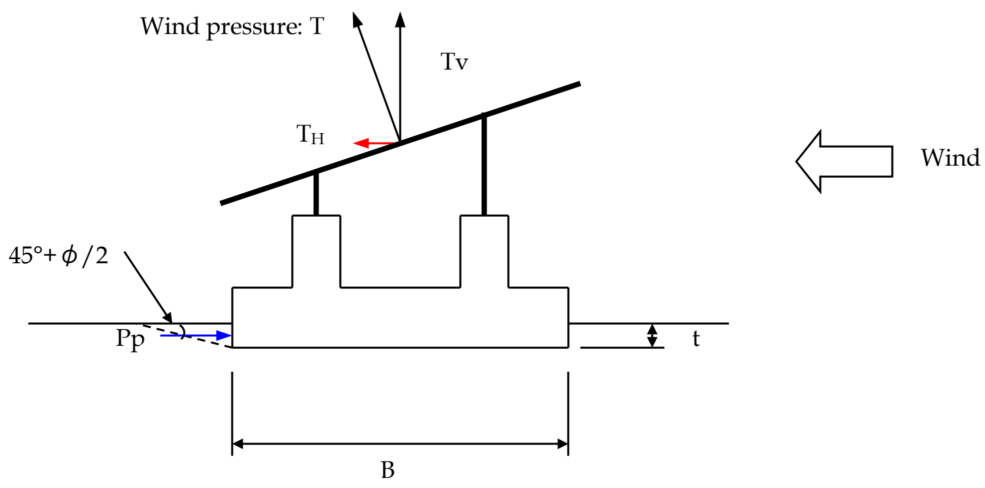


Fig. 3-3-5-4 Sliding for PV foundation

4) Foundation design condition

The conditions of PV foundation design are shown in Table 3-3-5-1.

Table 3-3-5-1 Conditions of PV foundation

Maximum Wind Speed (m/s)		26		
Ground Condition	Type of Soil	sand		
	Under Ground Water (m)	Approx. GL-5.0m		
	Supposed N Value	N = 10		
	Allowable Bearing Capacity (kN/m²)	50		
Minimum Ground Clearance (m)		1.0		
Type of Module		Poly Crystalline	CIS	MLTF
Supporting Panel Area (m²)		6.615 (4 panels)	7.406 (6 panels)	8.462 (6 panels)
Tilted Angle 25°	Wind Load (kN)	2.746	3.074	3.512
	Seismic Load (kN)	0.617	0.776	0.883
	Weight of PV Panel and Mounting Structure (kN)	2.466	3.103	3.531
20°	Wind Load (kN)	2.236	2.504	2.861
	Seismic Load (kN)	0.612	0.771	0.878
	Weight of PV Panel and Mounting Structure (kN)	2.447	3.084	3.512
15°	Wind Load (kN)	2.236	2.504	2.861
	Seismic Load (kN)	0.607	0.766	0.873
	Weight of PV Panel and Mounting Structure (kN)	2.426	3.063	3.491
10°	Wind Load (kN)	2.236	2.504	2.861
	Seismic Load (kN)	0.603	0.762	0.869
	Weight of PV Panel and Mounting Structure (kN)	2.410	3.047	3.475

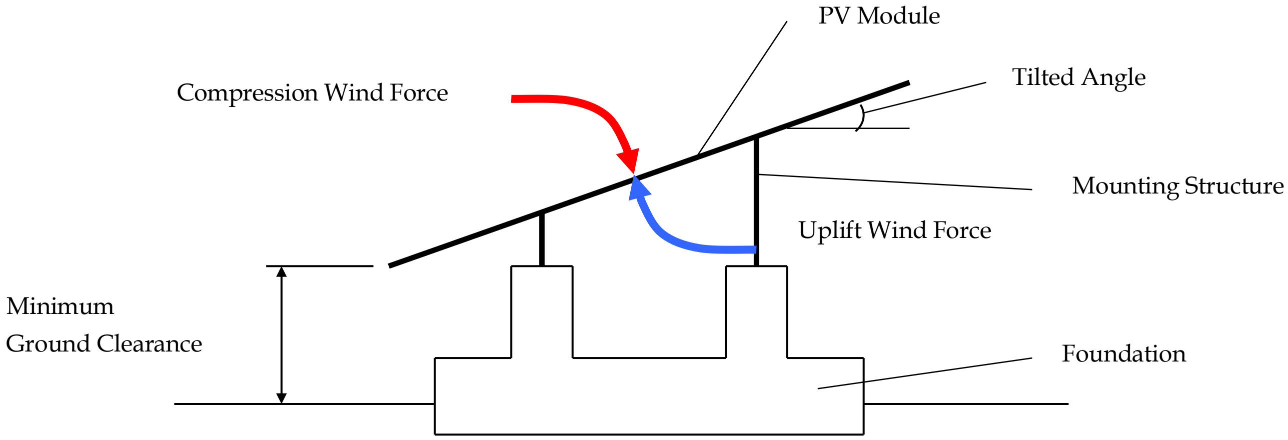


Fig. 3-3-5-5 Outline of foundation design conditions

In consideration of potential impact for the seismic, the Team and NREA agreed the followings:

- Size of foundations is divided into small size; a foundation structure supports 4 PV modules in case Poly Crystalline Silicon type and 6 PV modules in case Multi-Layer Thin Film (MLTF) type and CIS type

Result of calculation of flowing water pressure for a foundation, lateral force by water pressure is smaller than wind load and seismic load, and flowing water have little effect on the stability of the foundations.

Because of loose sand ground condition, scouring at the foundations might be expected when water runs off the site. Some countermeasures might be required after getting detailed information (may be during detailed design stage) at the in order to protect the PV foundations.

5) Result of stability analysis

Foundation of Poly Crystalline type is the smallest size in the three PV modules, and tilted angle 25° for PV panel is critical for stability analysis. Comparing wind loads with seismic loads, the governing loads for foundations are wind loads. Results of the analysis are shown in the following Tables. Calculation sheets for foundations of each type of module are attached in Appendix 3-3-3.

Table 3-3-5-2 Foundation for Poly crystalline

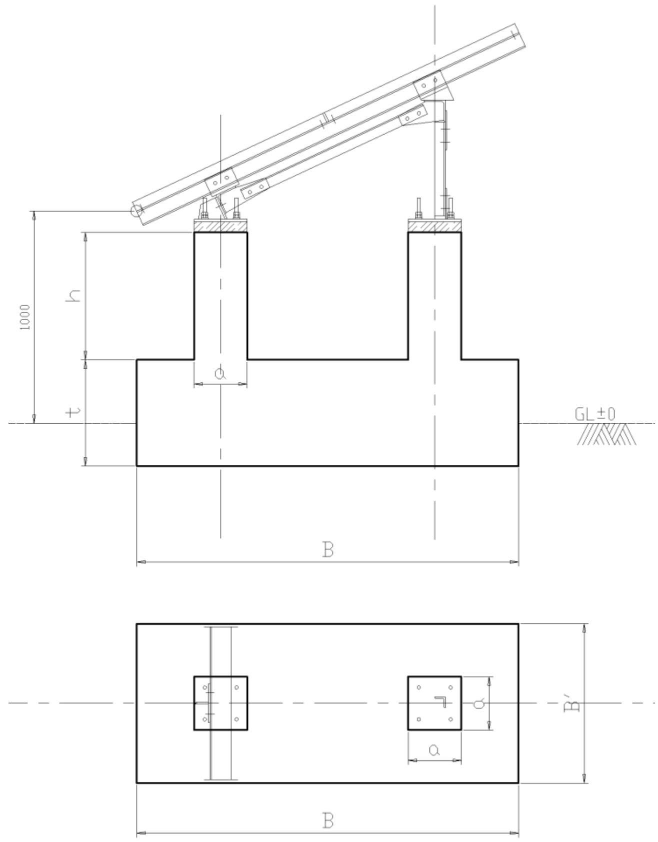
<table>
<tr><td colspan="2">Type of Module</td><td colspan="4">Poly Crystalline</td></tr>
<tr><td colspan="2">Foundation Shape</td><td colspan="4">
</td></tr>
<tr><td colspan="2">Tilted Angle (°)</td><td>25</td><td>20</td><td>15</td><td>10</td></tr>
<tr><td rowspan="5">Size (m)</td><td>a</td><td>0.25</td><td>0.25</td><td>0.25</td><td>0.25</td></tr>
<tr><td>h</td><td>0.8</td><td>0.8</td><td>0.8</td><td>0.8</td></tr>
<tr><td>B</td><td>1.5</td><td>1.5</td><td>1.5</td><td>1.5</td></tr>
<tr><td>B′</td><td>0.4</td><td>0.4</td><td>0.4</td><td>0.4</td></tr>
<tr><td>t</td><td>0.3</td><td>0.3</td><td>0.3</td><td>0.3</td></tr>
<tr><td rowspan="4">Result of Study</td><td>Uplift</td><td>Nil</td><td>Nil</td><td>Nil</td><td>Nil</td></tr>
<tr><td>Compression</td><td>1.63 ≧ 1.20</td><td>1.94 ≧ 1.20</td><td>2.10 ≧ 1.20</td><td>2.27 ≧ 1.20</td></tr>
<tr><td>Overturning</td><td>0.247 ≦ 0.500</td><td>0.146 ≦ 0.500</td><td>0.105 ≦ 0.500</td><td>0.066 ≦ 0.500</td></tr>
<tr><td>Sliding</td><td>12.65 ≧ 1.20</td><td>19.21 ≧ 1.20</td><td>25.38 ≧ 1.20</td><td>37.78 ≧ 1.20</td></tr>
<tr><td colspan="2">Concrete Volume of One Foundation (m^3)</td><td>0.280</td><td>0.280</td><td>0.280</td><td>0.280</td></tr>
</table>

Table 3-3-5-3 Foundation for Poly CIS

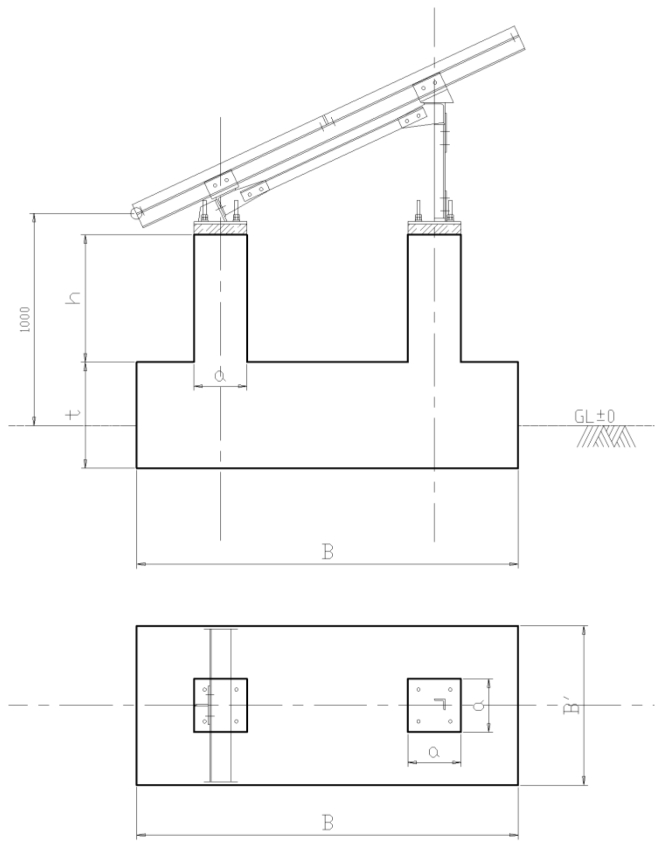
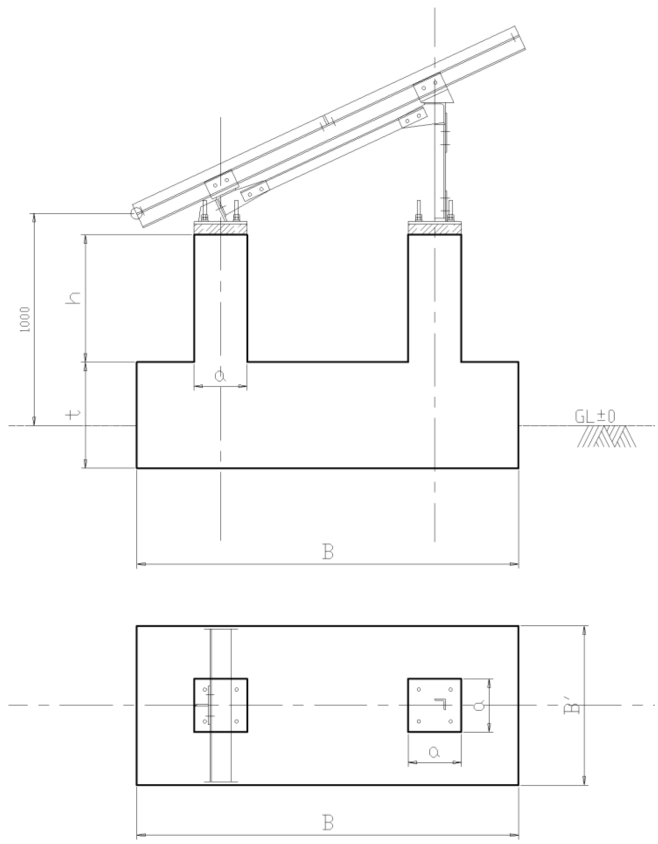
Type of Module		**CIS**			
Foundation Shape					
Tilted Angle (°)		25	20	15	10
Size (m)	a	0.25	0.25	0.25	0.25
	h	0.8	0.8	0.8	0.8
	B	1.5	1.5	1.5	1.5
	B′	0.4	0.4	0.4	0.4
	t	0.3	0.3	0.3	0.3
Result of Study	Uplift	Nil	Nil	Nil	Nil
	Compression	1.50 ≧ 1.20	1.78 ≧ 1.20	1.93 ≧ 1.20	2.09 ≧ 1.20
	Overturning	0.262 ≦ 0.500	0.154 ≦ 0.500	0.111 ≦ 0.500	0.070 ≦ 0.500
	Sliding	11.30 ≧ 1.20	17.15 ≧ 1.20	22.64 ≧ 1.20	33.78 ≧ 1.20
Concrete Volume of One Foundation (m^3)		0.280	0.280	0.280	0.280

Table 3-3-5-4 Foundation for MLTF

Type of Module		**MLTF**			
Foundation Shape					
Tilted Angle (°)		25	20	15	10
Size (m)	a	0.25	0.25	0.25	0.25
	h	0.8	0.8	0.8	0.8
	B	1.5	1.5	1.5	1.5
	B′	0.4	0.4	0.4	0.4
	t	0.3	0.3	0.3	0.3
Result of Study	Uplift	Nil	Nil	Nil	Nil
	Compression	1.36 ≧ 1.20	1.64 ≧ 1.20	1.79 ≧ 1.20	1.95 ≧ 1.20
	Overturning	0.300 ≦ 0.500	0.175 ≦ 0.500	0.126 ≦ 0.500	0.080 ≦ 0.500
	Sliding	9.89 ≧ 1.20	15.01 ≧ 1.20	19.83 ≧ 1.20	29.57 ≧ 1.20
Concrete Volume of One Foundation (m^3)		0.280	0.280	0.280	0.280

6) Considering potential flash flood to civil design

Taking into account information raised in public consultation meeting held on February 29, 2012 in Hurghada and consequent survey for grasping flood situation surrounding the project site carried out in June 2012, the Team and NREA agreed to consider the followings even though potential impact by flash flood is assumed to be very low, but as precautions and safety for unexpected natural disaster:

- No structures to protect water flow to be caused by the potential flood will be provided surrounding the project site (the fence of the foundation shall not be raised up to the ground).
- Floor of houses for electric components to be constructed in the project site such as Inverter House and Switchgear House should be raised to certain level (minimum 30 cm) in order to avoid wet for electrical components in case the flash flood come into the project site. In addition the houses should have proper sealing in order to avoid rain penetration into the houses.
- Providing drainage trench along service road to be constructed in the project site in order to treat rain and flash floods properly.
- In order to maintain the above facilities properly, the proper number of maintenance staff to the above shall be allocated by NREA. NREA and the Team agreed that 8 persons forming 2 teams will be provided to clear the accumulated sand around the drainages in the 20MW power plant.

Clause 6 Power Grid Connection

1) Grid Connection Options of PV

Based on the study done by the Team, there are three options on how to connect the PV power to the existing network. Details are written below and a simple image of the options is shown in Fig. 3-3-6-1 and Fig. 3-3-6-2.

- ✓ **Option (1):** The voltage level will be stepped up to 22kV at Hurghada PV Power Plant, and two of 22kV switchgears will be newly installed at 22kV/11kV EDC's Hurghada Wind Farm Substation (DP), and each switchgear will be connected to 10MW of the power plant with 22kV power cables.
- ✓ **Option (2):** The voltage level will be stepped up to 22kV at Hurghada PV Power Plant, and 22kV transmission line which its length is about 15km will be installed between Hurghada PV Power Plant and Central Hurghada Substation (66kV/22kV/11kV).
- ✓ **Option (3):** The voltage level will be stepped up to 66kV at Hurghada PV Power plant, and 66kV transmission lines which are located at the south side of Hurghada PV Power Plant will be connected with π-junction power system. Length of each transmission line is about 3km.

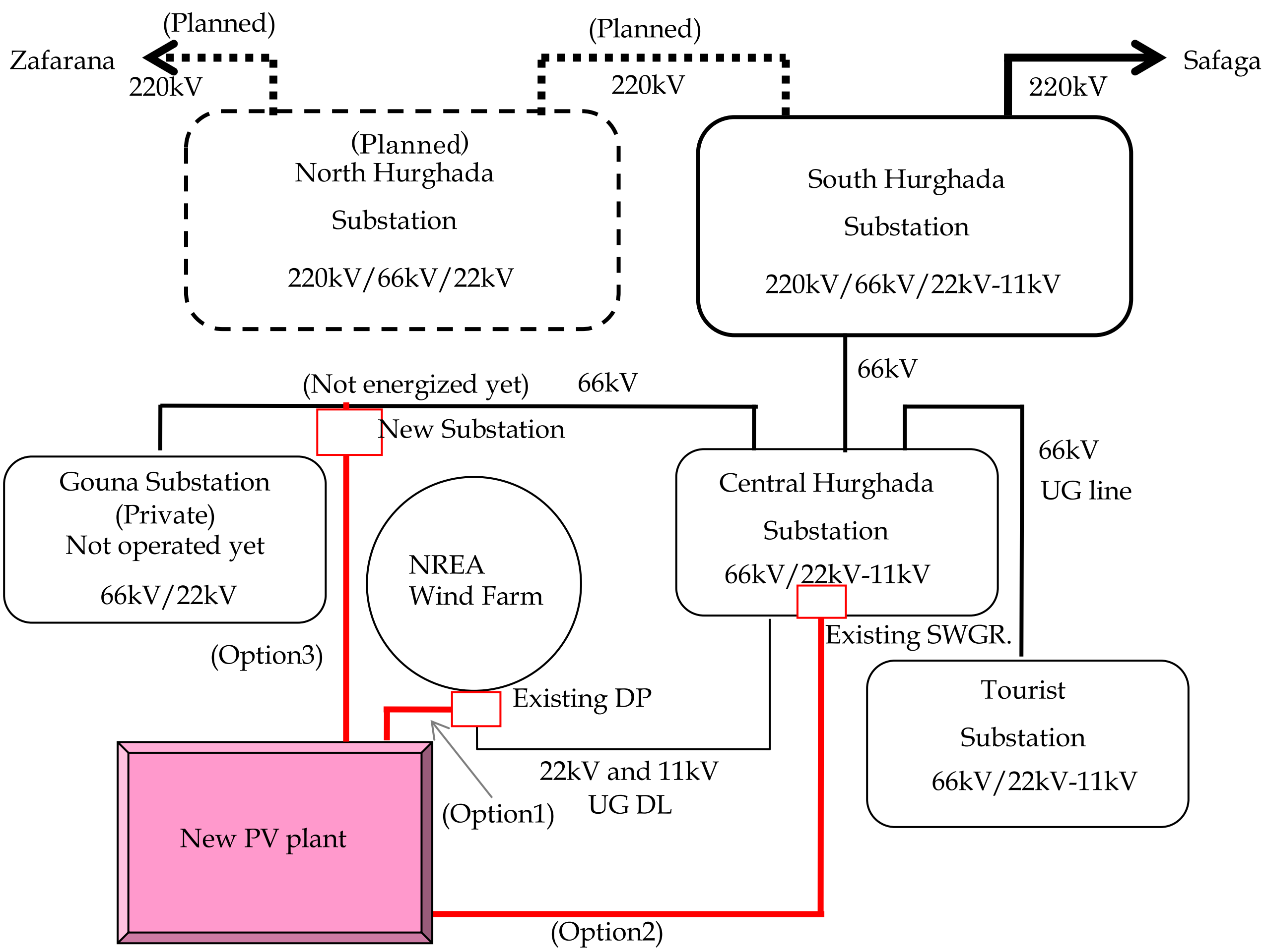


Fig. 3-3-6-1 Transmission network for options of the grid connection method

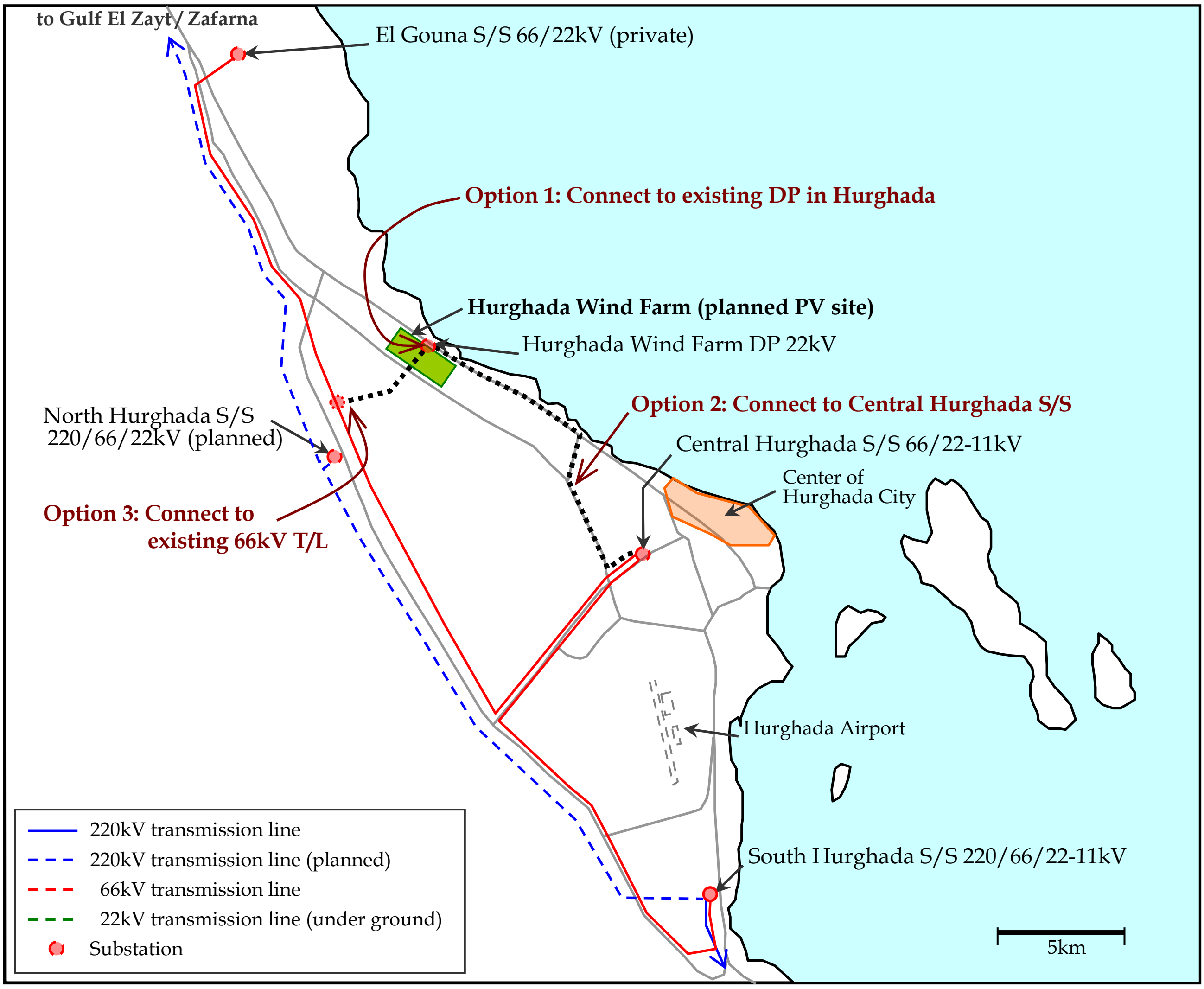


Fig. 3-3-6-2 Location for each Option's grid connection point

■ Option 1: Connect to existing DP in Hurghada Wind Farm

The most time and cost saving way is to connect the PV power plant using the existing DP in the wind farm and to supply power to the increasing load around Hurghada as shown in Fig. 3-3-6-3. And existing DP has space for installation of two 22kV switchgears. The candidate space for the new switchgears is shown in Fig. 3-3-6-4.

There is a concern that this connection may cause reverse power flow from DP back towards Central Hurghada S/S when the load is low in certain times of the day. As there is no regulation of EETC purchasing electricity from distribution companies, this new method may have to be taken into account for another future study described as follows.

The issues of the reverse power flow will be examined further in 2) Grid network analysis described later.

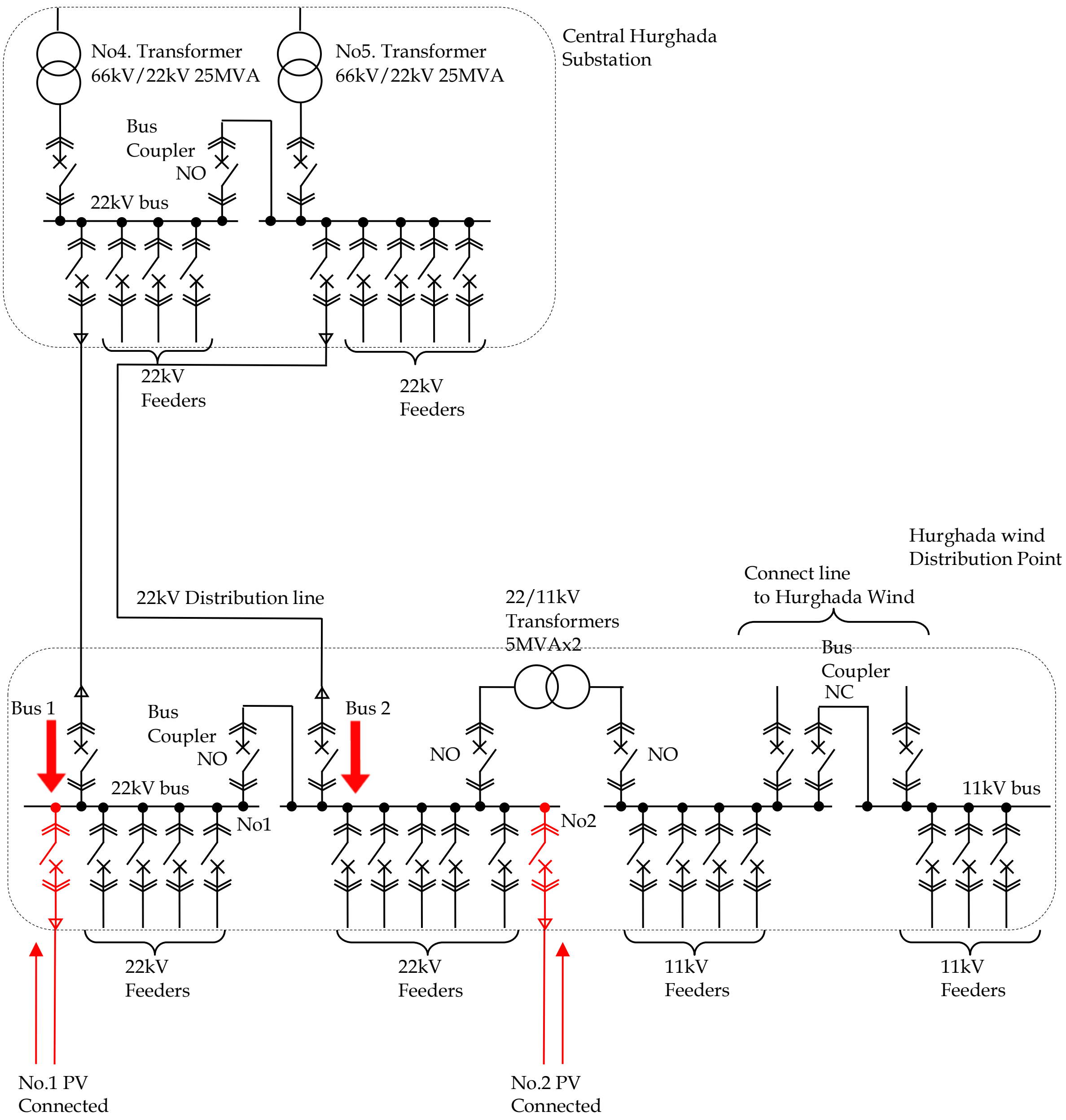


Fig. 3-3-6-3 Option1 grid connection method

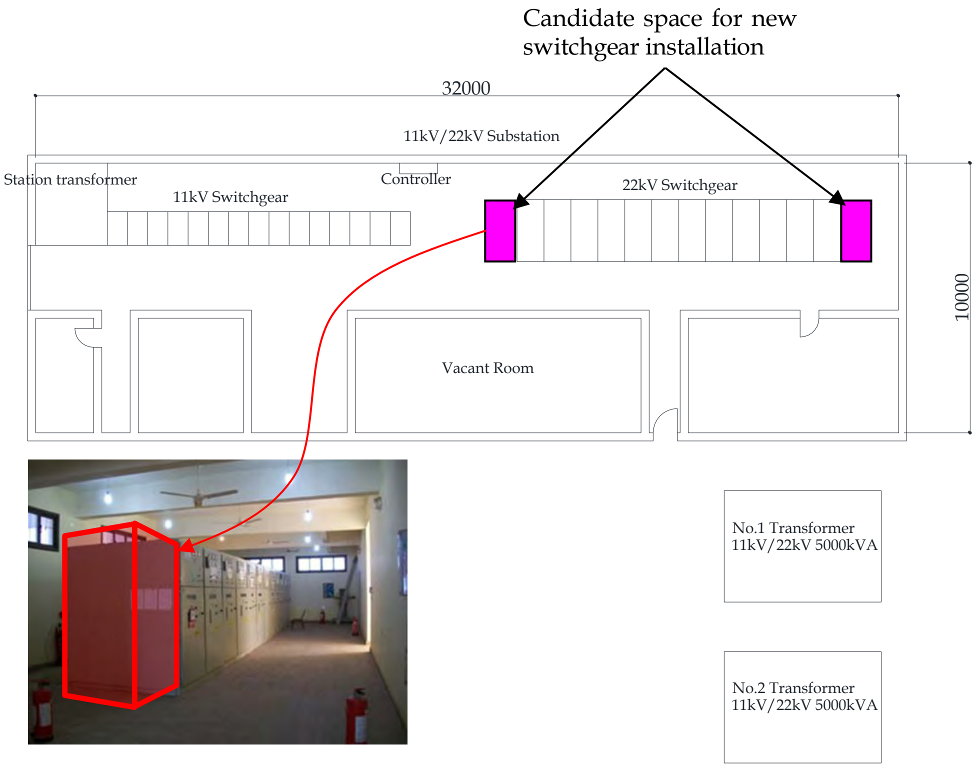


Fig. 3-3-6-4 Available space for installation of 22kV switchgears at Hurghada wind DP (Connection point of Hurghada wind distribution point)

In option 1, 10MW PV power will be connected to each bus of Hurghada Wind Farm DP. As a result, power flow of the Hurghada Wind DP will be changed. The team studied the daily load curve of when the PV power had been connected. Daily load curve after connecting PV power is shown in Fig. 3-3-6-5.

This means at times when the load is small and the PV generates more than enough power necessary for the consumers through the DP, reverse power flow to Central Hurghada Substation will occur. A diagram of this flow is shown in Fig. 3-3-6-6.

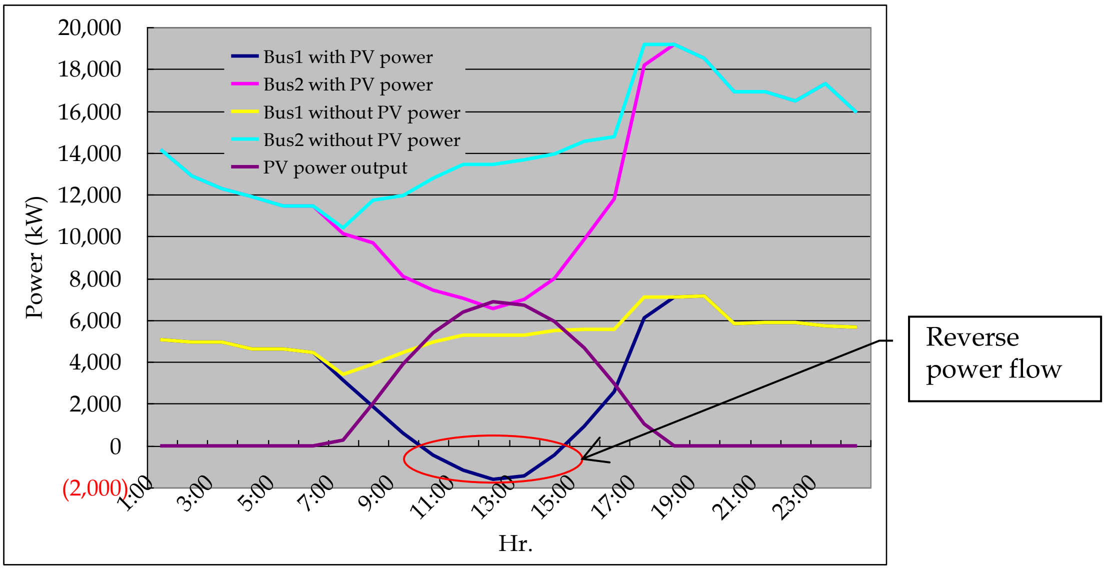


Fig. 3-3-6-5 Daily load curve estimation for maximum and minimum loaded days at Hurghada Wind DP 22kV Bus with PV power

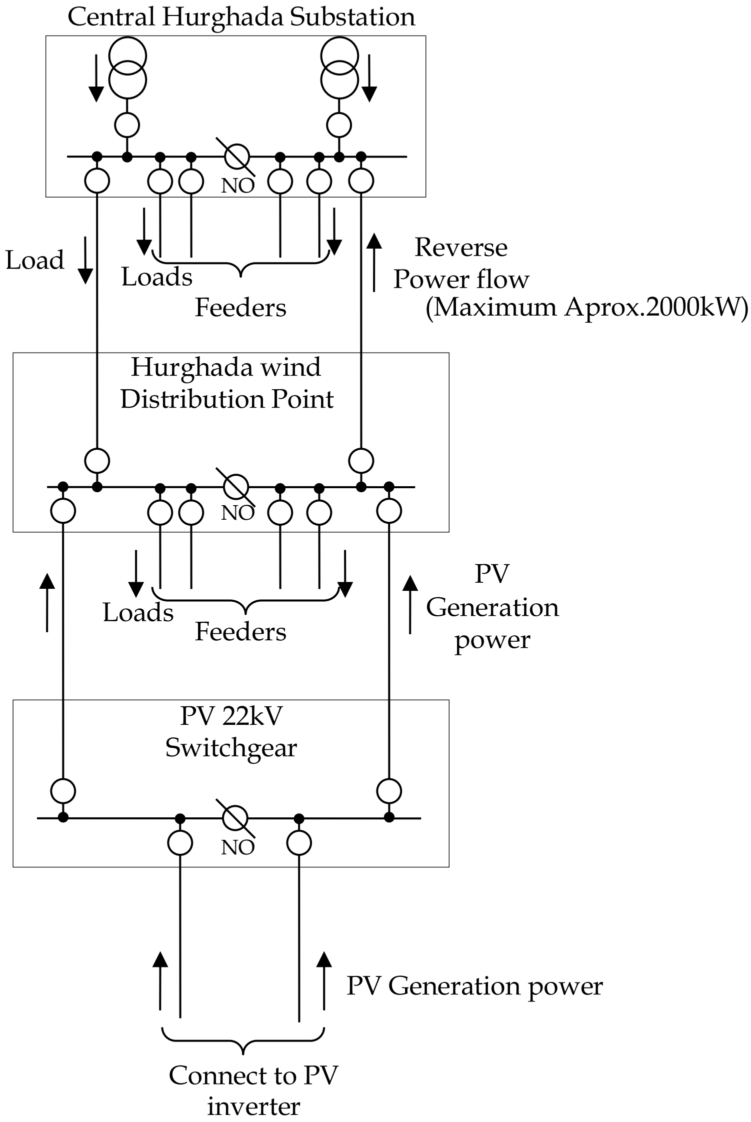


Fig. 3-3-6-6 Explanation of reverse power flow from the DP to Substation

- Necessity of modification of Central Hurghada substation

The Team made site survey to Central Hurghada substation in consideration with the above situation. As a result, the followings are found:

✓ There are two 66kV/22kV transformers installed in the substation. They have On-Load Tap Changers (OLTC). However the OLTC is used manually, thus erroneous of automatic tap changer control by reverse power flow will never occur.

✓ Energy meters are installed at secondary side of 66/22kV transformer circuit. Also, these energy meters can measure energy power flow for both directions. Thus modification for energy meter will not be required.

✓ Feeder protection relay of 22kV feeders are using non directional relay such as Over Current Relay and Earth Fault Relay, thus modification of feeder protection relay will not be required.

Although possibility of necessity of modification work for the Central Hurghada substation by reverse power flow is low, the Team considered some additional cost for modification of the substation, because grid condition is always changing depending on the situation of power flow.

Photo 3-3-6-1
On-load tap changer of 66/22kV Transformer

Photo 3-3-6-2
Energy meter of secondary of 66/22kV Transformer

Photo 3-3-6-3
Protection Relay for 22kV Feeder

- Option 2: Connect to Central Hurghada S/S

  Regarding the uncertainty of option 1, this option comes in the next suitable way to connect the PV power to the network. It proposes to have a 22kV underground cable (XLPE Aluminum 400mm^2) double circuit laid 15km to Central Hurghada S/S from the PV site as shown in Fig. 3-3-6-7

  The two 22kV cables will be connected to each of the switchgears and the switchgears will be connected to different buses in the S/S, respectively.

  The available space left for the installation of the new 22kV switchgears may not be sufficient enough. It is necessary to replace the existing capacitor controller panels when fitting in the new switchgears as shown in Fig. 3-3-6-8

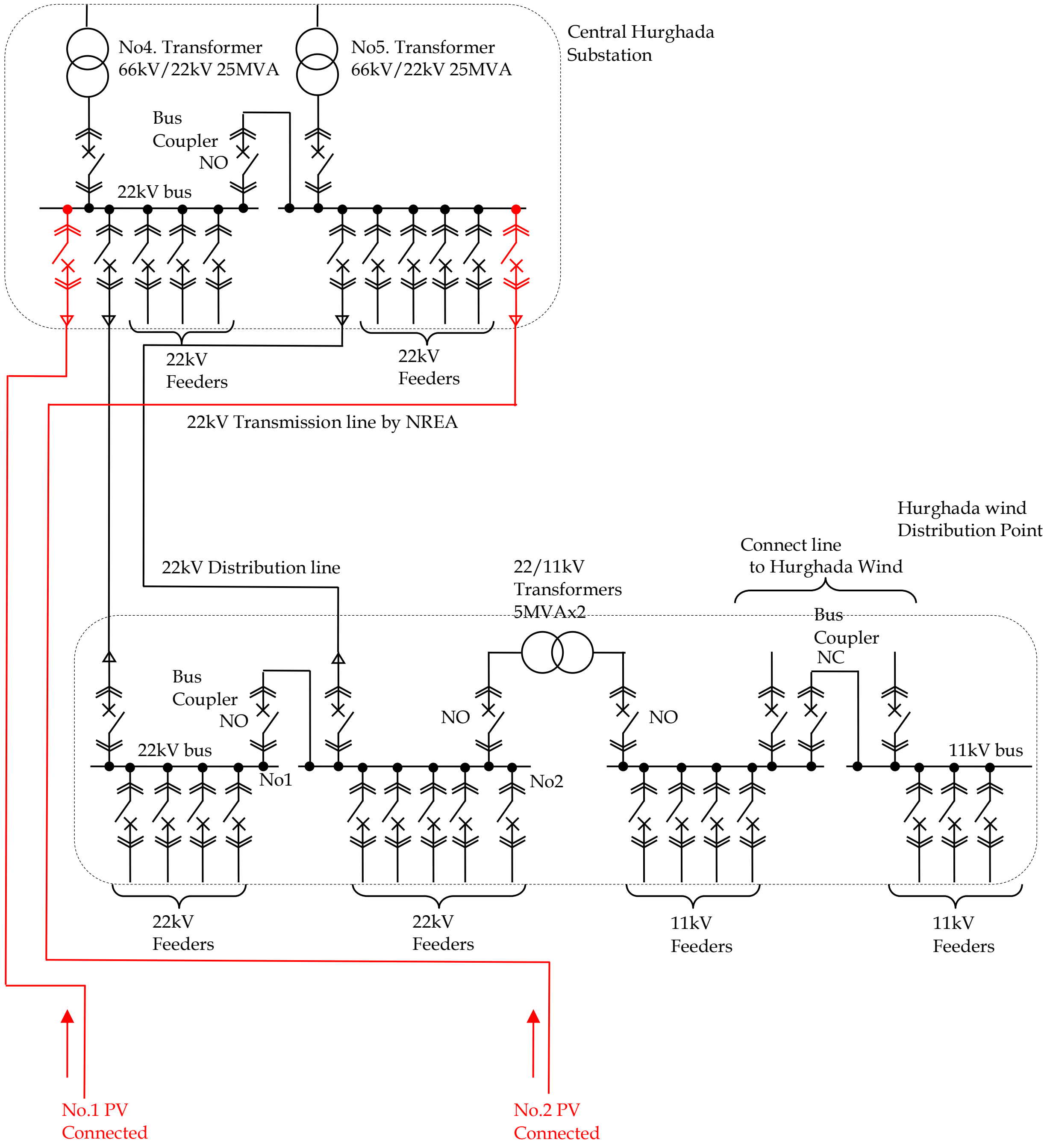


Fig. 3-3-6-7 Option 2 grid connection method

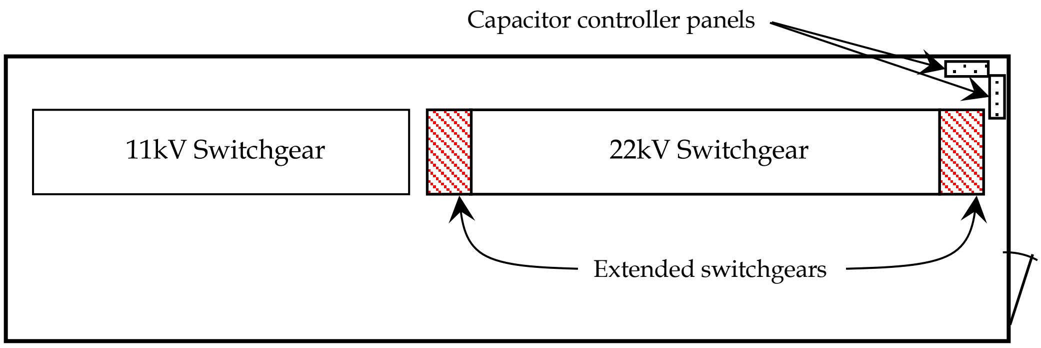


Fig. 3-3-6-8 Layout image of MV Switchgear room in Central Hurghada S/S

Source: The Study Team

Photo 3-3-6-4
Switchgear of Central Hurghada S/S

Photo 3-3-6-5
Capacitor controller panel

- Option 3: Connect to existing 66kV T/L through new S/S
  This option will require constructing a new substation of 66/22kV at few kilometers southwest from the site. Compared to the other options it is obvious that this will be very costly.

- Additional option : Connect to North Hurghada S/S 220/66kV/22kV
  During the Team's survey, it was found that EETC is planning for a new 220/66/22kV substation, North Hurghada S/S. As shown in Fig 3-3-6-2, the substation will not be far from the PV site and can be taken advantage of supplying the power from PV site to the network. However, at the moment, the construction schedule is not even on the planning stage, so the Team did not consider this option to be studied of.

Within the mentioned options, as the construction schedule for North Hurghada S/S is not on the planning stage, the Team excluded this option. For the remaining options, from the point of cost effectiveness, the advantages are in the next order;

option 1 > option 2 > option 3

This takes into consideration that when the option needs to have new transmission lines or substations, the cost for maintenance will also have to be afforded by NREA.
The Team studied on the network analysis based on the above priority.

For option1 and 2, there is an issue of reverse power flow. The annual load growth of Hurghada is around 11% for the past 5 years and this may lessen the cause of the reverse power flow. But in hours when the load gets low, there still will be possibilities of this phenomenon to occur. The followings are the countermeasure to avoid the reverse power flow.

- ✓ Install a large capacity storage battery to absorb the power.
- ✓ Control output by inverter.

2) Grid Network Analysis

■ Background and purpose of the study

As the location of the 20MW PV power plant is already fixed in (nearby/besides) the Hurghada wind farm site, its connection to the grid network must be carefully studied up on.

There are several ways to connect this power plant to the grid network which has been mentioned in the former clause. Here, the analysis will be done from the options described in the former Clause starting from option 1 and will be continuing to option 2, 3, if there will be an unacceptable result to the option.

Considering the behavior (characteristic) of the PV power and how it influences the connected grid network, the Team carried out analysis to examine the technical situation supporting the realization of the grid network connection based on local surveys, data/information and approvals from NREA, EETC and CEDC.

■ Study points for PV power connection

The following points must be considered when connecting PV powers to the existing grid network.

- Voltage fluctuation

  Voltage fluctuation is often caused by parallel in/off operation of solar power generators. PV power output is controlled by PCS (in this report either "PCS" or "Inverter" is used as same meaning by the context), which has range to be considered of the voltage at the grid network side.

  Also, as the PV power plant will be located at the end of the grid network, the voltage drop must also be observed. Although in this study the 66kV side voltage will be assumed to be operating in rated normal condition to focus on the behavior of the PV power side.

  Here, the voltage fluctuation will be considered at peak and off-peak load at static state.

  Target value of limitation for voltage fluctuation should be complying with IEC standard 60038, 2009. Thus, voltage fluctuation on 22kV should be less than ±10%.

- Power Flow

  Power flow of the network around the PV power site has to be observed to check the existence of overload problems of the transmission lines/cables and transformers after each capacity will be clearly informed.

- Frequency fluctuation

  As each of the PV modules' output are small enough, the output fluctuation of this power plant dropping out of the power system can be said to have no effect to the 66kV or upper voltage side of the power system.

  Therefore, study for frequency fluctuation will not be considered in this report.

- Short circuit current

  As mentioned above, the output of the PV power is totally controlled by PCS to react immediately at failures. Physically, PCS will not supply fault current. Therefore, there is no need to consider the short circuit current here as well.

In this study, the Team will carry out studies on voltage fluctuation and power flow. Generally, it is said that if the PV power grows to be one of the mega power plants reaching more than 10% of the entire power generation of Egypt, it is recommended to conduct transient stability analysis, because when in failure of this power plant, the influence of the incident will likely to go through the whole power network. However, the planned level of power generation is small enough to omit this analysis in this study.
Also, to simulate PV power generation by output from certain solar radiation condition will also be effective to study in deeper level of how the PV power plant will have an impact on the grid network.

- Prerequisites for the study
  - Criteria Required for Network Analysis
    - ✓ The N-1[1] criterion is applied in the Egyptian high voltage grid network for network security. While here, mainly targeting the distribution lines, this criterion will not be considered.
    - ✓ Voltage regulation within ±5% of normal operating voltage in normal condition
  - Conditions for Network Analysis
    - ✓ The study will be done on ETAP[2] Ver. 7.1.0 based on data received from CEDC.
    - ✓ The network analysis will be done on the 2016 network system, as the assumed commissioning period for the PV power plant in 2015/2016 from the latest available data.
    - ✓ The load is assumed to increase at 11.8% rate annually (average value calculated from the records of past 5 years).
    - ✓ The peak/off-peak load time is based on the data received from CEDC.
    - ✓ PV power modules and loads are using the same model while PCS is not modeled in this study.
    - ✓ The transmission capacity of 22 kV underground cables at around Hurghada region will be having approximately 20MVA/circuit.

[1] General reliability of power system called "N-1 criteria"; Among the N units of the power system, even when 1 unit is shut down by accident, the remaining N-1 unit holds (enables) the situation of the power system for stable power supply. (Not applied when in planned outage or maintenance.)

[2] Electrical Transient and Analysis Program (software program for electrical engineers): Comprehensive analysis platform for the design, simulation, operation, control, optimization, and automation of generation, transmission, distribution, and industrial power systems, developed by Operation Technology, Inc.

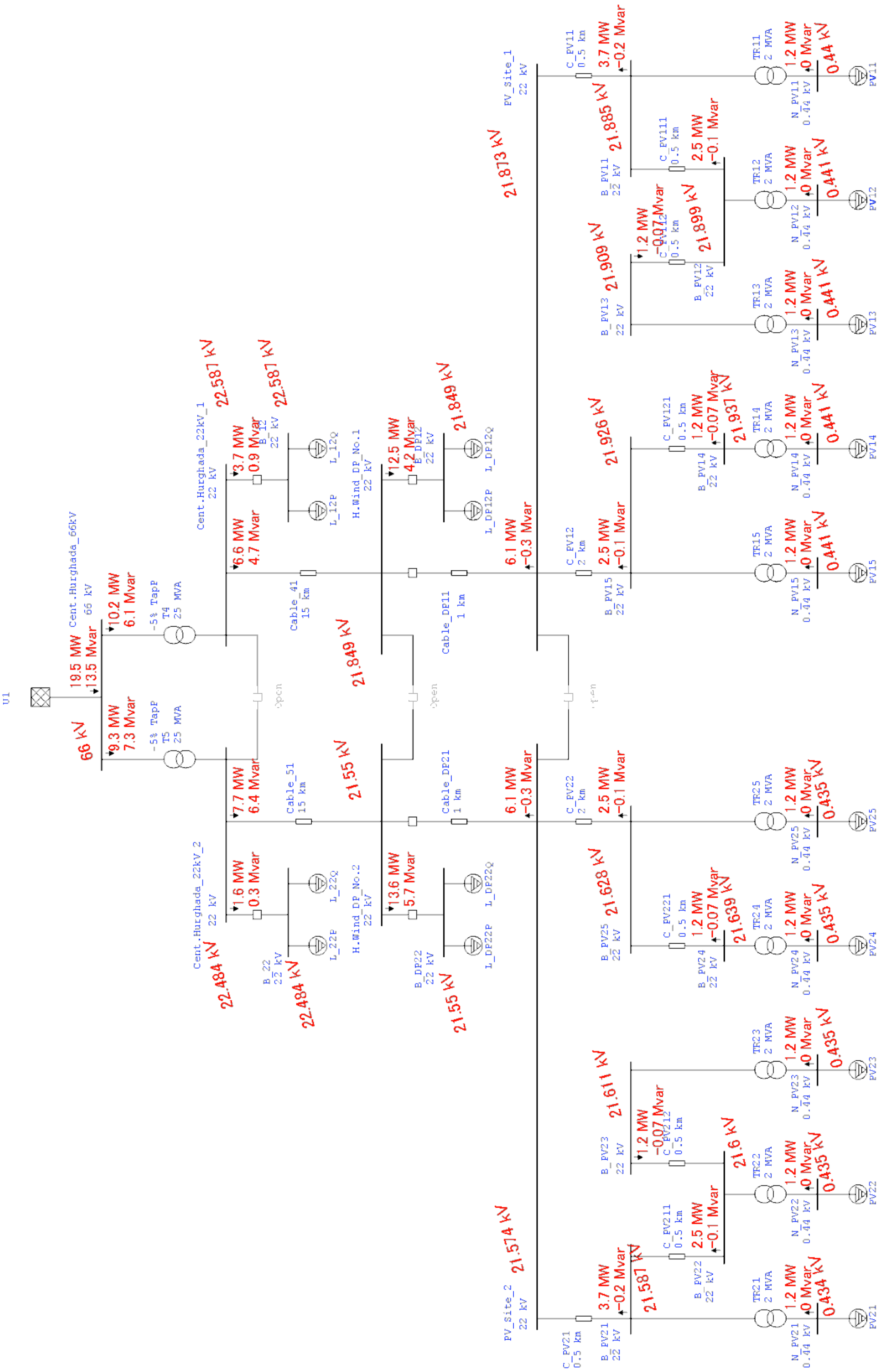
- ✓ The PV power plant of maximum output at 13.6MW (AC side) is considered after connection to the network by having variables depending on 3 time zones; morning/noon/evening. In the analysis, there will be no power output from the PV power at evening times.
- ✓ The tap ratios of the transformers will all be considered being adjusted in optimum state. The range of the tap ratio will be 1.1 – 0.9 changing the voltage at the primary side.
- ✓ The slack/swing bus is set at Central Hurghada S/S 66kV side.
- ✓ Central Hurghada S/S is assumed at 1.0P.U. (66kV).

■ PV power connection and effects on existing network

➢ Voltage and Power Flow under Peak Load Conditions

The peak load condition is studied based on the data from CEDC with PV power connected to the grid network at morning, noon and evening time.

Fig. 3-3-6-9 shows the grid network diagram around the PV site modeling from Central Hurghada S/S to the PV power plant. (Refer to first part of this Clause for an overview of the targeted area.)



Source: JICA Study Team, Data source: CEDC

Fig. 3-3-6-9 Power System Diagram at Peak Load after connection of PV Power Plant

Table 3-3-6-1 shows the voltage condition at peak load after the connection of the PV power at Hurghada, and Table 3-3-6-2 shows the power flow at Central Hurghada 66kV (primary) side and 22kV (secondary) side at peak load.

Table 3-3-6-1 Voltage Conditions at Peak Load after connection of the PV Power Plant

Location		Reference Voltage	Morning		Noon		Evening	
			without PV	with PV	without PV	with PV	without PV	with PV
Central Hurghada S/S	66kV Bus	66.00kV	66.00kV	66.00kV	66.00kV	66.00kV	66.00kV	66.00kV
			(100.00%)	(100.00%)	(100.00%)	(100.00%)	(100.00%)	(100.00%)
	22kV Bus (Secondary of Tr#4)	22.00kV	22.27kV	22.30kV	22.52kV	22.59kV	22.65kV	22.65kV
			(101.22%)	(101.36%)	(102.38%)	(102.67%)	(102.95%)	(102.95%)
	22kV Bus (Secondary of Tr#5)	22.00kV	22.30kV	22.33kV	22.42kV	22.48kV	22.53kV	22.53kV
			(101.36%)	(101.50%)	(101.89%)	(102.20%)	(102.42%)	(102.42%)
Hurghada Wind Distribution Point	#1 Bus	22.00kV	21.41kV	21.59kV	21.39kV	21.85kV	21.27kV	21.27kV
			(97.34%)	(98.12%)	(97.24%)	(99.32%)	(96.70%)	(96.70%)
	#2 Bus	22.00kV	21.36kV	21.54kV	21.08kV	21.55kV	20.99kV	20.99kV
			(97.09%)	(97.89%)	(95.82%)	(97.96%)	(95.39%)	(95.39%)
PV Site	#1 Bus	22.00kV	-	21.60kV	-	21.87kV	-	21.27kV
			-	(98.16%)	-	(99.42%)	-	(96.70%)
	#2 Bus	22.00kV	-	21.54kV	-	21.58kV	-	20.99kV
			-	(97.93%)	-	(98.07%)	-	(95.39%)
	PCS AC end (#1 Bus)	0.44kV	-	0.43kV	-	0.44kV	-	0.43kV
			-	(98.41%)	-	(100.27%)	-	(96.70%)
	PCS AC end (#2 Bus)	0.44kV	-	0.43kV	-	0.43kV	-	0.42kV
			-	(98.18%)	-	(98.71%)	-	(95.39%)

Source: JICA Study Team, Data source: CEDC

Table 3-3-6-2 Power flow Conditions at Peak Load after connection of the PV Power Plant

Location		Rated Capacity	Morning		Noon		Evening	
			without PV	with PV	without PV	with PV	without PV	with PV
Central Hurghada S/S	Tr#4	25.0MVA	13.8MW	11.6MW	16.8MW	10.2MW	21.4MW	21.4MW
			3.0Mvar	2.7Mvar	6.9Mvar	6.1Mvar	9.2Mvar	9.2Mvar
	Tr#5	25.0MVA	13.2MW	11.0MW	15.9MW	9.3MW	21.5MW	21.5MW
			2.7Mvar	2.3Mvar	8.1Mvar	7.3Mvar	10.6Mvar	10.6Mvar
	Feeder (Secondary of Tr#4)	-	11.7MW	9.5MW	13.0MW	6.6MW	15.9MW	15.9MW
			2.0Mvar	1.9Mvar	4.8Mvar	4.7Mvar	6.0Mvar	6.0Mvar
	Feeder (Secondary of Tr#5)	-	12.8MW	10.6MW	14.2MW	7.7MW	16.9MW	16.9MW
			2.3Mvar	2.2Mvar	6.5Mvar	6.4Mvar	7.4Mvar	7.4Mvar

Source: JICA Study Team, Data source: CEDC

From the network analysis in peak load condition, the following facts have been found:

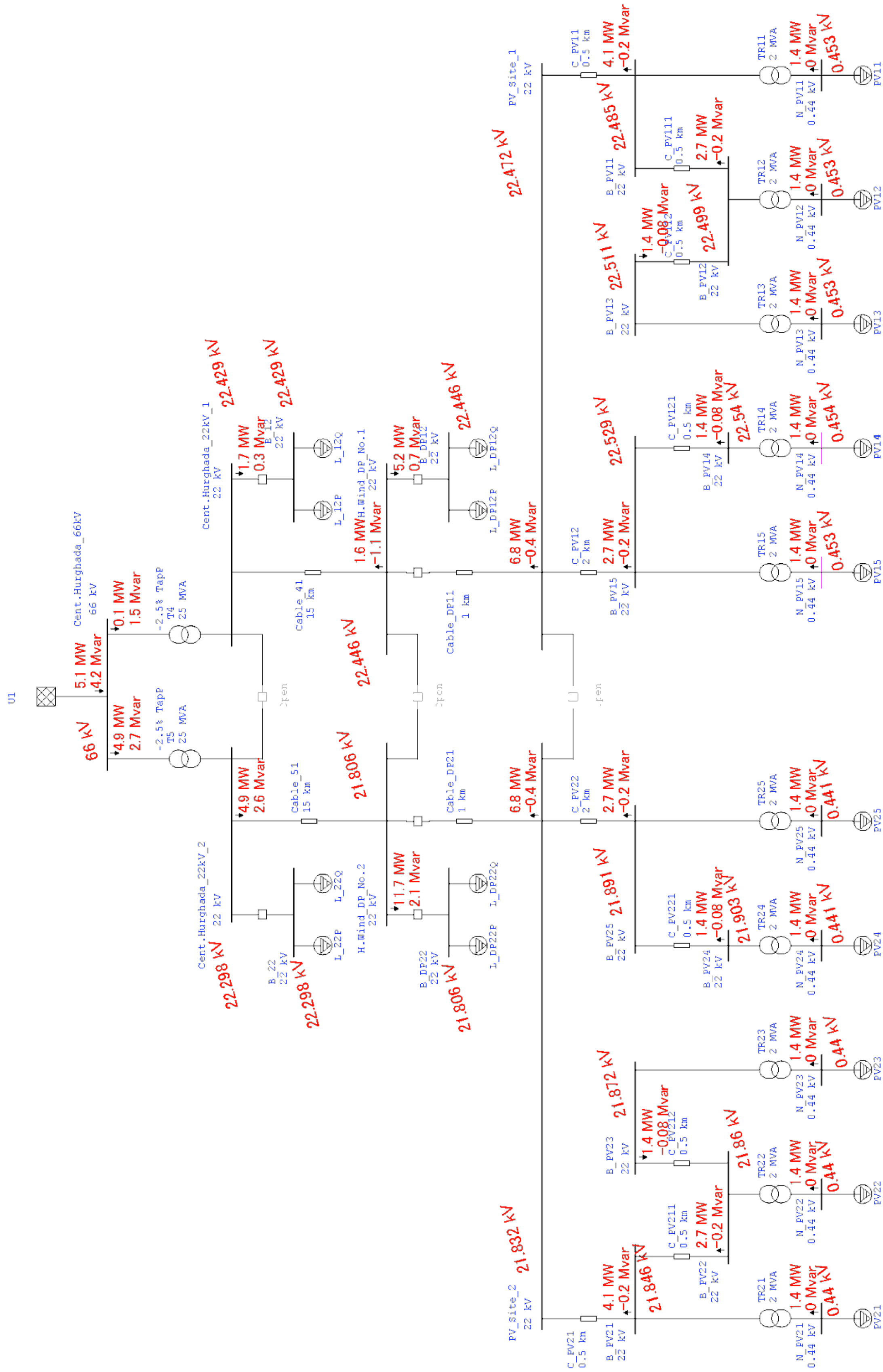
- On the condition that the voltage level at Central Hurghada S/S 66kV is kept in a normal level, the power output fluctuation from the PV power plant will not cause any critical voltage fluctuation without any tap changing of the transformer at the S/S.
- On the same condition as above, the voltage at the load side can be kept in an appropriate level by adjusting the transformer tap at the S/S.

- The maximum voltage fluctuation ratio with/without the PV power plant will be approximately 2.1%.
- In the evening time the power flow at Central Hurghada S/S reaches up to its rated capacity but this is not a problem as it will not exceed the limit.
- The connection of the PV power effectively feeds power to load and there will be no reverse power flow.

➢ Voltage and Power Flow under Off-Peak Load Conditions

The off peak load condition is also studied based on the data from CEDC with PV power connected to the grid network at morning, noon and evening time.

Fig. 3-3-6-10 shows the grid network diagram around the PV site modeling from Central Hurghada S/S to the PV power plant. (Refer to first part of this Clause for an overview of the targeted area.)



Source: JICA Study Team, Data source: CEDC

Fig. 3-3-6-10 Power System Diagram at Off Peak Load after connection of the PV Power Plant

Table 3-3-6-3 shows the voltage condition at off peak load after the connection of the PV power plant at Hurghada, and Table 3-3-6-4 shows the power flow at Central Hurghada 66kV (primary) side and 22kV (secondary) side at off peak load.

Table 3-3-6-3 Voltage Conditions at Off Peak Load after connection of the PV Power Plant

Location		Reference Voltage	Morning		Noon		Evening	
			without PV	with PV	without PV	with PV	without PV	with PV
Central Hurghada S/S	66kV Bus	66.00kV	66.00kV	66.00kV	66.00kV	66.00kV	66.00kV	66.00kV
			(100.00%)	(100.00%)	(100.00%)	(100.00%)	(100.00%)	(100.00%)
	22kV Bus (Secondary of Tr#4)	22.00kV	22.27kV	22.27kV	22.42kV	22.43kV	22.38kV	22.38kV
			(101.22%)	(101.23%)	(101.92%)	(101.95%)	(101.73%)	(101.73%)
	22kV Bus (Secondary of Tr#5)	22.00kV	22.20kV	22.20kV	22.25kV	22.30kV	22.18kV	22.18kV
			(100.90%)	(100.92%)	(101.13%)	(101.35%)	(100.82%)	(100.82%)
Hurghada Wind Distribution Point	#1 Bus	22.00kV	21.95kV	21.97kV	22.04kV	22.45kV	21.85kV	21.85kV
			(99.75%)	(99.85%)	(100.20%)	(102.03%)	(99.33%)	(99.33%)
	#2 Bus	22.00kV	21.35kV	21.38kV	21.33kV	21.81kV	20.94kV	20.93kV
			(97.06%)	(97.17%)	(96.95%)	(99.12%)	(95.16%)	(95.15%)
PV Site	#1 Bus	22.00kV	-	21.97kV	-	22.47kV	-	21.85kV
			-	(99.85%)	-	(102.15%)	-	(99.33%)
	#2 Bus	22.00kV	-	21.38kV	-	21.83kV	-	20.94kV
			-	(97.18%)	-	(99.24%)	-	(95.16%)
	PCS AC end (#1 Bus)	0.44kV	-	0.44kV	-	0.45kV	-	0.44kV
			-	(99.89%)	-	(103.05%)	-	(99.33%)
	PCS AC end (#2 Bus)	0.44kV	-	0.43kV	-	0.44kV	-	0.42kV
			-	(97.22%)	-	(100.16%)	-	(95.16%)

Source: JICA Study Team, Data source: CEDC

Table 3-3-6-4 Power flow Conditions at Off Peak Load after connection of the PV Power Plant

Location		Rated Capacity	Morning		Noon		Evening	
			without PV	with PV	without PV	with PV	without PV	with PV
Central Hurghada S/S	Tr#4	25.0MVA	6.5MW	6.2MW	7.0MW	0.1MW	9.6MW	9.6MW
			3.0Mvar	3.0Mvar	1.3Mvar	1.5Mvar	1.8Mvar	1.8Mvar
	Tr#5	25.0MVA	9.9MW	9.6MW	12.1MW	4.9MW	17.4MW	17.4MW
			3.8Mvar	3.7Mvar	3.2Mvar	2.7Mvar	4.1Mvar	4.1Mvar
	Feeder (Secondary of Tr#4)	-	3.3MW	3.0MW	5.3MW	-1.6MW	7.3MW	7.3MW
			1.6Mvar	1.6Mvar	0.8Mvar	1.1Mvar	1.2Mvar	1.2Mvar
	Feeder (Secondary of Tr#5)	-	9.9MW	9.6MW	12.1MW	4.9MW	17.4MW	17.4MW
			3.3Mvar	3.3Mvar	2.6Mvar	2.6Mvar	2.8Mvar	2.8Mvar

Source: JICA Study Team, Data source: CEDC

From the network analysis in off peak load condition, the following facts have been found:

- It is noteworthy to mention that at off peak load with high PV power output, there will be a reverse power flow from Hurghada Wind Farm DP back to Central Hurghada S/S, assuming a redistribution to other 22kV feeders.
- On the condition that the voltage level at Central Hurghada S/S 66kV is kept in a normal level, the power output fluctuation from the PV power will not cause any

critical voltage fluctuation without any adjustment of the transformer tap at the S/S.

- The maximum voltage fluctuation ratio with/without the PV power plant will be approximately 2.2%.

■ Conclusions and Recommendations

From the results of the voltage and power flow analysis at peak/off peak load in Hurghada from Central Hurghada S/S to the PV power site; connection of PV power to the existing network applying option 1, the following points have been confirmed:

- Before/after the connection of PV power at Hurghada, there are no deviations from voltage regulation level either in peak or off-peak load.
- There are no power flow problems by installing the PV in the same condition mentioned above.
- Reverse power flow from the Hurghada Wind Farm DP to Central Hurghada S/S occurs only at low load hours.

The following recommendations are made from the prospective future development of the PV power plants in Hurghada and neighboring regions.

- The foreseen occurrence of the reverse power flow should be discussed over with the relevant authorities/companies especially in the term of energy sales.
- In order to use the power generated by PV effectively, there should be a way to store the energy; such as batteries of large capacity to correspond to the high demand hours. (Refer to Clause 9.)
- This study was carried out with Central Hurghada S/S assumed to be 1.0P.U. (66kV) to focus on the PV power site, but as the place is at the end of the high voltage grid network with high growing demand, the tendency of the voltage drop is concerned and therefore, further study from this point of view might be necessary. This may be a scheduled issue to be solved by EETC.

Clause 7 Electric facility design

The PV Module and the Inverter are main components of the PV power generation system. When the PV power generation system is connected to the grid, equipment such as transformers and circuit breakers are necessary for this grid-connection.

Additionally, as for the mega-scale PV power plant, the central controlling system for monitoring and controlling of the system should be installed as usual.

The characteristic of the PV module is described in the previous clause, therefore the functions of the inverter, the central controlling system and the other equipment for the grid-connection are described in the following:

1) Inverter (PCS: Power Conditioning System)

Main function of the inverter is to convert electricity from DC to AC by power semi-conductor. The inverter has not only the function to convert from DC to AC but also the function of deriving the best performance of the PV module and the protection function in case unexpected fault occurs. The other functions of the inverter are as follows;

- ✓ Automatic Operation/Stop Function

  The inverter can start operation automatically on the condition that it can produce the power output when the sun rises and the solar radiation intensity increases and the inverter can monitor the output of the PV module by itself and can continue the operation automatically as long as it can produce the power output. At sunset, the inverter can stop the operation automatically. Furthermore, the inverter can continue the operation, even if it is a cloudy/rainy day.

- ✓ Maximum Power Point Tracking Control

  The output of the PV module changes according to the solar radiation intensity and the surface temperature of the PV module. In order to correspond with these changes, the function which is called as MPPT (Maximum Power Point Tracking) control usually can obtain the maximum output of the PV module by changing the operating point of the PV module to follow the maximum output point.

  The MPPT control realizes that it varies the DC operating voltage of the inverter slightly at regular time intervals, measures the output of the PV module, compares with the last measuring value and moves the DC voltage of the inverter into the direction which always can produce larger output.

- ✓ Prevention Function for stand-alone islanding operation

  When the stand-alone islanding operation occurs, there is a possibility to harm the maintenance staffs, because of supplying electricity from the PV power generation system to the distribution line which shall be disconnected from the electric power company. Accordingly, in order to correspond to this issue, Prevention Function for the stand-alone islanding operation, which can detect sudden change of the voltage phase and change of the frequency, and can stop operation of the PV power generation system is equipped with the inverter.

✓ Automatic Voltage Adjustment Function

When reverse power flow occurs by connecting the PV power generation system to the power grid, there is a possibility of increasing the voltage at the connecting point and exceeds the voltage operation range of electric power company.

In order to avoid this issue, the Automatic Voltage Adjustment Function which can suppress the increasing voltage at the connecting point by controlling the power factor and the output of the PV power generation system shall be equipped with the inverter.

As for the mega scale PV power plant, the larger capacity of the inverter is usually utilized as much as possible in order to obtain better conversion rate and decrease the number of facilities which shall be maintained.

On the other hand, the large capacity inverter need to be installed into building with air-conditioner in general, because inverters are kind of control system with many electronic parts and it is necessary to keep them within rated air temperature without high temperature, humidity and dust, etc.

Additionally, the DC power system such as UPS shall be installed as well to secure continuous power supply to the inverters in the case of power outage.

2) Central control system

In the mega scale PV power plant, the central control system shall be installed to monitor and record the operation situation and the abnormal event of PV modules, inverters, transformers and circuit breakers for grid-connection.

Additionally, there are some cases that the central control system can send a signal to the inverter and can control active power or reactive power of the inverter in order to dissolve the unusual situations which are abnormal voltage at the connecting point by sudden change of the output of the PV power generation system or the reverse power flow to the distribution line.

The configuration image of the central control system is shown in the Fig. 3-3-7-1.

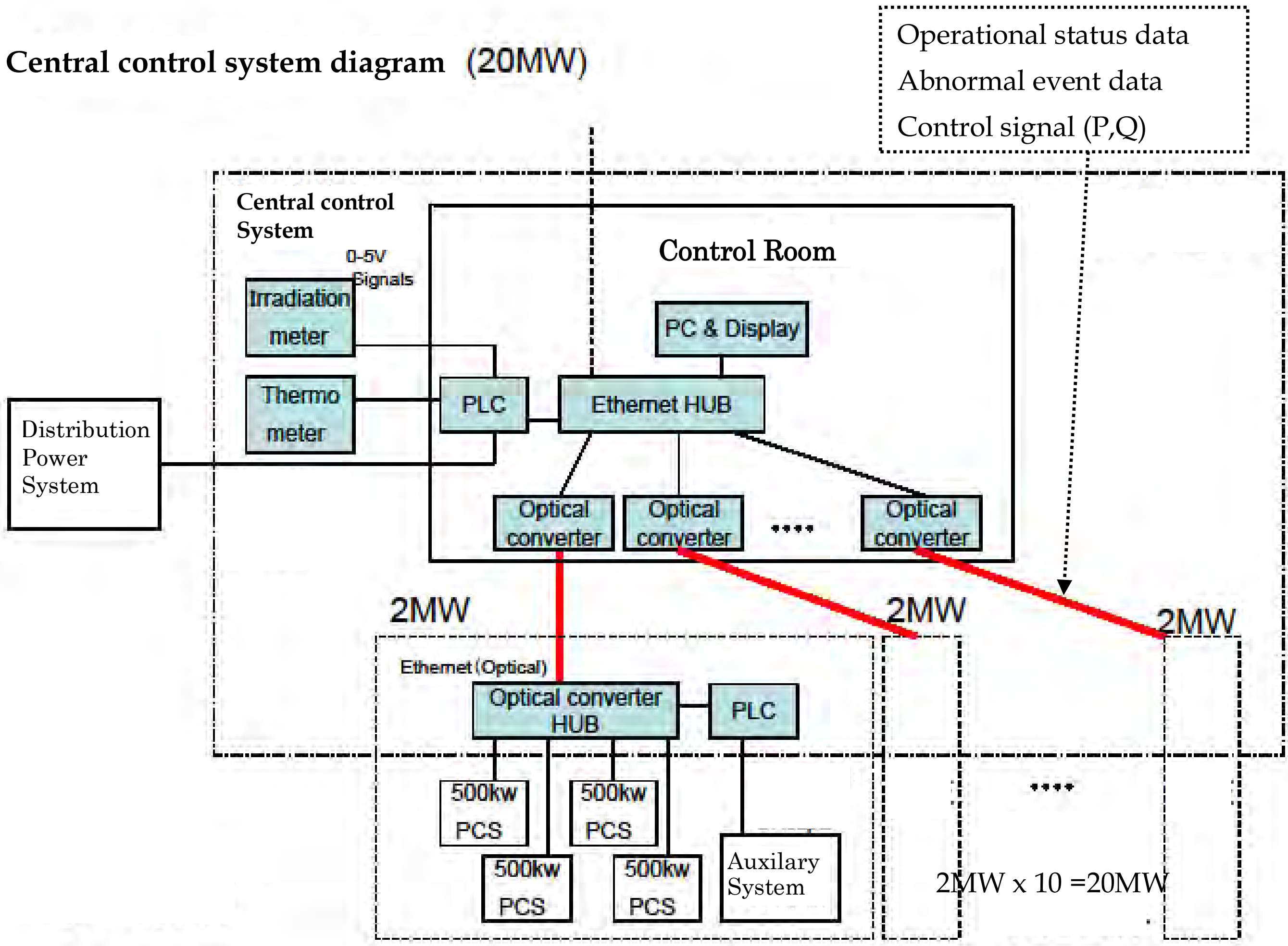


Fig. 3-3-7-1 Configuration Image of Central Control System

3) Necessary Equipment for Grid-Connection, etc.

✓ Transformer

The Step-up Transformer shall be installed according to the output voltage of the inverter and the voltage of the power grid-connected PV power generation system. Capacity of transformer shall be determined based on the capacity and the number of the inverters.

✓ Switchgears such as Circuit Breaker and connection cable

Each type of the Switchgears is installed to connect electric power from the PV power generation system to the power grid, and these Switchgears can separate fault facilities from the power system in case of fault.

[1] In Fig. 3-3-7-1 PLC means Programmable Logic Controller, PCS means Power Conditioning System, both PLC and PCS can be considered a inverter. Control signal (P,Q) can control both active power and reactive power.

The Team selected size of each cable for DC, AC- LV and MV in consideration of capacity, losses and regulations as follows:

Table 3-3-7-1 Study for selecting cable conductor size

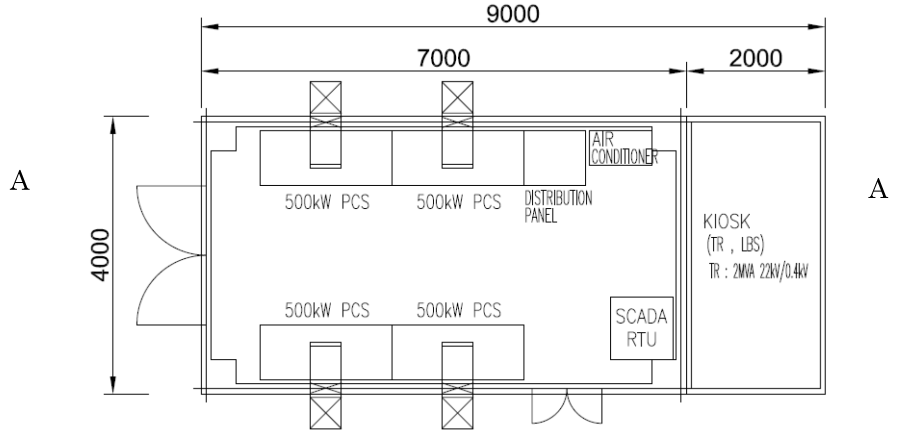
Item	From	To	Electric type	Power (kW)	Voltage (V)	current (A)	Selected cable size(mm2) XLPE AL	Cable resistance r(ohm/km)	Maximum Distance (km)	Voltage drop (V)	Voltage drop ratio(%)
PCS Input No.1	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.2	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.3	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.4	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.5	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.6	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.7	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.8	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.9	Collection Box	PCS	DC	50	404	124	300	0.121	0.3	8.97	2.22
PCS Input No.10	Collection Box	PCS	DC	32	404	79	185	0.197	0.3	9.36	2.32
PCS Input No.11	Collection Box	PCS	DC	32	404	79	185	0.197	0.3	9.36	2.32
MDB PCS output	PCS	Dist.-Box	AC	500	440	656	630×2	0.0369	0.05	0.61	0.14
Tr Tr (400V side)	Dist.-Box	Tr	AC	2,000	440	2,624	630×8	0.0369	0.05	0.61	0.14
LBS Tr (22kV side)	Tr	LBS	AC	2,000	22,000	52	95	0.383			
LBS Main SW (Tr×2)	LBS	LBS	AC	4,000	22,000	105	95	0.383	0.05	2.01	0.01
LBS Main SW (Tr×3)	LBS	LBS	AC	6,000	22,000	157	120	0.304	0.05	2.39	0.01
22kV SWGR Input No.1	LBS	22kV SWGR	AC	4,000	22,000	105	95	0.383	2	80.41	0.37
22kV SWGR Input No.2	LBS	22kV SWGR	AC	6,000	22,000	157	120	0.304	2	95.74	0.44
DP Output	22kV SWGR	DP	AC	10,000	22,000	262	240	0.151	2	79.25	0.36

- ✓ Inverter house and Switch gear house

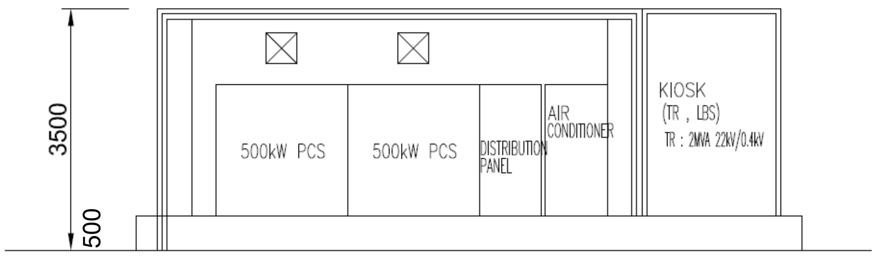
In the 20MW PV power generation system at Hurghada, each 2MW (500kW x 4units) can be considered as 1 (one) unit based on the Team's basic design. Then, the layout drawing of the inverter house for this 1 (one) unit is shown in Fig. 3-3-7-2.

Kiosk is a container box including transformer, MV switchgears, LV switchgears and protection relays, etc.

Additionally, the layout drawing of the switchgear house which is equipped with the central control system and the switch gears, etc. are shown in the Fig. 3-3-7-3.

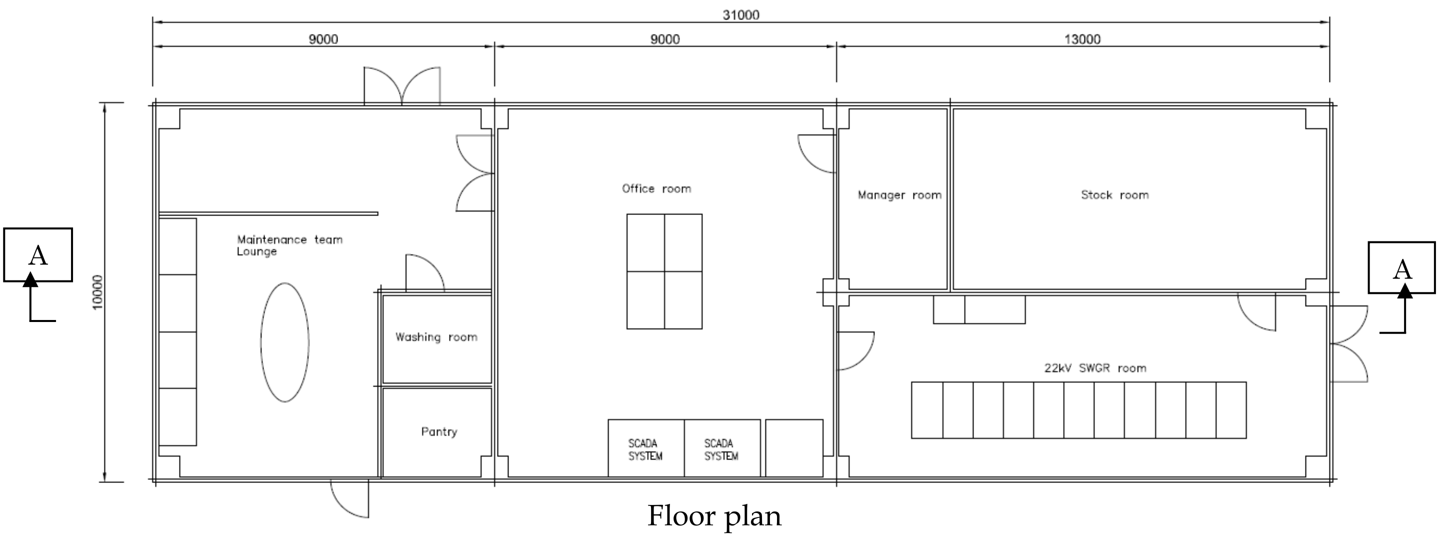


Floor plan

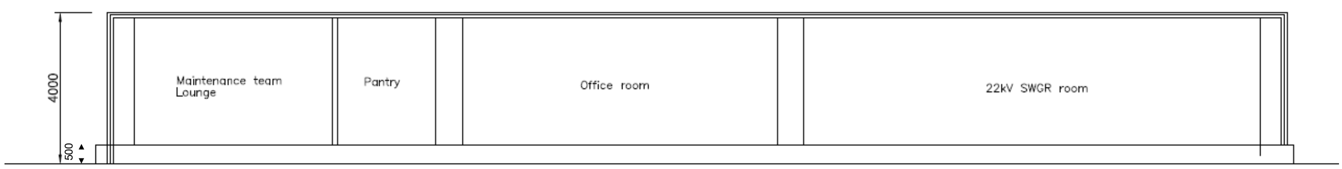


Sectional plan（A-A）

Fig. 3-3-7-2 Layout Image for Inverter House



Floor plan



Sectional plan（A-A）

Fig. 3-3-7-3 Layout Image for Switchgear House

4) Grounding system

✓ Method of grounding system

Grounding system of the PV power plant shall be composed from buried mesh cupper conductor laying in entirely the whole site as shown in Fig. 3-3-7-4.

All of the modules including frames and electrical equipment shall be connected to the same grounding system.

✓ Grounding resistance

Grounding resistance shall be complied with the following objectives:

- Electric power circuits for 22kV and 400V (MV and LV) shall be less than 5 ohm.
- Communication circuits such as control system shall be less than 2 ohm.

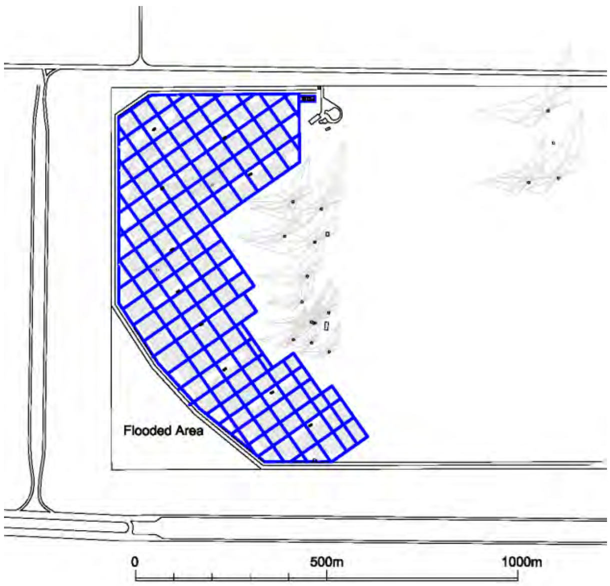


Fig. 3-3-7-4 Grounding conductor for PV power plant in case of poly-crystalline

5) Grid Connection Equipment

As for the method of the grid-connection, the single-line diagram is shown in Figure 3-3-7-5 in case of selecting option 1 (Grid-connection at 22kV to the Hurghada Wind DP) mentioned in Clause 6.

The system shall be configured as the following from the low voltage side.

✓ Each 500kW of the PV power generation system is integrated and connected to the 500kW inverter.

✓ 4 units of the 500kW inverters are integrated and connected to the transformer step up voltage to 22kV.

- ✓ 2 or 3 units of the step up voltage transformers are integrated and connected to the 22kV Switchgear (No.1 Bus Unit and No.2 Bus Unit).
- ✓ Each line through the 22kV Switchgear (No.1 Bus Unit and No.2 Bus Unit) is connected to the 22kV switchgear in the Hurghada Wind DP.
- ✓ Design for switchgears and other equipment for connecting energy storage battery is described in Clause 9.

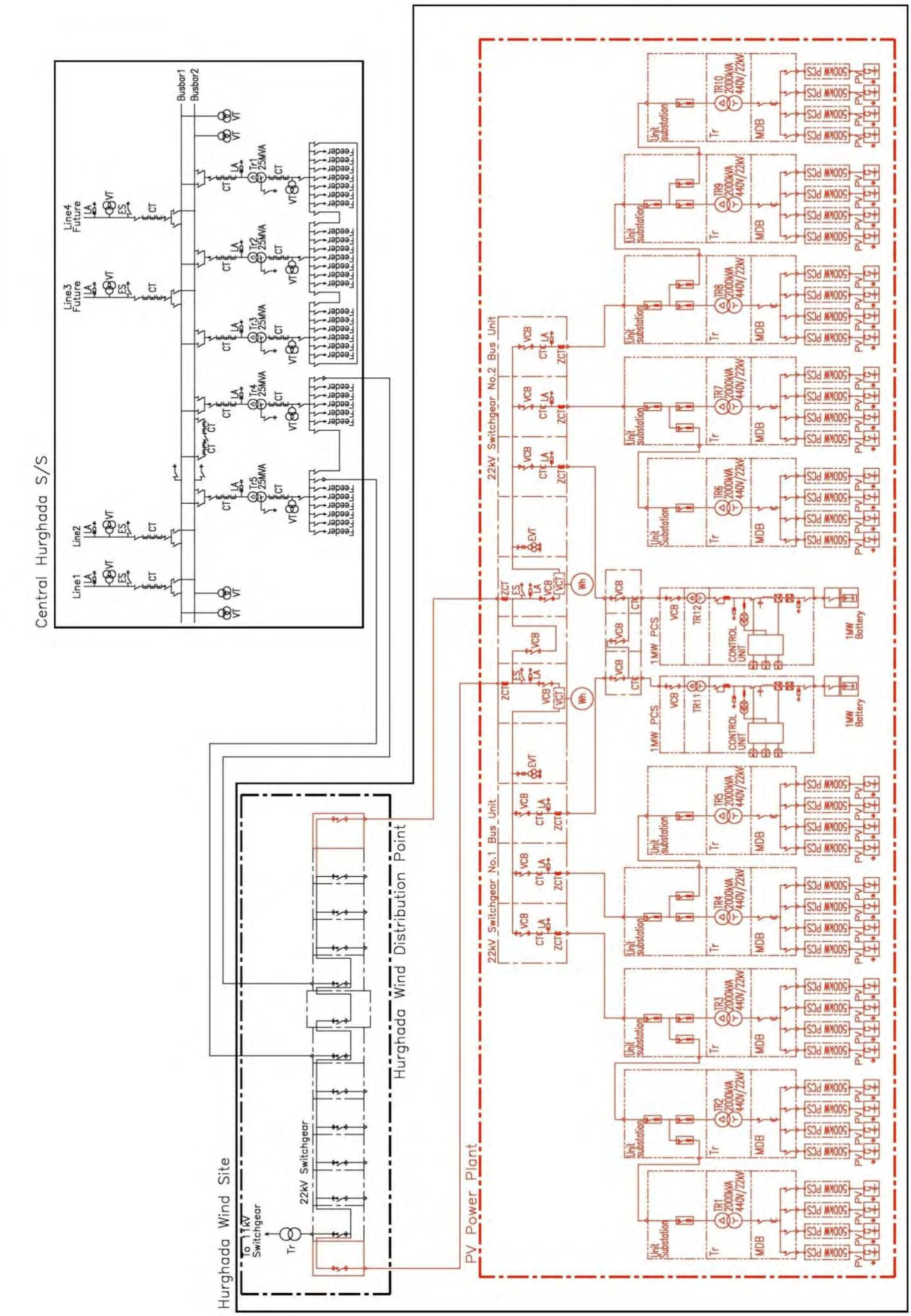


Fig 3-3-7-5 Single-line Diagram from PV power plant connected to Central Hurghada S/S

Clause 8 Layout design of PV module

Specifications for PV modules for three types (Poly Crystalline type, CIS type and MLTF type) with series of output at 500kW including Inverters are shown in Table 3-3-8-1.

The Team carried out basic design in this report considering the following points:

- ✓ Number of series of the modules is decided by the maximum inverter input voltage, i.e., 500kW.
- ✓ Every array has two parallel circuits considering 2 (two) series of module lines in upper and lower array in order to avoid suspending circuit operation due to the shadow effect for either line.
- ✓ 1 (one) block of arrays consist from 500kW capacity of arrays taking into account the maximum capacity of the inverter.
- ✓ 4 inverters will be connected to 1 (one) transformer. Thus, 1 (one) group of transformers will be 2,000kW. This group will be a unit of the layout.

Component of 1 (one) inverter block of arrays for each type of modules is shown in Fig. 3-3-8-1.
Basic layout of 1 (one) unit (2,000kW group of arrays) for each type of modules is shown in Fig. 3-3-8-2

Additionally, as for the design of the frame and the foundation, the foundation is designed with 1m height in consideration with the ventilation of air under the PV modules and taking into account any expected flash flood.

Fig. 3-3-8-3, Fig. 3-3-8-4 and Fig. 3-3-8-5 show the frame and the foundation image and the array image of the three types of the PV modules respectively.

In addition, Fig. 3-3-8-6, Fig. 3-3-8-7 and Fig.3-3-8-8 show the total layout image at the 20 degree lifted angle of the three types of PV modules respectively. The figure in the left side shows the result of installing the PV arrays considering the effect of the shade in the period from 8 AM to 4 PM.
Two existing towers drawn inside the PV module layout area in the same figures will be removed for the installation of the PV modules.

Table 3-3-8-1 Specifications for PV modules and Inverters in case of lifted angle 20 degree

Specification of PV modules and series of output at 500kW

Type of PV module		Poly Crystalline	CIS	MLTF	Remarks
Pmax (W)		240	140	128	-
Voc (V)		36.9	109	59.8	-
Isc (A)		8.59	2.1	3.45	-
Vmpp [Ipm] (V)		29.8	77.0	45.4	-
Impp [Ipm] (A)		8.06	1.82	2.82	-
Number of series		20	6	12	-
Number of parallel		105	596	326	-
Input Voltage (V)	Open	738	654	718	less than 750V
	Rated	596	462	545	-
Input Current (A)	Rated	846	1085	919	-
Combination power (kW)		504	501	501	around 500kW

Specification of size of PV modules

Type of PV module	Poly Crystalline	CIS	MLTF	Remarks
Length (mm)	1,662	1,257	1,402	-
Width (mm)	990	977	1,001	-
Thickness (mm)	46	35	24	-
Area (m^2)	1.645	1.228	1.403	-
Weight (kg)	21.0	20.0	26.0	-
Power per area (W/m^2)	145.9	114.0	91.2	-

Specification of inverter

	Specification	Remarks
Maximum DC power	600kW	-
Maximum DC voltage	1000V	-
MPPT operating range	450 ~ 950V	-
Maximum DC current	1155A	-
Nominal AC output power	500kW	-

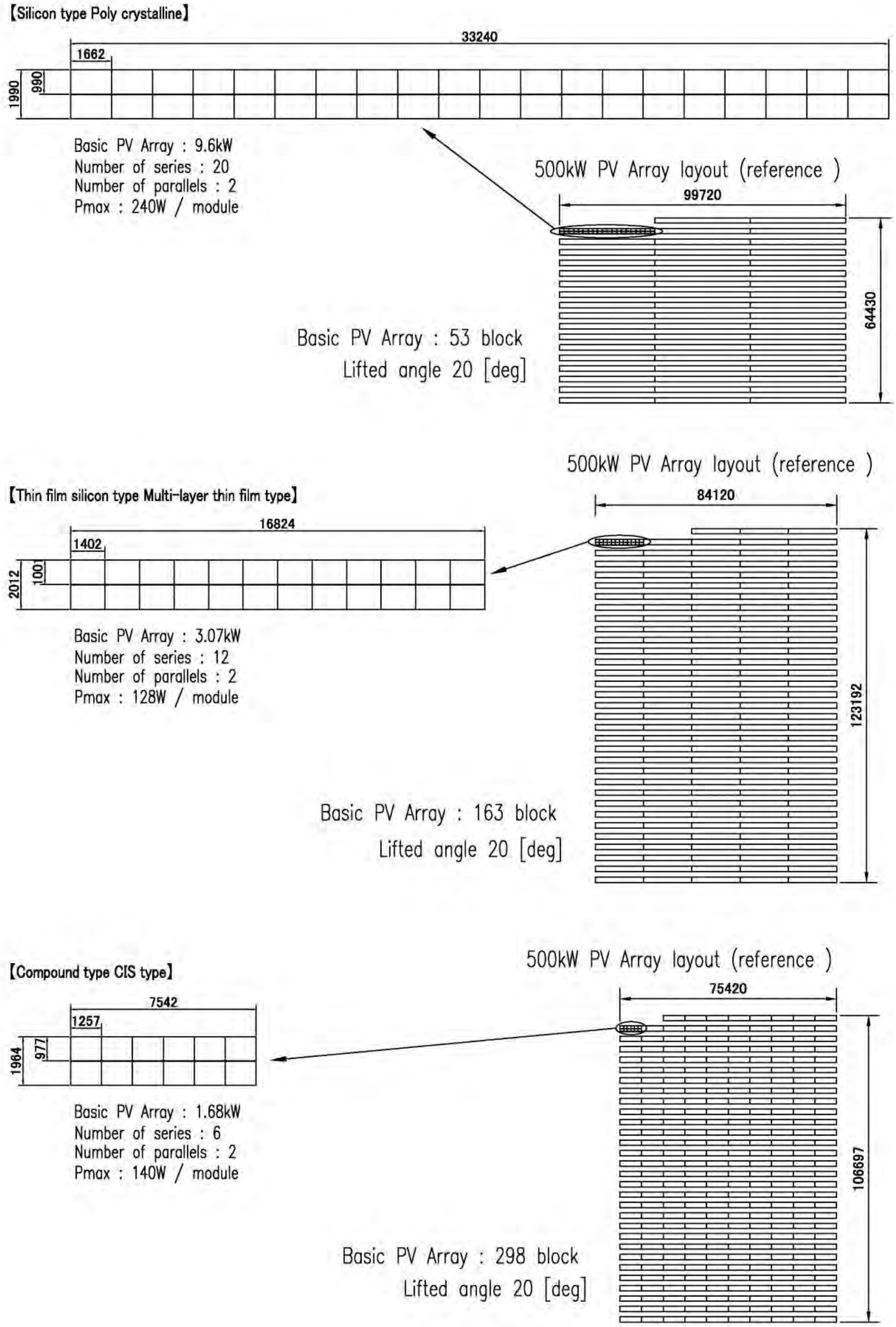


Fig. 3-3-8-1 Component for 500kW capacity block of PV arrays

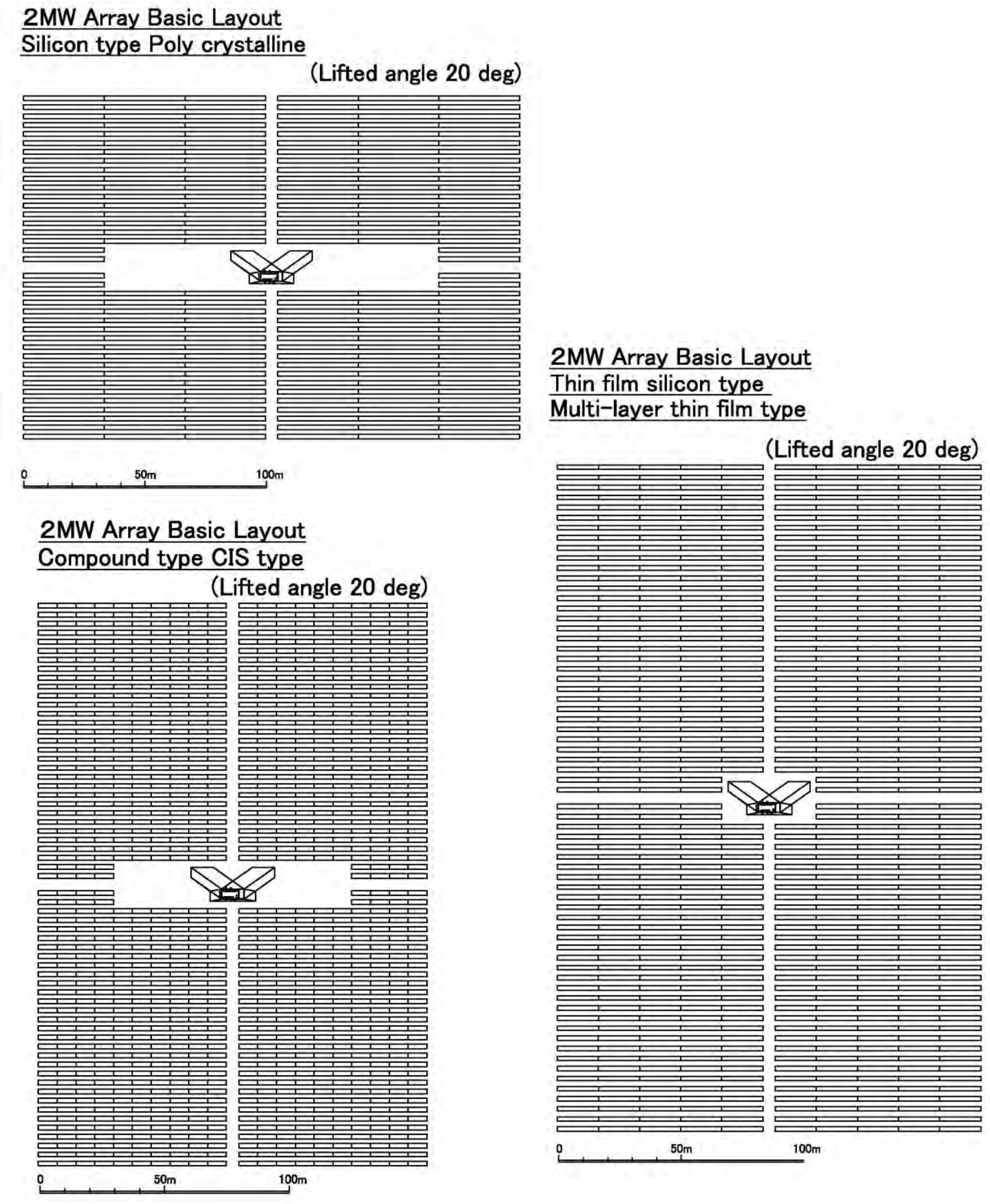


Fig. 3-3-8-2 Basic layout of 1(one) unit (2,000kW group of arrays) for each type of modules

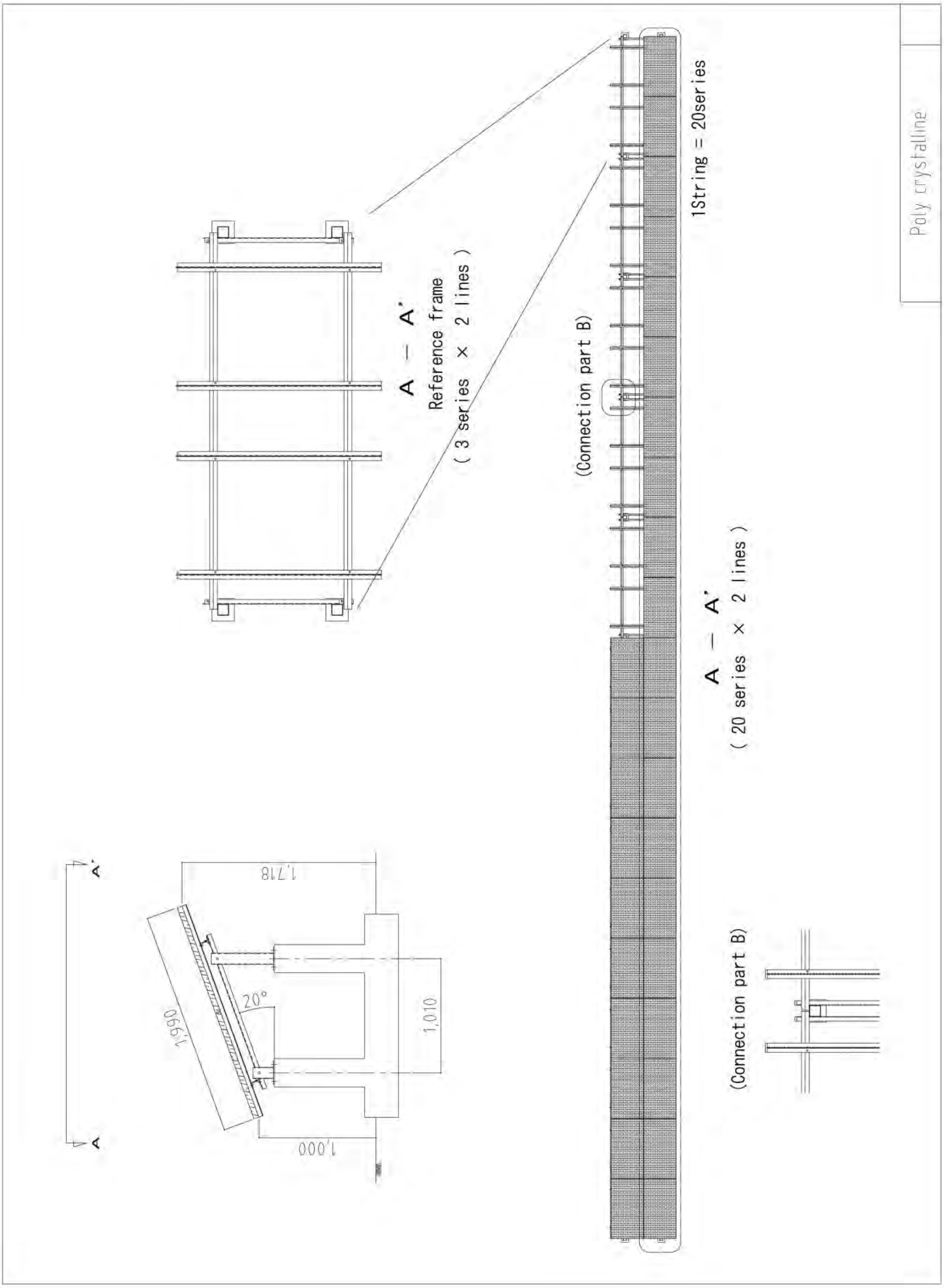


Fig. 3-3-8-3 Frame and foundation image for 1 (one) array of Poly Crystalline

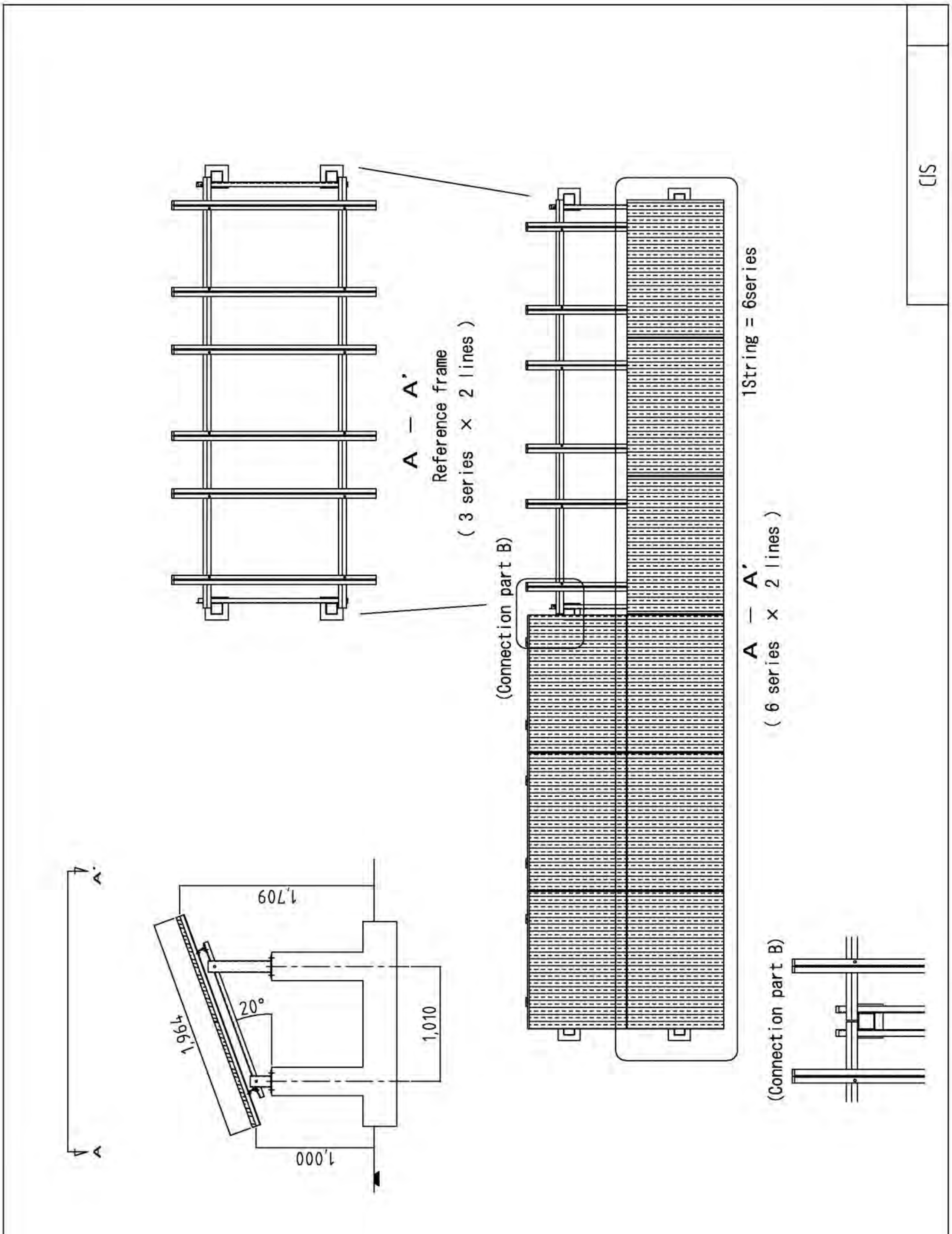


Fig. 3-3-8-4 Frame and foundation image for 1 (one) array of CIS

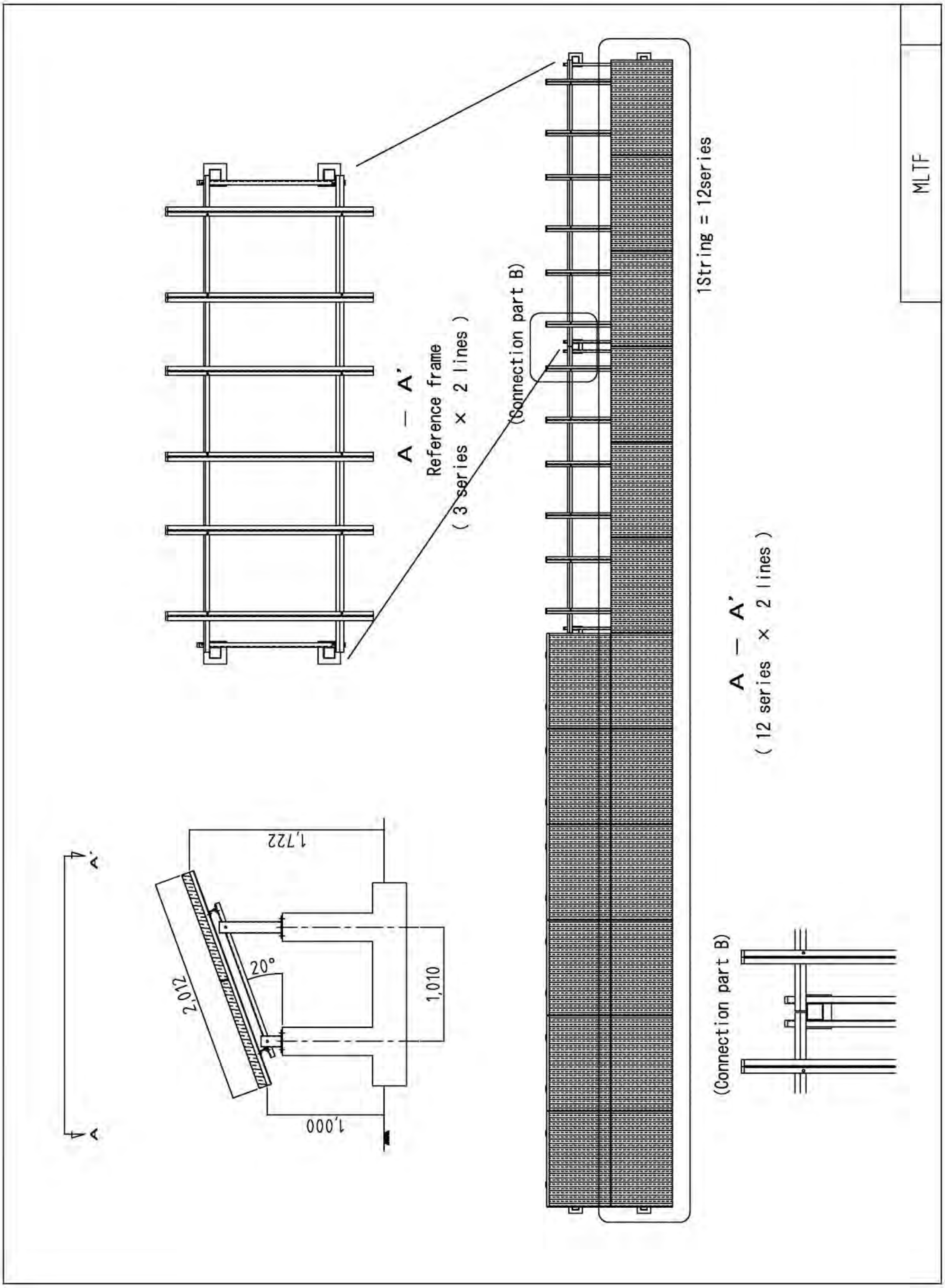


Fig. 3-3-8-5 Frame and foundation image for 1 (one) array of MLTF

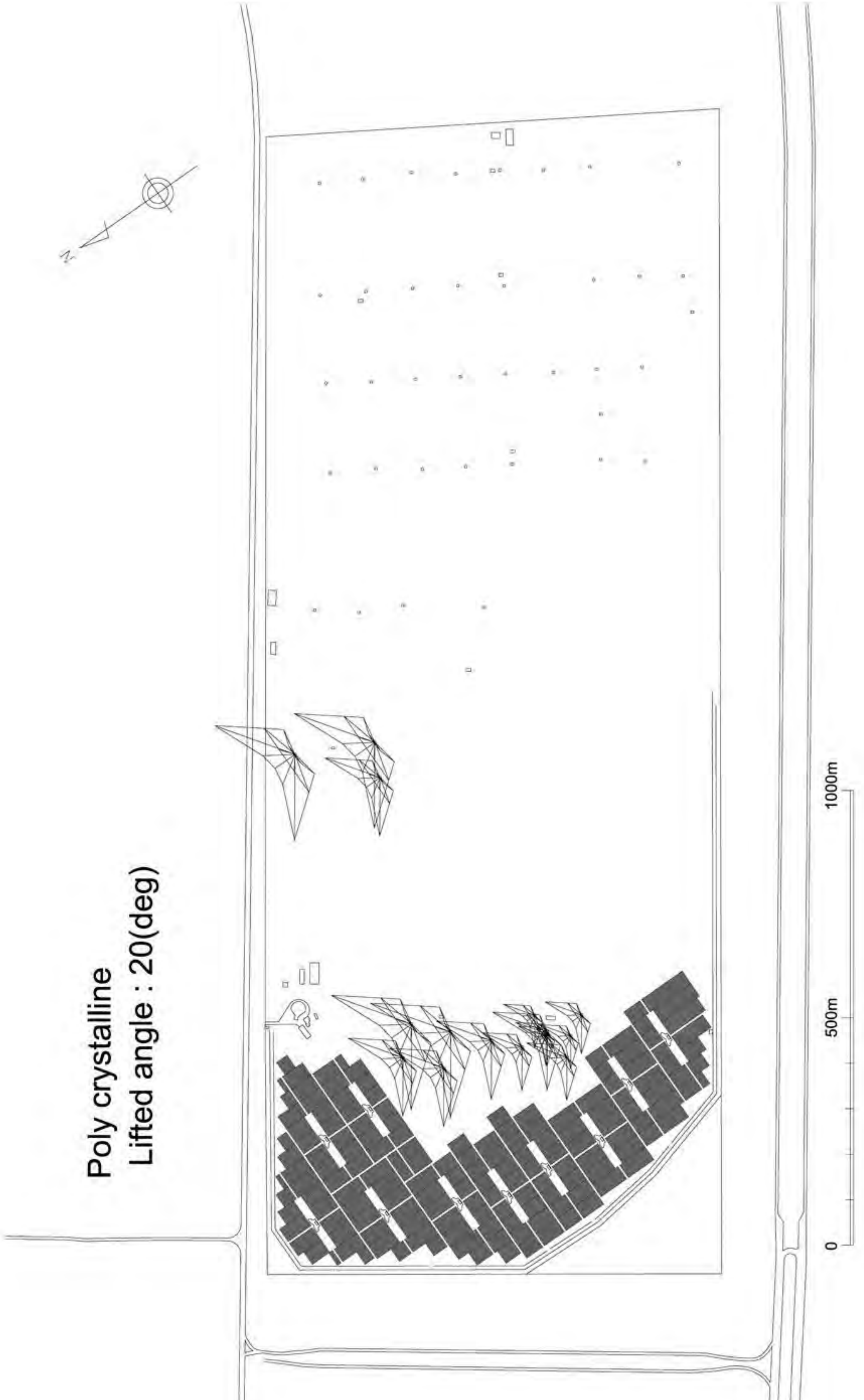


Fig. 3-3-8-6 Total layout image at 20 degree lifted angle of Poly Crystalline

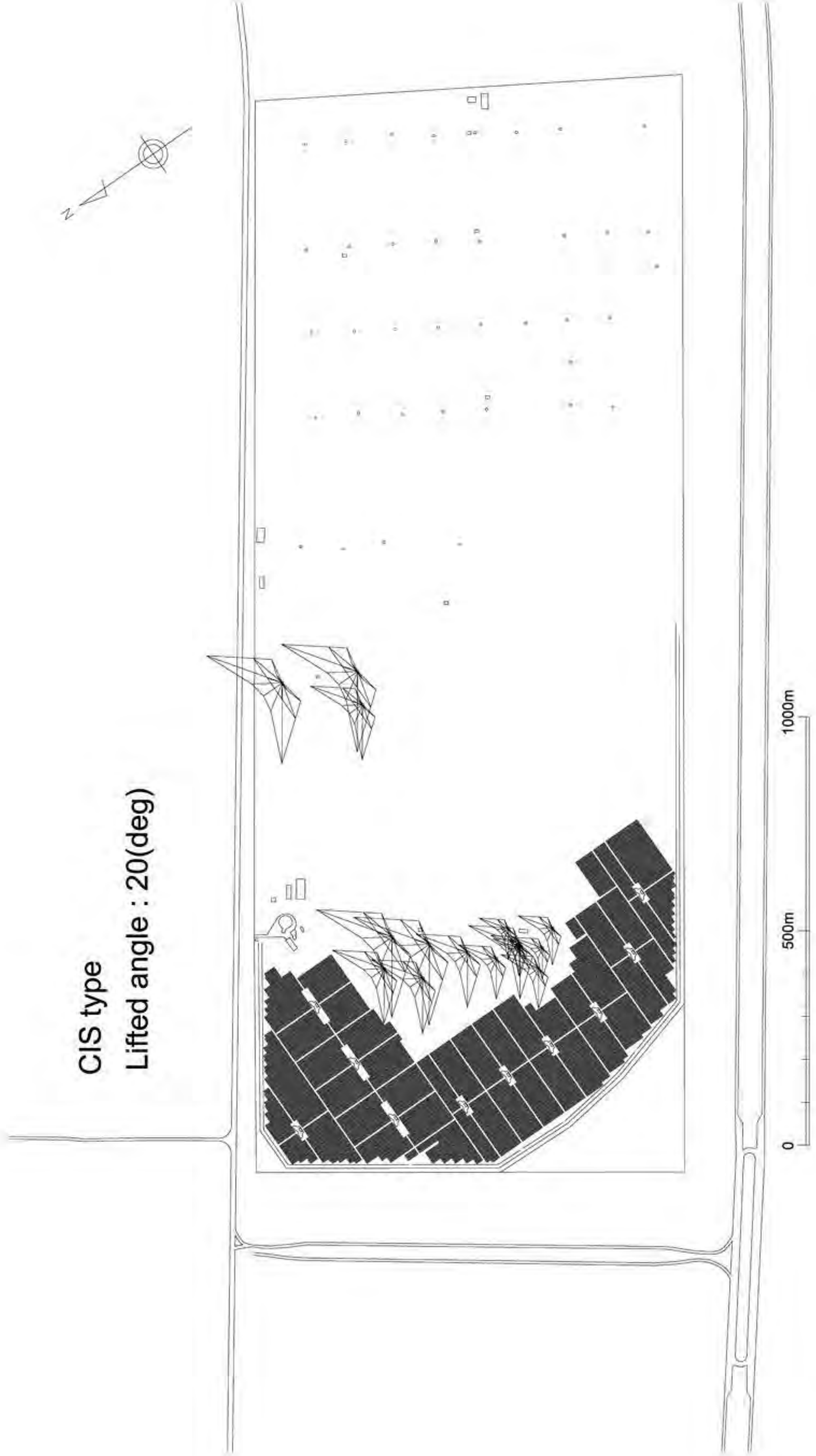


Fig. 3-3-8-7 Total layout image at 20 degree lifted angle of CIS

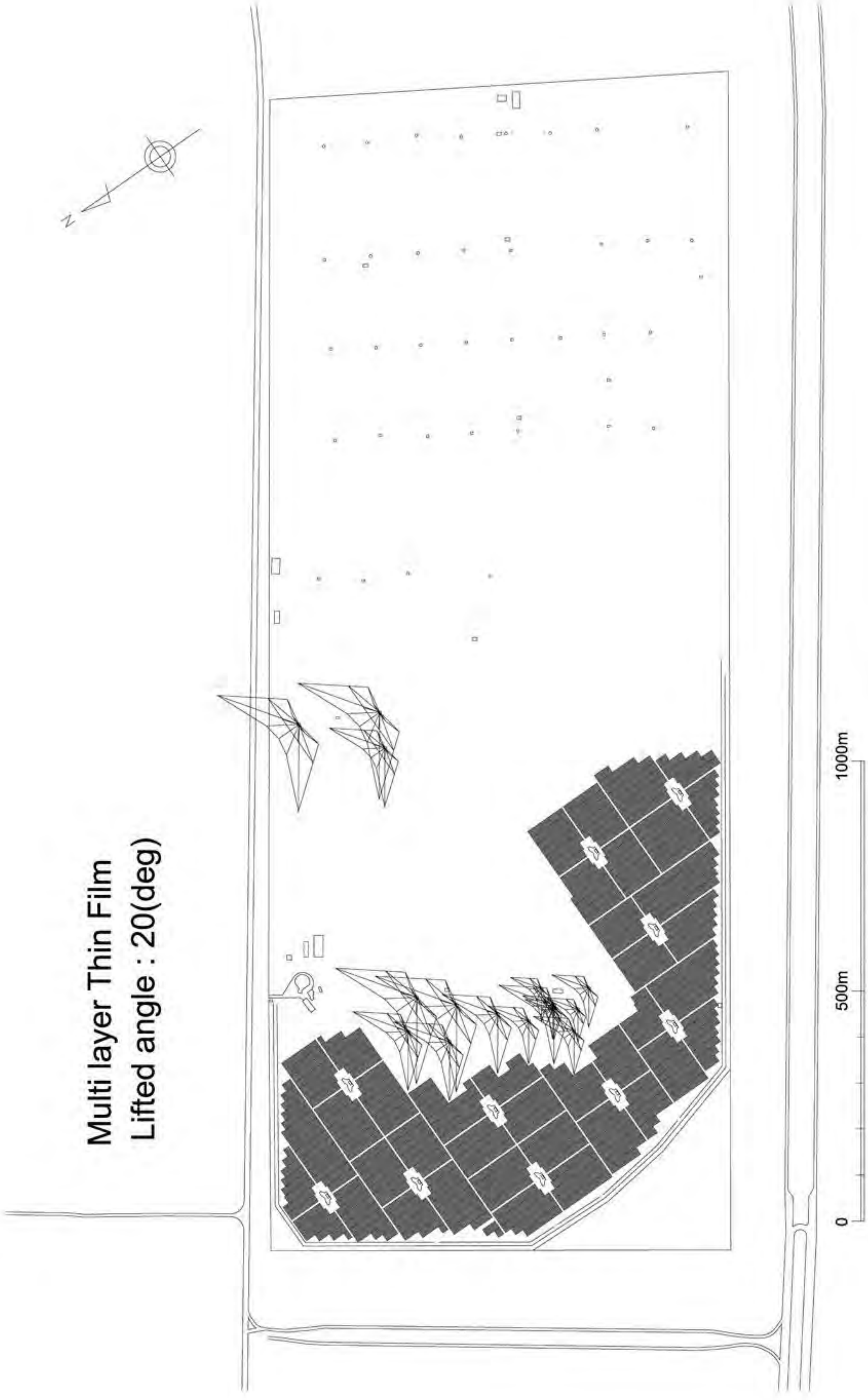


Fig. 3-3-8-8 Total layout image at 20 degree lifted angle of MLTF

Clause 9 Necessity of High Performance Battery

1) Necessity of high performance battery

As described in Clause 6 of this Chapter, this PV power plant will be connected separately in 2 (two) system parts to the existing 22kV Distribution Point (option 1). But this option might cause reverse power flow as described in Clause 6 and the power supply is not effective enough to supply the peak demand hours, e.g., from evening to night time, which shall be adjusted by appropriate method, if possible.

From the above reasons, the adaption of a high performance battery can be taken into account. By using the battery, stored power in the battery produced by PV power at daytime can be shifted to supply the peak demand hours.

The advantages of using the battery are as follows:

- Avoid reverse power flow from distribution line to substation.
- Supply PV power to peak demand at evening time and/or any time required.
- Reduce voltage fluctuation caused by PV power output fluctuation (increasing and decreasing).
- Compensate for lacking reactive power.
- Ease sharp variance of PV power output / precipitous change of load.

2) Appropriate type of battery

There are many types of energy storage batteries which can be applied to electric power network, recently. Since each battery has different characteristics, it is better to examine each kind carefully taking into account the purpose of use, size and effect, etc.

Characteristics and present condition of each battery is shown in Table 3-3-9-1.

Table 3-3-9-1 Comparison of energy storage batteries

	Sodium-Sulfur battery	Lead battery	Nickel hydrogen battery	Lithium ion battery
Characteristic	· Large capacity · Very high density of energy · High efficiency of energy charge · No memory effect · Long life cycle time · Reasonable cost	· Small to large capacity · Generally maintenance free · Load Leveling battery has long life cycle time · Relatively Reasonable cost	· Small to medium capacity · High efficiency of energy charge	· Small to medium capacity · No memory effect · High efficiency of energy charging · long life cycle time
Present condition	· Specialized for large scale energy storage –more than 2MW · Largest scale for grid is 34MW in Japan, and planned to install 80MW in Japan.	· Generally used for UPS system · LL battery is used for large scale energy storage · It requires large space for using energy storage · Largest scale for wind turbine is 4.5MWh-10.4MWh	· A lot of experiences for electric vehicle · Development as medium or small capacity energy storage system	· Under developing for electric vehicle · Largest scale for grid is 12MW in Chile, and planned to install 40MW in USA
Consideration for use	· Consider heater loss if not working every day since this battery requires heating (300 C deg.) to operate · Apply danger material treatment regulation for sodium and sulfur	· Life time turns down extremely, when its life time is coming to an end. · Capacity is relative with air temperature, thus, it requires air conditioner for room.	· Costly when it will be installed as large scale at the present condition · Capable for direct connection to DC circuit of PV power thus good compatibility with PV power	· Costly when it will be installed as large scale in the present condition.
Comment	· A lot of experiences as large scale energy storage · Compact · Long life of cycle time	· Reasonable price · Many experiences as a industrial use, ease of acquisition	· Adequate for medium scale solar hybrid system	· Most compact as used in room temperature

Photo 3-3-9-1 Sodium-sulfur battery (34MW system) Wind farm, Japan

Photo 3-3-9-2 Lead battery for Load Leveling (10.4MWh system) wind farm in Japan

Quote from leaflet of shin-Kobe electric

Applying a high performance battery to this project is very useful as a countermeasure for reverse power flow and supplying power at the evening peak demand. Considering PV power generation capacity and the above effects, it is recommended to use large scale capacity for power storage under this project.

And also, appropriate O&M and waste treatment method should be considered for this project. Because batteries use chemical material, it requires proper treatment after removing the battery.

For this reason, the Team assumed that lead acid battery is suitable to be applied for this project. The reasons are as follows:

- ✓ It has relatively large scale and long life
- ✓ Cost for project is relatively cheap
- ✓ O&M and treatment/recycling method are general in every country

On the other hand, the other new type of battery such as sodium-sulfur battery can also be applied for this project. This new type of battery has reasonable price and long life. In case of selecting new type of battery, proper O&M and after removing recycling/treatment method by contractor, should be required.

If the price of lithium ion battery reduces, this battery can also be applied to this project.

3) Effects of the battery

a) Supplying power from PV plant at evening peak time

As described in Chapter 2, peak demand is occurring in the evening time in Egypt. However PV generation power system can generate power only in the daytime. Battery can be used for compensating this demand – supply gap; charging power during the daytime and supplying charged power in the evening peak time.

In this case, the team selecting 6 hours discharging capacity for each regulated power. Thus, 1 MW battery system has 6 MWh capacity for discharging.

The simulation made by the Team is shown from Fig. 3-3-9-1 to Fig. 3-3-9-6 taking into account the followings:

- ■ The original daily load curve is using power flow of the incoming line to the Hurghada wind 22kV distribution point's on peak load date.
- ■ The batteries charge energy from PV power in the day-time, and supply power in the evening peak time.
- ■ PV power plant will connect to the 2 distribution lines by 10MW each explained in the electric circuit design. So it assumed 2 battery systems are prepared and connected to each 2 buses.
- ■ Installed capacity is varied from 2MW (1MW each) to 8MW (4MW each).

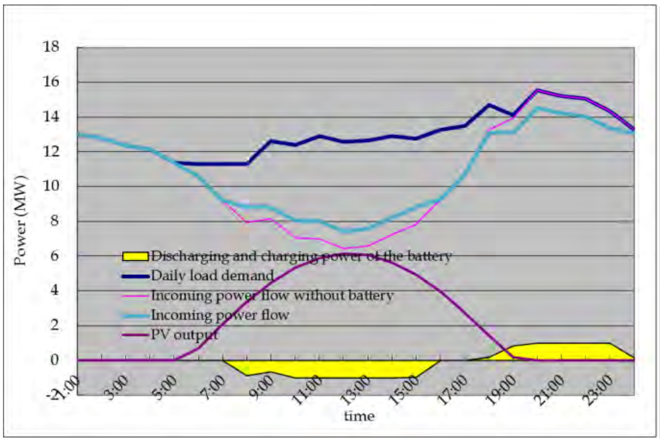


Fig. 3-3-9-1 Simulation of battery operation1MW battery on bus1 at maximum load

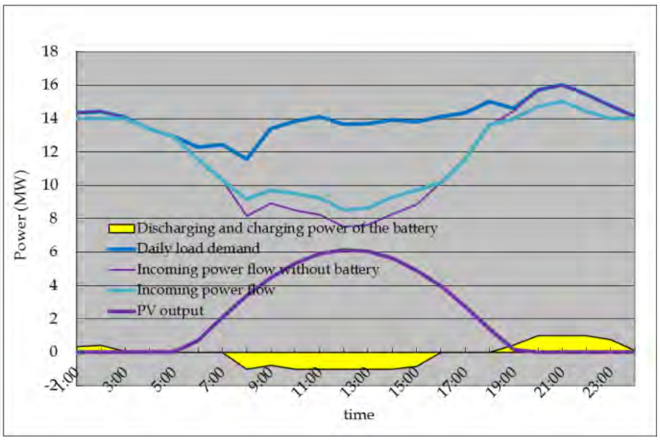


Fig. 3-3-9-2 Simulation of battery operation 1MW battery on bus2 at maximum load

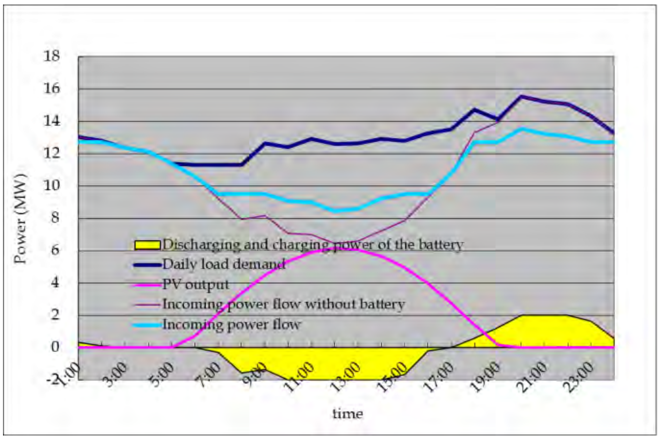


Fig. 3-3-9-3 Simulation of battery operation 2MW battery on bus1 at maximum load

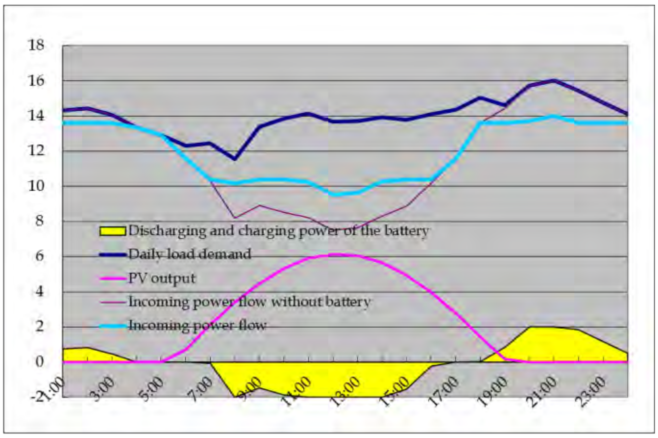


Fig. 3-3-9-4 Simulation of battery operation 2MW battery on bus2 at maximum load

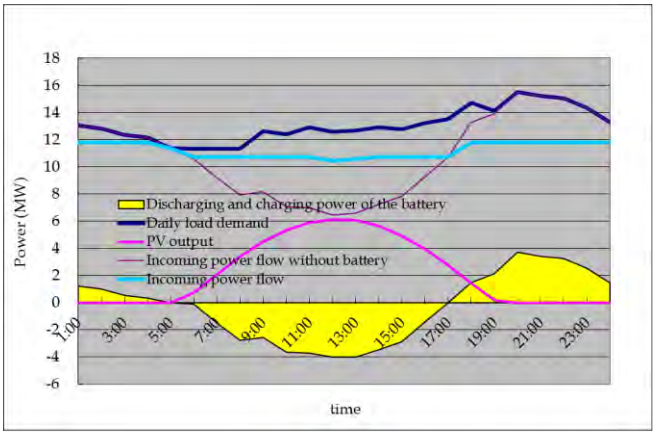


Fig. 3-3-9-5 Simulation of battery operation 4MW battery on bus1 at maximum load

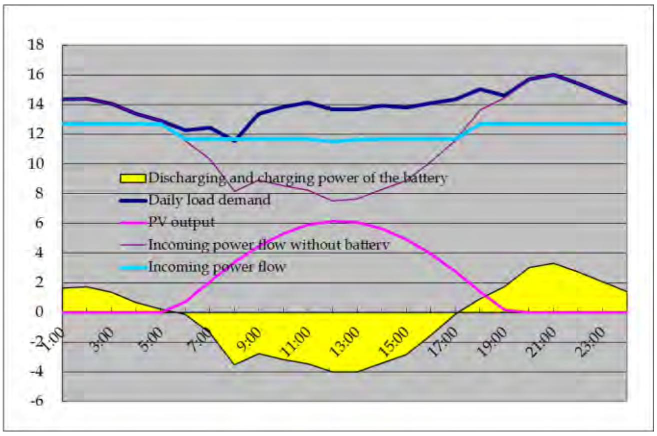


Fig. 3-3-9-6 Simulation of battery operation 4MW battery on bus2 at maximum load

Table 3-3-9-2 Result of simulation of battery operation at maximum load

<table>
<tr><th colspan="2"></th><th>Base case
PV only</th><th colspan="3">Case of battery installation</th></tr>
<tr><td colspan="2">Installed power (MW)</td><td rowspan="4">None</td><td>2</td><td>4</td><td>8</td></tr>
<tr><td colspan="2">Installed capacity (MWh)</td><td>12</td><td>24</td><td>48</td></tr>
<tr><td rowspan="2">Installed power for each bus (MW)</td><td>Bus1</td><td>1</td><td>2</td><td>4</td></tr>
<tr><td>Bus2</td><td>1</td><td>2</td><td>4</td></tr>
<tr><td rowspan="2">Maximum power flow at the peak demand of the distribution line from Central Hurghada substation (MW)</td><td>Bus1</td><td>15.5</td><td>14.5</td><td>13.5</td><td>11.8</td></tr>
<tr><td>Bus2</td><td>16.0</td><td>15.0</td><td>14.0</td><td>12.7</td></tr>
<tr><td rowspan="2">Time of the peak demand</td><td>Bus1</td><td colspan="4">20:00</td></tr>
<tr><td>Bus2</td><td colspan="4">21:00</td></tr>
<tr><td colspan="2">Charging and discharging loss of batteries (MWh/day)</td><td>None</td><td>4.5</td><td>9.1</td><td>18.1</td></tr>
<tr><td colspan="2">Loss reduction of distribution line and transformer (MWh/day)</td><td>None</td><td>0.0</td><td>0.2</td><td>0.6</td></tr>
</table>

Installing capacity and reduction of peak load is summarized in Table 3-3-9-2.
Gas turbine generators are operated to supply power at peak load normally. If the battery is installed, gas turbine generators can be suspended or reduced its operation time at peak hours and can be replaced by the power provided from installed battery which charges from the PV power plant at day time.
The battery is flattening the peak load of the distribution line; which contributes to reducing distribution lines and transformer losses. However, it shall be noted that the battery has some loss due to charging and discharging.

b) Measures for reverse power flow

As described in the previous clause, reverse power flow to the Central Hurghada substation might occur when the load is low. Occurrence of reverse power flow is not a preferable situation for the grid protection relay, though voltages can be kept stable.

As described before, using the battery is one of a countermeasure to the reverse power flow.
Result of simulation for the battery operation at low loaded hours is shown in Fig. 3-3-9-7, which explains that the battery absorbs the surplus power flow, thus reverse power flow is solved. This daily load curve is coming from actual data of the

Hurghada wind DP in low loaded day. Considering this data, 2MW battery system is sufficient enough.

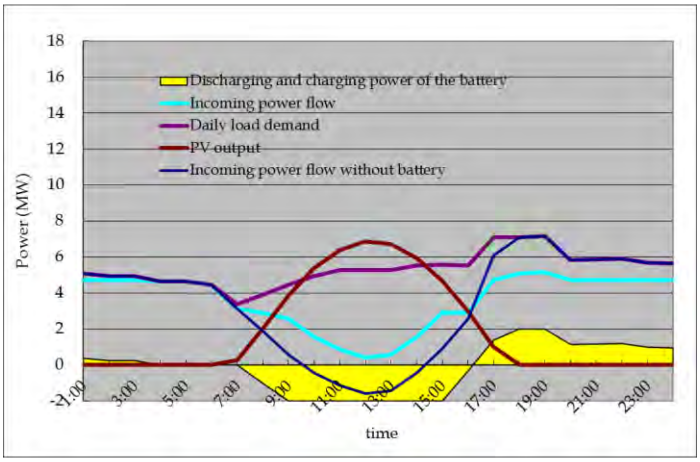


Fig. 3-3-9-7 Simulation of battery operation at low load

c) The other effects

In addition to the above function, following effects are expected:

Detail requirement/function for the battery system requires more profound inspection and study of the network in detail design stage.

- Stabilize voltage
- Measures for momentum interruption
- Compensate reactive power
- Emergency power supply for outage
- Independent power supply by PV and battery

4) Study for the cost benefit of battery storage

Project cost for each installation capacity of the battery with 20MW PV power plant is shown in Fig. 3-3-9-8. If the project includes 2-8MW-6h class battery system, total project cost will be increased approximately 15 - 60%.

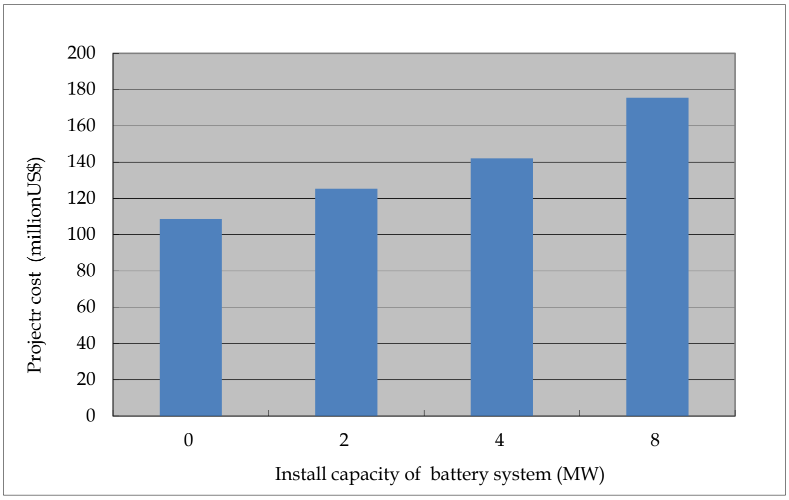


Fig. 3-3-9-8 Project cost for including battery system

a) Price difference

In accordance with Egyptian tariff regulation revised in the last fiscal year (2010/11), energy sales price between peak and off-peak hours differ approximately 50% in commercial use. Thus supplying additional power at peak hours is effective also from the point of cost reduction.

The battery's cost is approximately 550US$/kWh. This battery has a power output more than 1MW and each size of battery has a capacity of 6 hours by regulated specification output –for example 1MW system has 6MWh capacity.

Considering this situation, the Team made an analysis for appropriate capacity of the battery taking into account, cost performance and summarized as below:

- Since the battery charges the energy during off peak times and stores power, the battery can supply valuable energy to peak hours of which energy sales price is higher than the other times.
- Comparison between battery cost and sales price gap during off peak and peak time (cost benefit for price difference) is shown in Fig. 3-3-9-9.
- It is clear that the battery cost can be compensated by the cost benefit from the price difference in certain percentage.

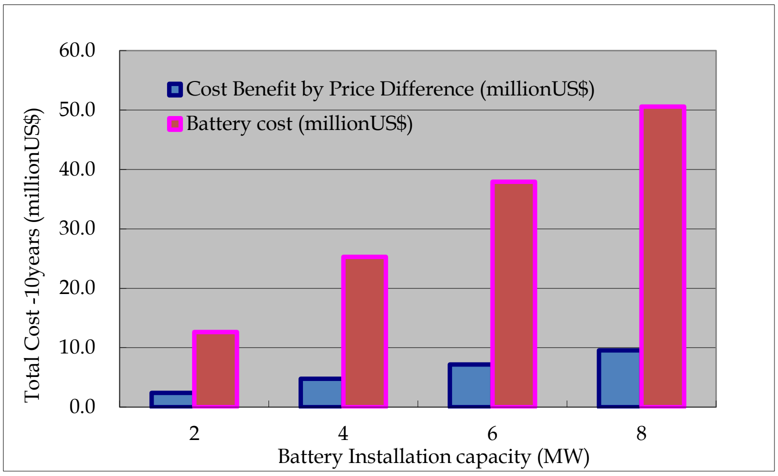


Fig. 3-3-9-9 Comparison between battery cost and tariff difference

b) Comparing with gas turbine generation

The Team made comparison between the battery and the gas turbine generation as well. If the network does not have enough capacity for supplying the power to peak time, operation of existing gas turbine generators (currently, its operation is suspended due to ageing of the generation system) is required to compensate demand-supply gap. If the battery is installed, this compensation can be realized by the battery instead of the gas turbine generation.

The Team made a rough comparison between battery cost and fuel cost for the gas turbine generation and the result is shown in Fig. 3-3-9-10.

It shows that the battery price is slightly expensive than applying present cost of gas turbine, i.e., using LFO with cost is 0.32 US$/liter.

Considering current trend of natural gas price in the world, cost benefit of the battery storage system may be catching up with the fuel cost of the gas turbine in the near future.

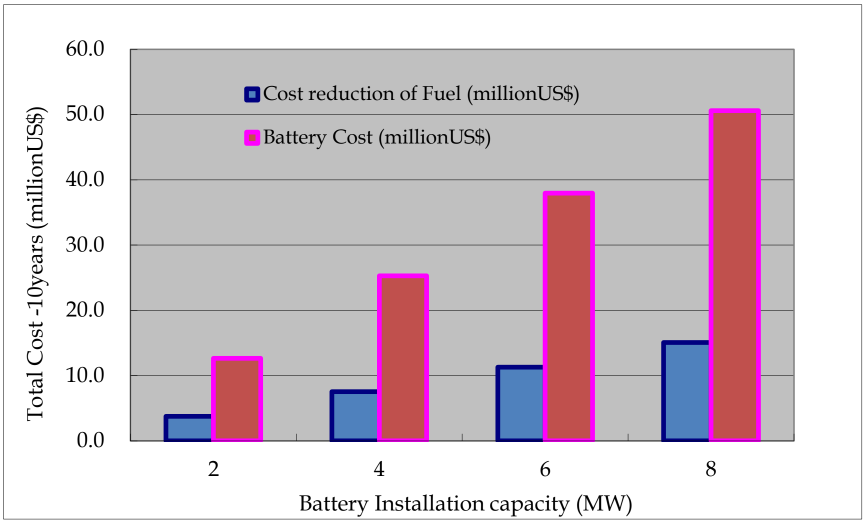


Fig. 3-3-9-10 Cost comparison between fuel cost and battery cost

5) Installed capacity of the battery

Considering the above matters, the Team recommends 2MW battery system (1MW in each bus) for this project.

Although this system requires just 10% increase of the cost for the project, it is useful for controlling electric power flow explained in 'Measures for reverse power flow' of this Clause. It obviously has the function for maximum 2MW power supply for the evening peak demand from stored power generated from the PV power plant in the day time.

Specification of the proposed battery is summarized in Table 3-3-9-3.

Lead battery or sodium-sulfur battery will meet the requirements of this specification.

Table 3-3-9-3 Specification of proposed battery

Item	Conclusion
Capacity	2MW (1MW x2)/12MWh(6MWh x2)
Inverter	1MW x 2
Grid connection	22kV 2 buses (1MW each)
Installation method	Indoor
Major purpose	Supply power in peak time from PV plant Measures for reverse power flow
Expected life time	3000 cycles (10 years)

6) Method of grid connection

The reverse power flow occurs only at Bus No.1, so it is better to install the battery to be connected to Bus No.1 for solving this problem. However, the PV power will be connected to both Bus No.1 and No.2. Then it is suggested to connect battery with each Bus respectively in order to secure efficiency of the system especially in peak load.

Considering the above condition, an idea for the method of connecting the battery to each bus is shown in Fig. 3-3-9-11.

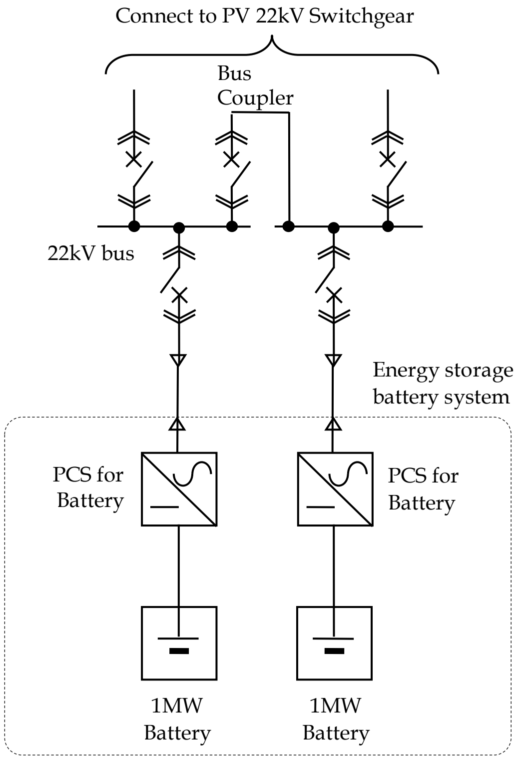


Fig. 3-3-9-11 Method of battery connection

7) Layout of battery room

Batteries, inverters and auxiliary equipment will be installed in the building/house in order to avoid damage from sand dust and heat.

Layout of the battery room is shown in Fig. 3-3-9-12. This layout is assuming the installation of lead battery.

Battery contains flammable dangerous material, so the room should be constructed based on fire-resistance concrete structure, and it also requires proper fire alarm system.

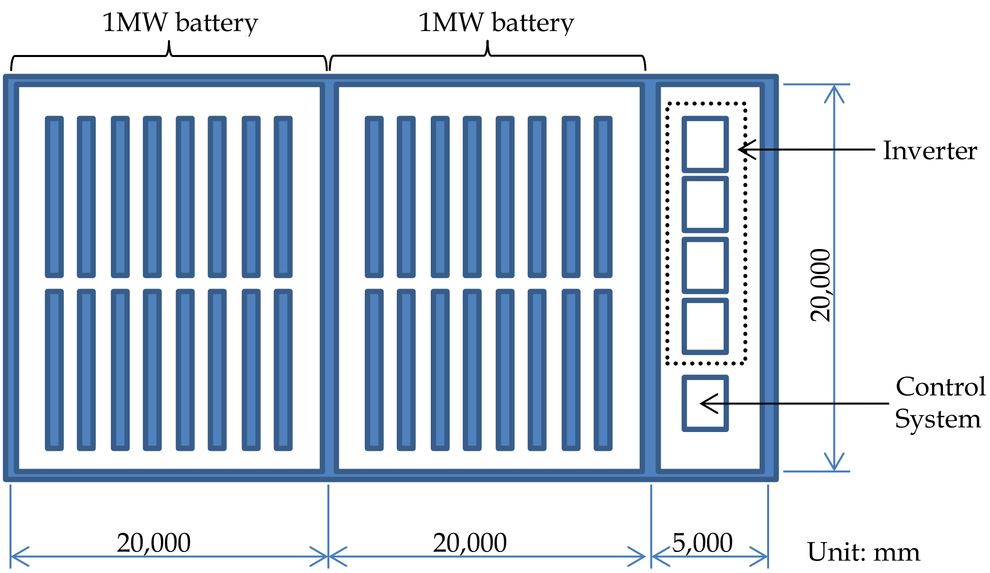


Fig. 3-3-9-12 Layout of battery house

8) O&M and disposal method

Battery system requires manufacturer's periodical inspection and maintenance, and operation engineer need to have knowledge of handling dangerous objects since battery contains flammable dangerous material and the battery of the inverter requires high technology maintenance schemes. So cost of periodical maintenance by manufacturer and training for O&M team (mainly for inverter) should be considered.

In addition to the above situation, at the end of the life time of the batteries, an appropriate disposal method should be applied. Collection method of the disposed battery cells should be considered as one of the tender requirements.

Section 4 Project Scope

Based on the basic design result described in previous Section, project scope for this project shall be determined with considering the following points:

- Type of PV module to be used and its capacity
- Scope to be included other than basic design items

Clause 1 Type of PV module to be used and its capacity

Referring to the appropriate type of PV module and its annual energy production described in Clause 1 and 4 of Section 3 in this Chapter; the basic design results for the selected 3 types of PV modules (Poly Crystalline, MLTF and CIS) are summarized in Table 3-4-1.

Table 3-4-1 Summary of results of basic design for 3 types of PV modules

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)	74.96 Million US$	65.29 Million US$	65.95 Million US$
Generation Cost [(b)/(a)*20]	11.9 US cents/kWh	10.1 US cents/kWh	9.89 US cents/kWh

(Note: cost breakdown of the above are enclosed in Appendix 3-4-1.)

From the above table and site conditions, the Team made comments as follows:

- Available land is enough for any of the 3 types considered (approx. 500,000 m^2 or more can be allocated).
- Even though project cost mentioned in the above Table is just a reference (the 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.

In addition to the above, the following information is useful for selecting PV modules:

1) Poly Crystalline

- Currently this type occupies around 80% of the international market, thus it is the most familiar type of PV module in the world.
- Many manufacturers including Chinese, Taiwanese can produce this type and very tough competition is made.
- Conversion efficiency is better than other two types.
- According to general information, the followings shall be noted as well:
  - ✓ This type of module is assuming to be suitable for relatively cool climates (rated on a standard of 25 deg. C).
  - ✓ Panels operating at a higher temperature (50 deg. C or more) will decrease their efficiency to big extent. -> Egypt is not suitable for this type.
- Further, considering spectrum sensitivity (this directly related to generation power, kind of efficiency), this type is suitable for high latitude countries such as North America, Europe, etc. while Egypt is belonging to low latitude country.

2) MLTF

- Commercial operation of this type has been started around 2005.
- Currently this type occupies around 20% of the international market and it is gradually expanding with competitive prices.
- Japanese "SHARP" and "KANEKA" can produce this type.
- Temperature coefficient is better than other two types thus this type is suitable for low latitude countries including Egypt.
- Largest PV power plant using this PV module is 73 MW in Thailand (operation started on December 2011) at this moment.
- Considering spectrum sensitivity, this type is suitable for low latitude countries including Egypt.

3) CIS

- Commercial operation of this type has been started around 2006.
- Currently this type occupies few percent of the international market and it is gradually expanding with competitive prices.
- Japanese "Solar Frontier" can produce this type.
- Deterioration coefficient is better than the other two types, thus long term generation power is relatively larger than the others.
- Due to light-soaking effect, produced power generally is more than rated one, thus total generation power might be larger than the expectations.
- Largest PV power plant using this PV module is 150 MW in USA (60MW put in services in November 2012 while 90MW is expected to be put in operation by June 2013) at this moment.

- Considering spectrum sensitivity, this type is suitable for low latitude countries including Egypt.

Taking the above into account, the Team recommended that the type of the PV modules for this project shall be selected at tender stage due to the following reasons:

- Costs described in the basic design and the above are only reference which the Team estimated based on collected information from manufacturers with the Team's expectations. Thus the costs may not be reflecting international market price at the tender stage. Some Tenderer may propose political/business strategic price for expanding and/or penetrating this business field, thus proposed cost might be lower than the Team's expectation.
- Accordingly, the Team would recommend that cost impact item shall be considered as part of the tender requirements. The rough ideas are as follows:
  - ✓ Proposed cost shall be evaluated by generation cost (=project cost / expected total generated power (kWh) for whole life period).
  - ✓ Expected total generated power shall be considered deterioration of PV modules which shall be verified some time later after the taking over (whether at the end of warranty period or at the end of maintenance period in case maintenance contract is included under this project).
- Since MLTF and CIS have been started of its operation within this decade and they are gradually expanding their share in the international market, thus the possibility of further technical development is expected. Then it is expected that the efficiency of the modules will be increased and the cost of the modules will be decreased. Accordingly, it is better to decide selecting of the modules at the time of the tender stage. Further, based on spectrum sensitivity, MLTF and CIS types are suitable for low latitude countries including Egypt thus these types can be understood as more efficient type than Poly Crystalline type at this moment as shown in Table 3-4-1.
- Since this is the first large scale PV power plant in Egypt, proper operation and maintenance to the PV power plant is required in line with technology transfer from manufacturers to NREA staffs. Thus, PV type shall be selected taking into account operation and maintenance scheme to be proposed from tenderers at the tender stage as well as considering tenderers' financial situation for sustainable operation for more than 20 years.
- Further, as technical verification of proposed PV modules from tenderers, the followings shall be confirmed at the tender stage:
  - ✓ Past performance record: 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.
  - ✓ Annual production capacity for the proposed PV module.

- ✓ Deterioration of the proposed PV module with its certificate or record.
- ✓ Certificate for the proposed PV module from International Accredited Organization.
- ✓ Warranty to the proposed PV module from the tenderer.
- ✓ Training menu of operation and maintenance.
- ✓ Recycling system for the proposed PV module after life type or when it is broken.

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 in this study, the Team assumed that 20 MW for Multi-Layer Thin Film (MLTF) type is suitable for PV modules to be used under this project as 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.

Reason for selecting this type of module is as follows:

- ✓ Although MLTF type requires the largest layout space for 20MW PV module installation because of its low conversion efficiency. Thus, MLTF can be proper reference for land requirements for PV module installation.
- ✓ Project cost for MLTF type is the least one among 3 types thus MLTF can be target of the expected cost.
- ✓ MLTF has largest annual energy production among 3 types thus MLTF's annual energy production can be target for proposed annual energy production from tenderers.
- ✓ There are several manufacturers to produce MLTF type thus competition can be made.

Energy production of MLTF type is shown as follows:

Table 3-4-2 Energy production for MLTF type for 20 years (MWh)

year	MLTF 20MW [MWh/year]
1	35,910
2	35,371
3	34,832
4	34,293
5	33,754
6	33,215
7	32,676
8	32,137
9	31,598
10	31,059
11	31,059
12	31,059
13	31,059
14	31,059
15	31,059
16	31,059
17	31,059
18	31,059
19	31,059
20	31,059
Total	645,435
Average	32,272

Site layout of the PV module arrangement is shown in Fig.3-4-1, and single line diagram is shown in Fig.3-4-2.

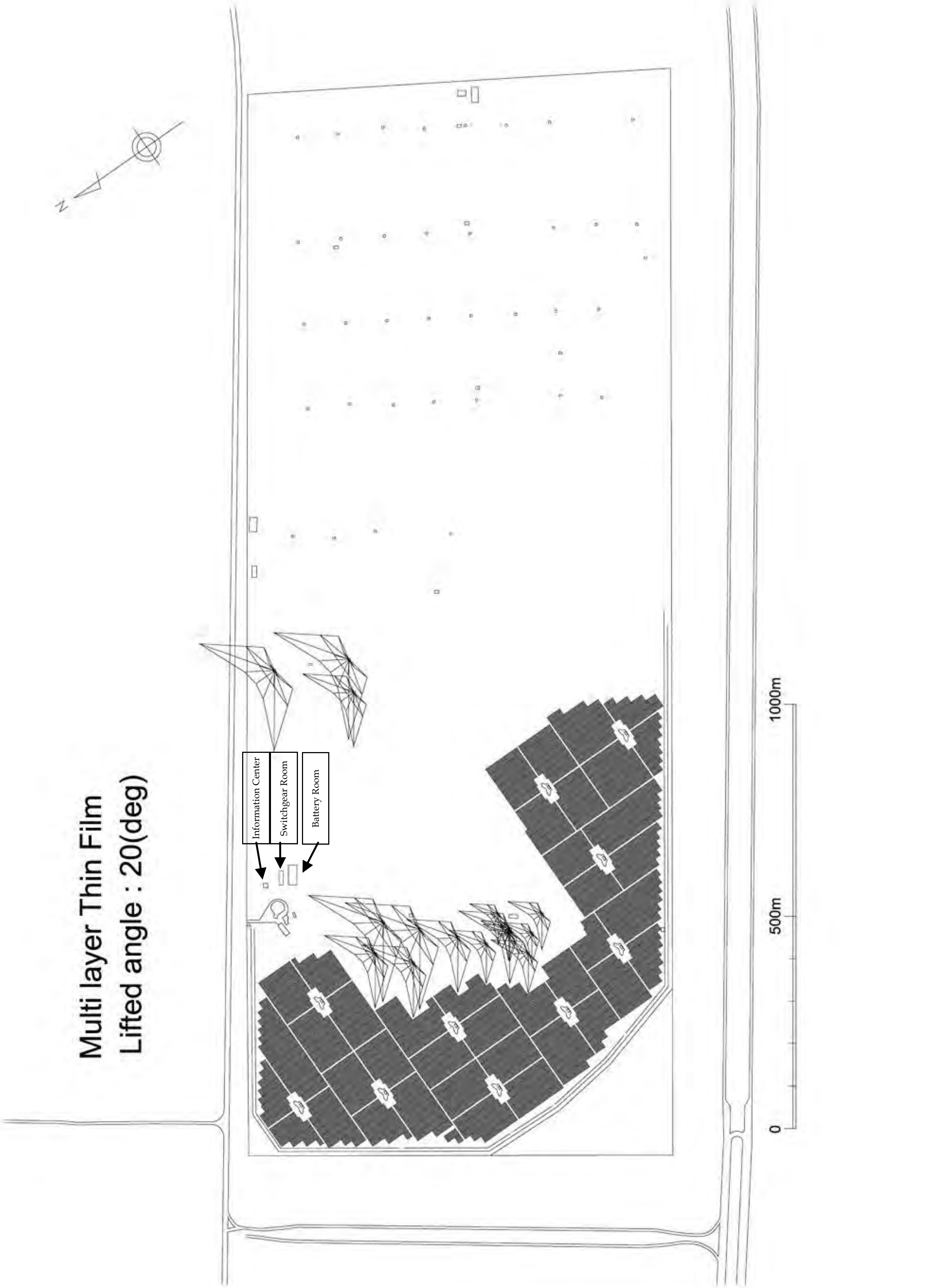


Fig.3-4-1 Layout design for the PV module

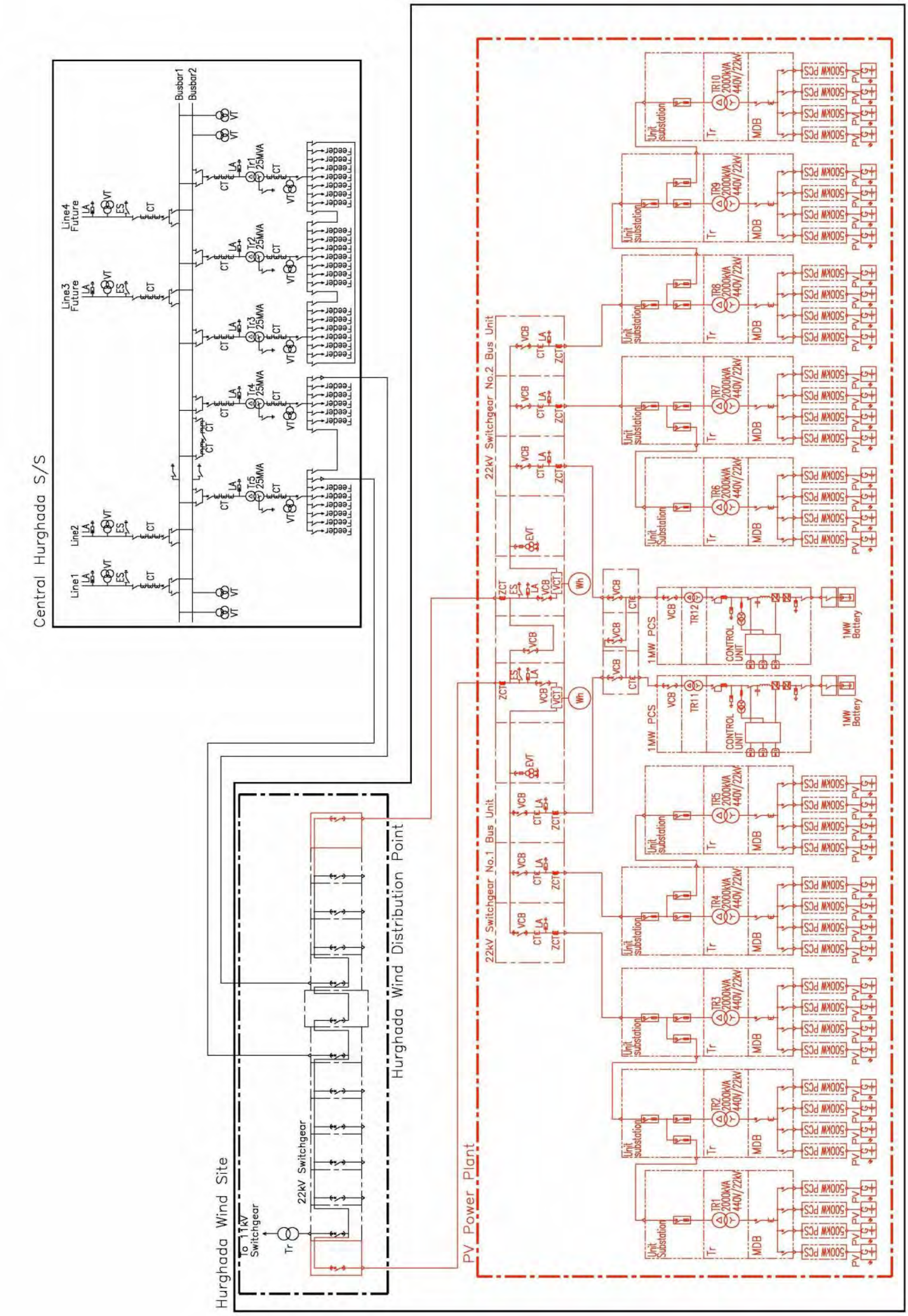


Fig.3-4-2 Single line diagram for the PV power plant

Clause 2 Scope to be included other than basic design items

In addition to the items considered in the basic design, the followings are taken into account as part of the project scope:

- Information center (exhibition house) for the PV power plant to be constructed within the project with the following facilities:
  - ✓ Exhibit overall condition/picture of the project
  - ✓ Showing current generated power with accumulation
  - ✓ Related solar energy as general information to visitor by using sophisticated 3 D and/or 2D screens
  - ✓ Outline of Egyptian renewable energy (potential, development plan and developed sites)

  Since the detailed requirements and conditions are not decided yet, details shall be decided during the detailed design stage. Then the rough image of this information center (layout and interior) is described in Appendix 3-4-2.
- Operation & Maintenance to be performed by contractor under this project with the followings conditions:
  - ✓ Operation & maintenance (O&M) of this project for 2 years after taking over shall be carried out by the Contractor.
  - ✓ Any consumables and spare parts for the O&M shall be proposed by the Contractor and such cost shall be covered by the project cost.
  - ✓ Annual generated power shall be evaluated every year after starting the operation.
  - ✓ At the end of O&M period, total generated power considering deterioration of the PV modules shall be verified.

Clause 3 Summary of Project Scope

As described in the previous section (Section 3 Basic Design) as well as the above, project scope to be performed by the Contractor under this project is summarized as follows:

1) General

The Contract for this project is one package for 20MW Photovoltaic (PV) power plant construction project in Hurghada.

The Contractor shall carry out necessary investigations, construction designs, manufacturing, any factory tests, delivery to the site, installation works including civil works, any site tests, commissioning of the power plant and warranty services.

2) Materials, equipment to be procured under this project

The Contractor shall procure the followings:

- 20 MW PV modules with accessories such as terminal boxes, DC power cables, optic fiber cables, supporting structures for PV modules, etc.
- Electrical equipment for PV power plant including Inverters (500kVA * 40 units), step-up transformers (400V/22kV, 2MVA, 10 units), switchgears, cables, etc.
- Electrical equipment for existing Distribution Point and Central Hurghada Substation including MV switchgears, bus- couplers, terminal units, energy meters etc.
- High performance battery (2MW, 12MWh)
- Monitoring systems including server, communication interface, UPS, etc.
- Exhibition system including sophisticated 3 D and/or 2D screens, etc.

3) Site works to be done under this project

The Contractor shall carry out the followings:

- PV modules installation with cable connections
- Electrical equipment installation with cable connections
- High performance battery installation and connection to electrical equipment
- Civil works including ground leveling, construction of PV foundations, fencing, service road, drainage, construction of houses for electrical equipment and information center, renovation of existing DP (Distribution Point), etc.
- Earthing

4) Services to be performed during warranty period

The Contractor shall carry out the followings:

- Power plant performance verification
- Verification of deterioration ratio of the installed PV modules
- End of warranty inspections

5) Services to be performed during O&M period

The Contractor shall carry out the followings:

- Operation of the PV power plant including monitoring and recording of the performance, any faults, 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

The Contractor shall be selected in accordance with Guidelines for Procurement under Japanese ODA Loans with its related standard or sample documents.

6) Consulting Services

Services to be performed by the Consultant are summarized in Terms of Reference (ToR) in Appendix 3-4-3.

The Consultant shall be selected in accordance with Guidelines for the Employment of Consultants under Japanese ODA Loans with its related standard or sample documents.

Section 5 Estimation of Total Project Cost

1) Basic philosophy for estimation of the cost

The basic philosophy for estimation of the project cost done by the Team is as follows:

- Costs for PV modules, inverters and other necessary equipment and works are estimated in future (in 2015) situation which is estimated based on interviews with manufacturers including the Team's expectation.
- Warranty period is assumed to be 2 years.
- Cost for O&M is assumed for 2 years period.
- Cost for equipment and materials, in case those to be procured from abroad to Egypt, such cost is estimated by CIF (Cost Insurance and Freight) basis. In case those to be procured domestically in Egypt, such cost is estimated based on site delivery basis.
- Cost for inland transportation is also considered.
- Cost of site works is estimated based on the required man-power referring to similar projects in other countries.
- Spare parts for each equipment are considered.
- Price escalation, physical contingency shall be considered under JICA's rule.
- Taxes and custom duties (for renewable energy project, actually custom duties are 0%) are considered.
- Cost of consulting services is considered.
- Cost is divided into two parts; one for eligible portion which can be financed by JICA and the other for non- eligible portion which NREA will finance.
- Annual fund requirement is prepared based on JICA's requirements.

2) Estimated Cost

The Team estimated the project cost for reference and it is summarized as follows:

- Total project cost estimated is 112.36Million US$.
- Summary of project cost is shown in Table 3-5-1, and cost break down of equipment is shown in Appendix 3-5-1 and 3-5-2.
- Annual fund requirement (for US dollar basis) for the project is shown in Table 3-5-2 and its JP Yen basis is shown in Appendix 3-5-3.
- Cost break down for consulting service is shown in Appendix 3-5-4 and Man-Months allocation for the consultant is shown in Appendix 3-5-5.

Project cost is estimated as approx. 112 million USD as mentioned above 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 (Overseas Development Assistance) 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 including the local currency portion (eligible portion) except Owner's administration cost.

Table 3-5-1 Project Cost for photovoltaic power plant with high performance battery

Category			Foreign Currency (Million USD) (Million JP Yen)	Local Currency (Million USD) (Million LE)	Total (Million USD)
A	**Cost for Sub-Projects**				
	1	Construction of 20MW PV Power Plant including necessary equipment incl. 2MW battery	46.68 (3,847.71)	18.61 (112.24)	65.29
			(0.00)	(.)	0.00
			(0.00)	(.)	0.00
			(0.00)	(.)	0.00
Total of A. Cost for Sub-Projects			46.68 (3,847.71)	18.61 (112)	65.29
B	**Contingency**				
	1	Price Escalation (2.1% for F/C, 8.8% for L/C)	3.79 (312.41)	6.98 (42.08)	10.77
	2	Physical Contingency (5%)	2.52 (208.05)	1.28 (7.71)	3.80
Total of B. Contingency			6.31 (520.46)	8.26 (49.8)	14.57
C	Consulting Services		11.69 (963.92)	2.96 (17.85)	14.65
	1	Price Escalation (2.1% for F/C, 8.8% for L/C)	0.68 (56.30)	0.78 (4.73)	1.47
	2	Physical Contingency (5%)	0.62 (50.94)	0.19 (1.13)	0.81
Total of C.			12.99 (1,071.16)	3.93 (23.71)	16.93
D	Interest During Construction and Commitment Charge		1.80 (148.70)	0.00 (.)	1.80
E	Total of the Eligible Portion (A+B+C+D)		67.79 (5,588.04)	30.80 (185.74)	98.59
F	Owner's Administration cost (5% of (A+B))		0 (0.00)	3.99 (24.08)	3.99
G	Land Acquisition & Compensation		0.00 (0.00)	0.00 (.)	0.00
H	Contingency		0.00 (0.00)	1.79 (10.76)	1.79
	1	Price Escalation (2.1% for F/C, 8.8% for L/C)	(0.00)	1.51 (9.11)	1.51
	2	Physical Contingency (5%)	(0.00)	0.28 (1.66)	0.28
I	Taxes (sales: 10% for all and custom duties: 0% for foreign materials)		(0.00)	7.99 (48.16)	
J	Grand Total		67.79 (5,588.04)	44.57 (268.75)	112.36

Note:

- All the above cost are reference for budget purpose only and may be changed as per discussion with JICA.
- exchange rate:
  - USD - JP Yen: Exchange Rate April 2012 provided by JICA 82.43
  - USD - LE: Exchange Rate April 2012 provided by JICA 6.03

Table 3-5-2 Annual fund requirement (US Dollar basis)

Annual Fund Requirement

(Million US$)

No.	Item	Total			2013			2014			2015			2016			2017			2018		
		F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
	A. ELIGIBLE PORTION																					
1	Construction of 20MW PV Power Plant including necessary equipment incl. 2MW battery	46.678	18.614	65.292							18.671	7.445	26.116	23.339	9.307	32.646	2.334	0.931	3.265	2.334	0.931	3.265
2																						
3																						
4																						
5	Total (1-4)	46.678	18.614	65.292							18.671	7.445	26.116	23.339	9.307	32.646	2.334	0.931	3.265	2.334	0.931	3.265
6	Price Escalation	3.790	6.979	10.769							1.201	2.144	3.345	2.023	3.734	5.757	0.256	0.488	0.744	0.310	0.613	0.923
7	Physical Contingency	2.524	1.279	3.803							0.994	0.479	1.473	1.268	0.652	1.920	0.130	0.071	0.201	0.132	0.077	0.209
8	Total (5+6+7)	52.992	26.872	79.864							20.866	10.068	30.934	26.630	13.693	40.323	2.720	1.490	4.210	2.776	1.621	4.397
9	Consulting Service	11.693	2.960	14.653	2.339	0.592	2.931	2.923	0.740	3.663	2.923	0.740	3.663	2.923	0.740	3.663	0.351	0.089	0.440	0.234	0.059	0.293
10	Price Escalation	0.683	0.784	1.467	0.049	0.052	0.101	0.124	0.136	0.260	0.188	0.213	0.401	0.253	0.297	0.550	0.038	0.047	0.085	0.031	0.039	0.070
11	Physical Contingency	0.618	0.188	0.806	0.119	0.032	0.151	0.152	0.044	0.196	0.156	0.048	0.204	0.159	0.052	0.211	0.019	0.007	0.026	0.013	0.005	0.018
12	Total (9+10+11)	12.994	3.932	16.926	2.507	0.676	3.183	3.199	0.920	4.119	3.267	1.001	4.268	3.335	1.089	4.424	0.408	0.143	0.551	0.278	0.103	0.381
13	**A. Total (8+12)**	65.986	30.804	96.790	2.507	0.676	3.183	3.199	0.920	4.119	24.133	11.069	35.202	29.965	14.782	44.747	3.128	1.633	4.761	3.054	1.724	4.778
	B. NON ELIGIBLE PORTION																					
14	Land acquisition & Compensation																					
15	Price Escalation																					
16	Physical Contingency																					
17	Total (14+15+16)																					
18	Administration cost		3.994	3.994								1.547	1.547		2.016	2.016		0.211	0.211		0.220	0.220
19	Price Escalation		1.510	1.510								0.445	0.445		0.809	0.809		0.111	0.111		0.145	0.145
20	Physical Contingency		0.275	0.275								0.100	0.100		0.141	0.141		0.016	0.016		0.018	0.018
21	Total (18+19+20)		5.779	5.779								2.092	2.092		2.966	2.966		0.338	0.338		0.383	0.383
22	VAT		2.687	2.687								1.007	1.007		1.369	1.369		0.149	0.149		0.162	0.162
23	CD		5.300	5.300								2.087	2.087		2.663	2.663		0.272	0.272		0.278	0.278
24	**B. Total (21+22+23)**		13.766	13.766								5.186	5.186		6.998	6.998		0.759	0.759		0.823	0.823
25	**Total (A+B)**	65.986	44.570	110.556	2.507	0.676	3.183	3.199	0.920	4.119	24.133	16.255	40.388	29.965	21.780	51.745	3.128	2.392	5.520	3.054	2.547	5.601
26	**IDC**	1.400		1.400				0.016		0.016	0.173		0.173	0.368		0.368	0.410		0.410	0.433		0.433
27	Commitment Charge	0.404		0.404	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067
28	**Grand TOTAL (25+26+27)**	67.790	44.570	112.360	2.574	0.676	3.250	3.282	0.920	4.202	24.373	16.255	40.628	30.400	21.780	52.180	3.605	2.392	5.997	3.554	2.547	6.101
		67.788	44.570	112.358																		

Price Escalation (F/C) : 2.1 %
Price Escalation (L/C) : 8.8 %
Physical Contingency :(construction) 5.0 %
Physical Contingency (others) : 5.0 %
Exchange Rate : 1.0 = 1.0 Yen

Administration Cost= 5% of the Eligible portion
VAT= 10% of expenditure in local currency of the Eligible portion
CD= 10% of expenditure in foreign currency of the Eligible portion (incl. VAT)

Commitment Charge ratio= 0.1%
Duration of Disbursement= 6 year

Eligible ratio 87.4%
Financing rate (Foreign/Total) 60.3 %
Interest rate 0.650 %
Interest rate for Consul= 0.01%

	Item	Total			2013			2014			2015			2016			2017			2018		
	Actual Disbursement/Temporally allocation				2.507			3.199			24.133			29.965			3.128			3.054		
	Debt at the end of term				2.507			5.706			29.855			59.993			63.489			66.953		
	Interest during const							0.016000			0.173000			0.368000			0.410000			0.433000		

Financing rate =Grand Total F/C / Grand Total
Actual Disbursement = Total cost except for Interest during construction * Financing rate
Debt at the end of term = Actual Disbursement of same year + Debt at the end of last year + Interest during const of last year
Interest during const = Debt at the end of term * Interest rate

Section 6 Implementation Schedule of the Project

1) Basic idea for scheduling

Based on the following basic idea, the Team estimated the project schedule.

- The schedule covers the period from "Pledge to this project by Japanese Government" to end of warranty period.
- For comparison purpose, JICA's standard project procedure and STEP (Special Terms for Economic Partnership, described in Section 8 in this Chapter) procedure is described.
- In case of STEP, JICA may hire consultant for this project in order to facilitate and accelerate this project. The role and function of JICA's consultant is assumed as follows:
  - ✓ To carry out basic design in order to prepare technical specifications.
  - ✓ To prepare Tender Document for this project in accordance with JICA's standard (sample) documents in consultation with NREA and JICA.
- JICA's standard procedures and Team's past experiences are considered as follows:
  - ✓ Selection of Consultant is assumed to be taken about 12 months.
  - ✓ Selection of Contractor including Pre-Qualification (PQ), Tender Documents preparation, Tendering, Evaluations and negations are assumed to be taken about 23 months.
- In accordance with the Team's experience and knowledge, Project Implementation period is assumed to be taken about 19 months.
- Warranty period is assumed as 24 months. During the warranty period, verification of generated power from the PV power plant and verification of deterioration for installed PV module is planned, thus suitable length for the warranty period is required.
- JICA may request the executing agency to submit documents from time to time depending on the cost of each package for JICA's review and concurrence. Such period shall be considered.

2) Project Schedule

The project schedule for comparison between STEP and standard procedure is shown in Table 3-6-1 and detailed schedule for project implementation is shown in Table 3-6-2.

Total project period estimated by the above is 83 months for standard procedure and 67 months for STEP starting from the selection of the consultant (same timing of signing of Exchange of Note) until the end of warranty period.

Table 3-6-1 Project Schedule for comparison (STEP vs. Standard Procedure)

Table 3-6-2 Detailed Project Implementation Schedule

Implementation Schedule

No.	Item	Duration	Schedule	Remarks
1	**Consulting service (Pre-Construction stage)**	**26months**		
1.1	Selection of DD Consultant to be done by JICA	**4 months**		
	1) incl. Public anouncement, Tendering upto contract sign.	4 months		
1.2	Pre-Construction Stage (Phase-1)	**8 months**		
	1) incl. Public Announcement, Tendering upto contract sign.	6 months		
	2) JICA's concurrence	2 months		
1.3	Selection of Consultant to be done by NREA	**12 months**		
	incl. Shortlisting, RFP, Public Announcement, Tendering upto contract sign.	12 months		
1.4	Pre-Construction stage (Phase-2)	**3 months**		
	1) issuing Tender Docs (3 envelopes method: PQ, Technical and Financial)	3 months		
	2) Tender Evaluations (PQ, Technical & Financial)	4 months		
	3) JICA's concurrence	1 month		
	4) Contract Negotiations	2 months		
	5) JICA's concurrence to Contract Document	1 month		
	6) L/C opening	1 month		
2	**Project Implementation Stage (Construction Stage)**	**20 months**		
2.1	Commencement date	–		
2.2	Detail Design incl. site investigation and approval	**4 months**		
2.3	Civil Works incl. land leveling, fence, road, foundation, etc.	**14 months**		
2.4	PV module	**14 months**		
	1) Manufacturing and shipping to the site	13 months		
	2) Installation	12 months		
2.5	Cable wiring and connection	**11 months**		
	1) LV cable; PV to Invertor	11 months		
	2) MV cable; TR to SWG to DP	8 months		
2.6	Inverters	**9 months**		
	1) Manufacturing and shipping to the site	6 months		
	2) Installation	3 months		
2.7	MV Transformer	**6 months**		
	1) Manufacturing and shipping to the site	5 months		
	2) Installation	1 month		
2.8	MV Switchgear	**7 months**		
	1) Manufacturing and shipping to the site	5 months		
	2) Installation	2 months		
2.9	Existing Distribution Point and Substation Modifications	**4 months**		
2.10	Testing & Commissioning	**2 months**		
2.11	Issuing Taking Over Certificate			
2.12	Warranty Period	**24 months**	for 2 years	
2.13	Issuing Final Acceptance Certificate			

note 1) Issuing of TOAC will be varied depending upon Contractor's responsibilities.
2) TOAC: Taking Over and Acceptance Certificate
3) FAC: Final Acceptance Certificate

Section 7 Procurement (including packaging)

1) Basic Philosophy of Procurement under Japanese ODA Loan

The Procurement under Japanese ODA Loans shall be made in accordance with "Guidelines for Procurement under Japanese ODA Loans, April 2012" with related Standard Documents (The standard documents became available since October 2012).

Several kinds of Standard/Sample Documents are available in JICA such as "WORKS: Procurements of Works", "PLANT: Procurement of Plant Design, Supply and Installation", "SMALL WORKS: Procurement of Small Works" and "GOODS: Procurement of Goods". Considering nature, complexity and other aspects of the project, the most suitable Standard/Sample Documents shall be selected and used for the procurement.

The Team would suggest using the Sample Document "PLANT" to this project taking into account the followings (This might be changed after issuing the standard documents related to "PLANT"):

- Scope of work to be performed by the Contractor includes design, procurement, supply, installation, etc.,
- Considering equipment, tools and materials (products) to be procured under this project, majority of the products will be imported from outside of Egypt. Then International Competitive Bidding (ICB) is recommended,
- Essentially lump sum fixed price and payment is applied.

However, General Conditions of the Sample Document "PLANT" is based on model form of International Contract for Process Plant Construction published by the Engineering Advancement Association of Japan (ENAA) which is relatively Contractors' side, then the Team would suggest using "Conditions of Contract for Plant and Design Build" of FIDIC (Federation International des Ingenieurs-Conseils) or updated version of FIDIC.

2) Approach of Deciding Packaging

The Team would recommend that this project shall be fixed lump-sum basis under one contract with international competitive bidding due to the following reasons:

- Numbers and required specifications for main component of this project such as PV modules and inverters are regulated and designated by the Bidding Documents or Proposals from Bidders, then essentially no numbers adjustment is required during implementation stage after contract signature.

- Main components are expected to be imported from outside of Egypt since Egyptian manufacturers do not have capabilities for manufacturing of large-scale PV productions.
- Comparing with the procured materials, civil works and site installation works are cost wisely very small, then if the contract is divided into several packages, the bid management will require a lot of effort.
- Since this project is the first large scale PV project in Egypt:
  - ✓ it is better to ease bid management since NREA has no experience of large scale PV power plant project,
  - ✓ it is better to identify single responsibility from the beginning since one of the operation indicators of this project is "AC generated power from PV" which can be used as an indicator to decide whether services and works are implemented properly or not.

Section 8 Applicability of STEP

1) Conditions of Japanese ODA Loan

This condition is just for reference.

Every year this condition is reviewed and amended based on Japanese financial situations.

There are several options of Japanese ODA Loan. The following conditions are standard cases:[1]

1) Normal Japanese ODA Loan for electricity power project in Egypt
- ✓ Interest: 1.4 %
- ✓ Repayment period: 25 years
- ✓ Grace period: 7 years
- ✓ Procurement conditions: untied

2) CCL[2] for Egypt
- ✓ Interest: 0.30 %
- ✓ Return period: 40 years
- ✓ Grace period: 10 years
- ✓ Procurement conditions: untied

3) STEP for Egypt
- ✓ Interest: 0.20 %
- ✓ Return period: 40 years
- ✓ Grace period: 10 years
- ✓ Procurement conditions: tied

4) STEP under CCL for Egypt
- ✓ Interest: 0.10 %
- ✓ Return period: 40 years
- ✓ Grace period: 10 years
- ✓ Procurement conditions: tied

2) Outline of STEP

STEP is the abbreviation of Special Terms for Economic Partnership which has been created the Japanese technology to transfer to the developing countries in 2002.

The outline including the conditions of STEP is as follows:

- ■ Targeted countries: countries for ODA and countries that can apply to untied loan under OECD rule; Egypt is one of the targeted countries.

[1] This condition is effective from April 1, 2012. Latest condition can be referred to in the following website. http://www.jica.go.jp/english/operations/schemes/oda_loans/standard/index.html

[2] In 2008, Japan established a new financial mechanism, Cool Earth Partnership, on the scale of US$ 10 billion. Through this, Japan would cooperate actively with developing countries' efforts to reduce emissions and mitigate adverse impacts as a result of climate change. This has been changed to Climate Change Japanese ODA Loan (CCL) since the reshuffle of the Japanese government.

- General objectives: Technology and/or equipment of Japanese manufacturer or contractor can contribute to the project implementation.
- Procurement condition: Main contractor shall be Japanese company. Joint Venture with Japanese company can be accepted subject to the condition that the Japanese company is the leading company.
- Financing ratio:100% of the total project cost can be covered by Japanese ODA Yen loan
- Rule of origin: 30% of the total contract amount financed by Japanese ODA loan shall be Japanese materials/services.
- Auditing for the procurement might take place by a third party.

3) Situation of Japanese manufacturers

Cost for this project is mainly divided into the following four items (very rough comparison):

- Photovoltaic modules: 50%
- Electrical equipment including inverter system, LV/MV cables, optic fiber cables, transformers and switchgears, etc.: 10%
- Battery with necessary facilities: 15%
- Civil and architecture works and site installation with necessary tests, etc.: 25%

Taking into account the conditions of STEP (not less than 30% of total contract amount financed by Japanese ODA loan (STEP) must be accounted for goods from Japan or services provided by Japanese firms), the Team investigated the following categories of Japanese manufacturers:

- PV module manufacturers
- Inverter manufacturers
- Battery manufacturers

A) PV module manufacturers

As described before, the following three types of PV modules are assumed to be adopted for this Project:

- Poly Crystalline type
- MLTF type
- CIS type

According to the Team's investigation, the following Japanese manufacturers listed below are capable of producing the above mentioned types of PV module.

- KYOCERA Corporation : Poly Crystalline type
- SHARP Corporation : Poly Crystalline type and MLTF type

- Solar Frontier : CIS type
- Mitsubishi electric: Poly Crystalline type
- Kaneka : MLTF type
- Panasonic : Crystalline tandem of mono-crystalline and amorphous (HIT[3]) , Poly Crystalline type

The features/characteristics of each PV module manufacturer and its interest to this Project are as follows:

a) KYOCERA Corporation

- KYOCERA is one of the leading and pioneer PV manufacturers in the world. KYOCERA has started PV module development in 1975 and currently its annual production capability reaches to 1GW in the worldwide level in 2012.
- Its factories are located not only in Japan but also in China, USA, and Czech.
- The largest supply record to large scale PV power plant is 32MW in Spain and 242MW in total in Thailand.
- KYOCERA expressed its strong interest to participate in this project.
- Its product has taken certification of "long-term sequential test" from the world's famous photovoltaic quality certification organization named "TÜV Rheinland". This test is more strict than IEC (International Electrotechnical Commission) standard test.
- KYOCERA will guarantee the followings:
  - ✓ Performance Warrantee:
    - o 1.0% per year of deterioration ratio (as actual measurement for 25 years, 9.6% in total is measured)

b) SHARP Corporation

- SHARP is one of the leading and pioneer PV manufacturers in the world. SHARP has started PV module development in 1959 and currently its annual production capability reaches to 1 GW in the worldwide level in 2012. Then it became the top supplier in Japan (accumulated production record reached to 5.5GW).
- SHARP can produce many kinds of PV modules such as mono-crystalline type, poly crystalline type and MLTF type.
- SHARP is not only PV module supplier but also EPC (Engineering, Procurement and Construction) contractor. As EPC contractor, SHARP implemented the world largest 73MW PV power plant in Thailand and 58MW power plant in California, USA.

[3] "HIT" is a trademark of Panasonic Group. The name "HIT" comes from "Heterojunction with intrinsic Thin-layer" which is an original technology of Panasonic Group..

- SHARP has granted accreditation of JIS Q 8901 which is kind of certificate for long term reliability of PV modules and its supporting organization on Nov. 2012.
- SHARP expressed its strong interest to participate in this project.
- SHARP is under developing supply and maintenance network in the Middle East and its business center is located in KSA (Kingdom of Saudi Arabia).
- SHARP will guarantee the followings for MLTF type module:
  - ✓ Performance Warrantee:
    - o For first 10 years : 1.5% per year of deterioration ratio
    - o For 11-20 years: more than 84.5% of performance ratio
  - ✓ Deterioration ratio: 0.5%/year (during self-test for 5 years, still continuing)
- SHARP's MLTF has passed reliability test (IEC-61646 and 61215: 1,000 hours AAT: Accelerating Aging Test). In addition, material test after AAT for around 40 years equivalent have passed in successfully.

c) Solar Frontier

- Solar Frontier was independent from Showa-Shell Oil Company and established in 2006 as Showa-Shell Solar Company, then renamed as Solar Frontier in 2010. One of the major stockholders of Showa-Shell Oil Company is Saudi Aramco.
- Solar Frontier developed the 3rd factory and its total annual production capability of PV module became 1 GW in 2011. Then Solar Frontier became the world largest CIS type PV module supplier.
- Their major supply experiences are as follows:
  - ✓ 13.2MW supplied to NRG Solar, USA
  - ✓ 10MW PV power plant in Northern Park at Saudi Arabia
- Solar Frontier has granted accreditation of JIS Q 8901 which is kind of certificate for long term reliability of PV modules and its supporting organization on Aug. 2012.
- Solar Frontier expressed its strong interest to participate in this project.
- Solar Frontier established Saudi Arabia branch office to supply its products to Middle East and African area.
- Solar Frontier guaranteed the followings for its CIS module:
  - ✓ Performance Warrantee:
    - o For first 10 years : more than 90% of performance ratio
    - o For 11 – 25 years: more than 80% of performance ratio
    - o CIS has "Light Soaking Effects" which can generate 5-10% more power than nominal capacity. Then no decrease against nominal capacity was recorded until this moment (for 7 year operation).
  - ✓ Deterioration ratio: 0.5%/year (during self-test for 7 years ,still continuing)

- ✓ Reliability Test: Test of IEC-61646 has passed successfully (1,000 hours AAT: Accelerating Aging Test). In addition 3,000 hours (more than 16 years equivalent) of AAT as self-test have successfully passed.
- ✓ PV module defective ratio at site : 0% in 2011
- ✓ PV module defective ration during installation: 0.008% (3 pieces/ 5.5MW)

d) Mitsubishi Electric

- This company has no interest in the international market at this moment.

e) Kaneka

- Kaneka started R&D for PV technology since 30 years ago.
- Kaneka has two major factories in Japan and Belgium. Japanese factory located in Toyooka has started production since 1999 and its annual production capacity reached 150MW in 2010. Kaneka is planning to expand its production capability to 1GW in 2015.
- Kaneka's PV module is kind of MLTF.
- Kaneka has interest to participate in this project.
- Biggest supply record is 4MW in Spain, 2MW in Germany.

f) Panasonic

- This company has no interest in the international market at this moment.

B) Inverter manufacturers

The features/characteristic of Japanese Inverters manufacturers and those interested in to this Project are as follows:

a) Toshiba Corporation

- Toshiba and Mitsubishi Electric (MELCO) have jointly established a company for electric power equipment manufacturer named Toshiba Mitsubishi-Electric Industrial systems Corporation (TMEIC). Toshiba and MELCO transferred all technologies related to inverters and switchgear devices to TMEIC.
- According to Toshiba, if Toshiba is awarded to the contract of overseas' PV project, Toshiba will use TMEIC's inverter.
- In case of Egyptian project, as Toshiba group, the project will be handled normally through Toshiba Transmission Distribution Europe (TTDE) in Italy or Toshiba Transmission Distribution Gulf (TTDG) in Abu-Dhabi.
- TTDE has a lot of experiences of large scale PV power plant projects in Europe.
- TMEIC has 3 kinds/capacities of inverter such as 250kW, 500kW and 600kW type. These products are used not only for domestic users, but also for overseas

customers. TMEIC supplied lots of inverters to Italy (total capacity approx. 30MW) and USA.

- Features of Inverters produced by TMEIC are as follows:
  - ✓ High efficiency, compact design, and low cost due to recently developed converter circuit.
  - ✓ Standardization by configuration into separate DC input/Converter/AC output cabins to enable easy application as the core of the power plant and provide various options for localization.
  - ✓ Less depth for easy container installation.
  - ✓ According to the specifications for the inverter, 20% overload can be secured.
- Since 1985, Toshiba produced the inverters and have a lot of experiences for supply to throughout the world. According to Toshiba, the oldest inverter is operating more than 25 years without major problems.
- Toshiba expressed its interest to this project as the System Integrator (kind of total technical coordinator).

b) Fuji Electric

- Fuji Electric has several kinds of inverter from 50 - 600kW and 1,000kW.
- Features of Inverters produced by Fuji Electric are as follows:
  - ✓ Fuji Electric developed 3 level modules based on combination of new type of IGBT(Insulated Gate Bipolar Transistor) and existing type of IGBT, thus the product can achieve high efficiency based on reduction of power loss because of decreasing numbers of the required parts.
  - ✓ According to the test record, inverter of Fuji Electric made significant high efficient performance such as 98.5%（product for DC 600V）under Japanese regulation and 98.2% （product for DC 1,000V）under IEC regulation which are the world highest level of efficiency.
  - ✓ Inverter of Fuji Electric will be made of outdoor unit with substation equipment. Thus, switchgears, transformers and inverters can be installed in the same bases and those facilities can be considered as one unit. Therefore, cost of site installation can be reduced dramatically.
- Fuji Electric has supplied some substation equipment to Egypt.
- Fuji Electric expressed its interests in this project as a supplier.

c) Meidensha

- Meidensha has been producing the inverter for PV power plants since 1980's which implies that this company is one of the longest experienced companies in this field.
- Features of Inverters produced by Meidensha are as follows:

- ✓ Maximum capacity of inverter system for large scale PV is 250kW.
- ✓ Regulated DC voltage inside Meidensha's inverter is higher than that of other manufacturers and this will improve DC circuit loss.
- ✓ Meidensha has two kinds of inverter type such as "without transformer" type and "with transformer" type. These two types can be used to any type of PV modules. In case of MLTF type of module, it is recommended to use "with transformer" type inverter since MLTF module requires negative pole grounding.
- ✓ Meidensha's MPPT (Maximum Power Point Tracker) control method is more sophisticated and use advanced technology than other manufacturers' in scanning interval and control steps. Accordingly, the inverters can produce more output energy than those of other manufacturers'.
- ✓ The inverters use Japanese IGBT as switching devices. As Japanese IGBT's function, the inverters can secure reliable operation.
- ✓ Inverters of Meidensha have lightning arrester as standard equipment thus the inverters can be protected from lightning surge or voltage fluctuation. As a result, failures caused by over voltage to the inverter will rarely be occurred.

- ■ Meidensha can also supply battery inverters for all types of batteries, such as Nickel hydrogen, Lithium-ion, Lead acid, Sodium sulfur and capacitor.
- ■ Meidensha has supply record of PV inverters to the global market such as 40MW for South Korea, 1MW for China, 26MW for Bulgaria.
- ■ Meidensha has a branch office in Dubai, and Dubai office is taking responsibility for supplying its products to the Middle East Market.
- ■ Meidensha has developed its original training course for overseas' PV inverter customers. After taking this training course, trainees can implement periodical maintenance and simple repair works to the inverters.
- ■ Remote supervising service can be provided as an optional service with its inverters.
- ■ Meidensha expressed its interests in this project as a supplier.

C) Battery manufacturers

The features/characteristic of Japanese battery manufacturers and those interested in this Project are as follows:

a) NGK Insulators

- ■ NGK Insulators produces Sodium-sulfur (NAS) battery system as a one and only company in the world.
- ■ NAS battery can be applied to large scale battery system, i.e., more than 2MW.
- ■ Cost of the battery is relatively low, and life time of the battery is relatively long.

- A lot of NAS batteries have been installed in Japan, USA, Europe and UAE as large scale energy storage system.
- This company expressed its strong interest in this project as a supplier.

b) Shin-Kobe electric

- Shin-Kobe electric produces long life lead acid load leveling (LL) battery for energy storage purpose.
- The LL batteries have been used in large scale wind farms and PV power plants.
- The LL battery is easy to maintain, because this type of battery does not need refilling of electrolyte.
- Cost and life time of the LL battery is becoming competitive with/ more than NAS battery.
- This company expressed its strong interest in this project as a supplier.

c) Furukawa battery

- Furukawa battery developed new type of lead battery for PV power plant in April 2012.
- Its new product has few experiences, and its production capacity is not so large at this moment. However, production capacity is expected to increase in the coming few years.
- This company has experiences to supply its lead battery to KSA for communication system.
- Its parent company "Furukawa Electric" has a lot of branch offices in the world. So Furukawa battery can supply its products through its parent company's network. Furukawa Electric Europe which is located in London will be a window for projects in Egypt.
- This company expressed its strong interest in this project as a supplier.

d) GS-Yuasa battery

- Although GS-Yuasa battery has large capacity lead acid battery, this product is not suitable for this project due to the life time according to its explanation. So this company recommended using Lithium-ion battery for this project.
- Cost of the lithium ion battery is still expensive at this moment, but it is expected that the cost will reach a reasonable level in the near future.
- As a fact, this company supplied large scale lithium-ion battery system to the coal steam power plant in Chili recently as securing reserve margin of the power plant with capacity of the 20MW - 6.3MWh.

- This company has supplied batteries to the Middle-East region including Egypt. Annual turnover of the Middle-East region reaches approximately 1 million Euro.
- This company supplied its battery system to Egypt Telecom for communication system purpose in the past.
- Lithium Energy Japan company has been established as a lithium ion battery manufacturer jointly with Mitsubishi Corporation, Mitsubishi motor and GS-Yuasa. GS-Yuasa procures the lithium-ion battery from this company.
- This company expressed its interest in this project as a lithium-ion battery supplier.

4) Conclusion of STEP

The Team would conclude that STEP shall be applied to this project due to the following reasons:

- NREA expressed its interest in the STEP scheme taking into account attractive loan conditions, grant support from JICA, earlier realization of this project, etc.
- Japanese products such as PV modules, Inverters and batteries have become competitive in the international market recently.
- Japanese manufacturers expressed their intention to participate this project in different way such as contractor, system integrator, supplier, etc.
- Major Japanese trading company such as Mitsubishi, Mitsui, Sumitomo, Toyota-Tsusho, Marubeni and Sojitz expressed their interest in this project with the condition that STEP loan will be applied to this project.
- 30 % Japanese origin can be secured by supplying PV modules and other electrical equipment including batteries from Japan.

According to NREA, NREA has submitted official request for this project with STEP scheme to MOIC through MoEE.

5) Special Notes

The Team understood that one of the issues in OECD-DAC for approving a tied project is the commercial viability.

Though Chapter 8 described economic and financial analysis, the analysis is made based on prospected feed-in-tariff scheme to be introduced in the near future in Egypt, then a reverse calculation is treated to identify an acceptable level of feed-in-tariff from IRR which is approx. 4%.

If the energy production from PV power plant is sold by the currently applicable scheme in wind projects, i.e., energy production sales price is 17.0 pt/kWh with 2.0 pt/kWh (in 2011/12) for fuel incentive, the level of B (benefit) -C (cost) become minus and IRR also become minus. Then no commercial viability is granted if currently applicable scheme is adapted to this project.

Chapter 4: Training

Chapter 4 Training

Since this project is the first large scale PV power plant project in Egypt, necessary technology transfer from experienced countries and/or manufacturers is indispensable in order to implement proper project management and operation and maintenance. Japan has already established a lot of large scale PV power plants and Japanese manufacturers supplied huge numbers of PV modules to all over the world. Hence technology transfer from Japanese side to Egypt is reasonable idea under JICA's assistance.

The Team would propose two phases training to Egyptian officials in this regard; one is already carried out in the project formulation stage (this has been done) and the other is to be carried out in project implementation stage.

Section 1 Trainings carried out in the project formulation stage

The Team coordinated the training course performed in Japan in cooperation with JICA. Objective of the training and the schedule was as follows:

- Purpose and Objectives
  - ✓ To understand /learn Japanese ODA rules and procedures including STEP scheme
  - ✓ To grasp productivities and efficiencies of Japanese products related to PV power plant project
  - ✓ To understand methodology of design, construction, management, operation and maintenance for PV power plant projects in Japan
- Period of Training in Japan
  - ✓ June17, 2012 to June25, 2012 as shown in Table 4-1.

The findings from this training and comments to this training are as follows:

- ✓ NREA gained sufficient knowledge about JICA's procurement rules and guideline including the conditions of STEP in Japan.
- ✓ NREA was so impressed by the Japanese exhibition/information center located at one of the visited PV power plant. And NREA expressed its preference to introduce such exhibition/information center in Egypt under this project.
- ✓ NREA was impressed by the Japanese manufacturing process at which majority of the work is done by automation system.
- ✓ This kind of Japanese training is useful for both Egyptian side and Japanese side for facilitating the project smoothly since majority of Egyptian officials do not have the experience of mingling with Japanese culture and business mind. And this kind of

Japanese training is encouraging Egyptian officials to have interest in Japanese product and Japanese companies.

- ✓ Accordingly, JICA is recommended to make this kind of training to Egyptian side as much as possible. According to NREA, many of NREA's officials visit European countries many times.

Table 4-1 Schedule of Training in Japan under JICA Feasibility Study for PV power plant project

	Date		Main Activity	Note
1	17 June	Sun	Departure from Cairo	
2	18 June	Mon	Arrival in Japan	Stay in Tokyo
3	19 June	Tue	Site visit to PV plant in Yamanashi	Stay in Tokyo Moving by car
4	20 June	Wed	Site visit to PV plant in Osaka and PV module factory visit	Stay in Osaka Moving by train and car
5	21 June	Thu	NAS Battery Factory visit	Stay in Osaka Moving by train and car
6	22 June	Fri	PV module factory visit in Miyazaki	Stay in Fukuoka Moving by airplane
7	23 June	Sat	Site visit to PV plant in Ehime	Stay in Osaka Moving by airplane
8	24 June	Sun	Meeting with Yonden & leaving for Cairo	Stay in Osaka
9	25 June	Mon	Arrival to Cairo	

Section 2 Trainings to be carried out during project implementation stage

The main purpose of this training is transferring O&M (operation and maintenance) technology for PV power plant to Egyptian officials in order to secure sustainable operation of this project.

The training includes not only conducting lectures and hands-on trainings for basic knowledge of the introducing PV power plant but also creating the O&M Manual in cooperation with Japanese side and Egyptian side, and developing capability of total coordination for PV power plant by conducting advanced lectures on equipment design and its economic efficiency, etc. of the PV power plant.

In addition to the above, training for battery system should be included in the training course.

- Purpose and objectives
  - ✓ To obtain necessary technology related to operation and maintenance for PV power plant including battery in order to secure sustainable operation of the project

- ✓ To obtain capability for PV power plant development plan including design, management for future similar PV project

- Proposed Training Contents
  - ✓ Considering with above conditions, the content of this training is summarized in Table 4-2.

Table 4-2 Proposed Training Contents

Subjects		Contents
PV System	Basic Knowledge	Solar resource Outline for Measuring system of meteorological data Meteorological data collection Types of PV System and module Characteristics of Facilities Maintenance and Inspection, etc.
	Design	Estimation of Solar Radiation Calculation of shade length Electric Demand and System Capacity Selection of equipment Measures for Stable Output Measures for Lighting Surge Frame and foundation design, etc.
	Advanced Knowledge	Outline of electric power system Characteristic and Design of Grid-connected PV System Considered Items for Grid connection Energy loss estimation Method of Selecting the Optimum Electrification Standards and Certification for PV facilities, etc.
	Hands-on Training	I-V Characteristic Measuring of PV Module Performance Confirmation Test of Inverter Maintenance and Inspection Method of PV System, etc.
	O&M Manual	Discussion for Making Policy and Considered Items Group Making of O&M Manual Trouble-shooting, etc.
Battery	Basic Knowledge	Types of battery Characteristic of battery etc.
	Design	Calculation of appropriate capacity of battery Selection of proper type of battery Electric circuits design Countermeasure for fire, etc.
	Advanced Knowledge	Effect of battery Components and method of power conditioning system Safety operation method Disposal method
	Hands-on Training	Performance Confirmation Test of Power Conditioner Maintenance and Inspection Method of battery System, etc.
	O&M Manual	Discussion for Making Policy and Considered Items Group Making of O&M Manual Trouble-shooting, etc.
Follow-up		Confirmation of O&M Adjustment based on Confirmation Results Trouble-shooting, etc.

Source: created by the Study Team

- Training plan & Conducting Method

  This training is mainly composed of the following two categories:

  - ✓ Lectures from basic knowledge, design of the PV System to O&M Manual creation
  - ✓ Follow-up for confirming settlement of O&M skill based on O&M Manual

As for the schedule of this training, total schedule is composed of four training periods, and they will be carried out according to the progress of site work to enhance good settlement of the technical transfer.

In addition to the time span of each training period is basically two weeks, and the total schedule is two months.

As for training conduction method, total lecturers will be two persons (one lecturer will mainly conduct lectures, and the other one will support trainees) for all the trainees to take lectures evenly and efficiently. Moreover, lectures will confirm settlement of knowledge and skill by a confirmation test after each lecture, and they will support trainees with less understanding by conducting follow-up lectures, etc. so that every trainee can achieve certain level of understanding.

- Proposed Training Curriculum

Proposed training curriculum based on the aforementioned contents is shown in Table 4-3.

- Proposed Schedule for the Training
  - ✓ First Period: Basic Knowledge and Design for the PV System, battery
  - ✓ Second Period: Advanced Knowledge for the PV System, battery, grid connection and other electrical aspects

  The First and the Second period will be completed before introducing the PV System because acquirement of total knowledge from basic to advance of the PV System before the introduction can contribute to conducting hands-on training during the introduction efficiently and effectively.

  - ✓ Third Period: Hands-on Training & O&M Manual Preparation

  As for the Hands-on Training, lectures with actual facilities can contribute to acquiring knowledge more effectively since it makes it possible for trainees to be educated in the similar environment to the actual work. As for the O&M Manual, it will be conducted between the beginning of facility introduction and the actual start of its operation as it should be completed before it starts operating.

✓ Fourth Period: Follow-up

The fourth training period will be conducted within four months after starting the operation of the PV System including starting the operation of the battery; it is because the main purpose of this period is to confirm if the Egyptians can operate and maintain the system properly by themselves.

Table 4-3 Program of the training

Item		week	Sun	Mon	Tue	Wed	Thu
Basic Knowledge	1st period	1	Solar resource Measuring system	Type of PV Type of Battery	Data collection Selection of battery	Characteristic of facility Characteristic of battery	Maintenance and inspection
Desgin		2	Estimation of radiation Calculation shade	Electric demand capacity of battery	Selection of equipment	Measures for issue of PV and battery	Frame and foundation
Advanced Knowledge	2nd period	3	Outline of power system	Grid-connected PV system	Effect of battery	Items for grid connection	Components for Inverter
		4	Electric circuit	Loss calculation	Safety operation method of battery	Disposal method of battery	Standards and certification for PV
Hands- on Training	3rd period	5	IV measuring for PV	Performance confirmation of PV	Performance confirmation of battery	Maintenance for PV	Maintenance for battery
O&M Manual		6	Discussion for making policy of O&M manual for PV	Ditto	Groupwork for O&M manual for PV	Ditto	Ditto
		7	Discussion for making policy of O&M manual for battery	Ditto	Groupwork for O&M manual for battery	Ditto	Ditto
Follow-up	4th period	8	Confirmation of O&M	Ditto	Revise of O&M manual	Ditto	Ditto

Source: created by the Study Team

Chapter 5: Organization for Implementation and O&M

Chapter 5 Organization for Implementation and O&M

Section 1 NREA's Organization for Implementation

Existing organization of NREA is shown in Fig. 5-1-1.

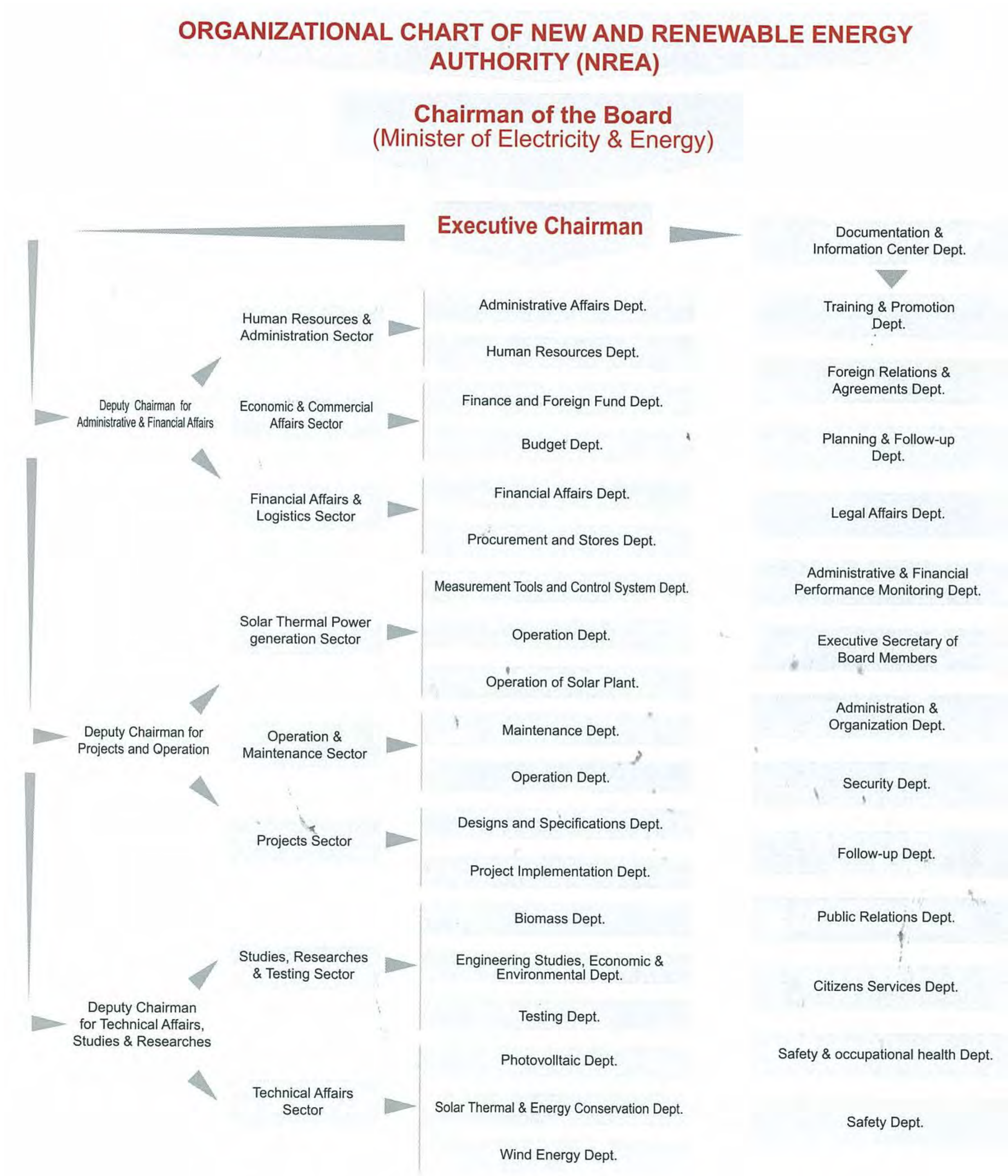


Fig.5-1-1 Existing organization of NREA

According to NREA, development of PV power plant is implemented by Photovoltaic Department of Technical Affairs Sector with full responsibility. Also NREA has explained that the development of this project will be in cooperation with Photovoltaic Department and Project Implementation Department under Projects Sector.

According to NREA, planned organization to this project stage by stage is shown in Table 5-1-1.

Table5-1-1 NREA's organization for this project

Stage	Department	Chief Person
Selecting consultant	(Leading Organization) Technical affairs sector, photovoltaic Dept.	Head of photovoltaic department
Conceptual design and preparation of technical specifications	(Leading Organization) Technical affairs sector, photovoltaic Dept. (Supporting Organization) Project sector, designs and specifications Dept.	Consultant +Head of photovoltaic department
Tender documents preparation	(Leading Organization) Technical affairs sector, photovoltaic Dept. (Supporting Organization) Project sector, designs and specifications Dept.	Consultant +Head of photovoltaic department
Tendering and receipt of proposals	(Leading Organization) Financial affairs and Logistics sector, Procurement and stores Dep. (Supporting Organization) Technical affairs sector, photovoltaic Dept.	Head of photovoltaic department
Evaluation and contracting	(Leading Organization) Technical affairs sector, photovoltaic Dept. (Supporting Organization) Financial affairs and Logistics sector, Procurement and stores Dep. Legal Affairs Dept.	Consultant +Head of photovoltaic department
Implementation	(Leading Organization) Project sector, Project Implementation Dept. (Supporting Organization) Financial affairs and Logistics sector, Procurement and stores Dep. Technical affairs sector, photovoltaic Dept.	Consultant +Head of Project Implementation Dept.
Operation and maintenance	Operation and Maintenance sector, Maintenance Dept. and Operation Dept.	Director of Operation and Maintenance for PV

Section 2 NREA's Organization for O&M

1) Operation and Maintenance

The optimum operation and maintenance structure (referred to hereinafter as O&M structure) is necessary for the healthy and sustainable operation of power plants.

Specifically, it is necessary to secure technical staff, working staff and managers to control O&M.

Additionally, it is necessary to consider the following items in order to consider the necessary number of the staff.

- ✓ What are the countermeasures in the case of accidents occurring not only at daytime but also at night time
- ✓ Which kind of special technical works required for outsourcing
- ✓ How technicians and engineers are trained for sustainable O&M structure

2) O&M Structure

NREA is planning to develop the 20MW PV power plant O&M structure as shown in Fig. 5-2-1.

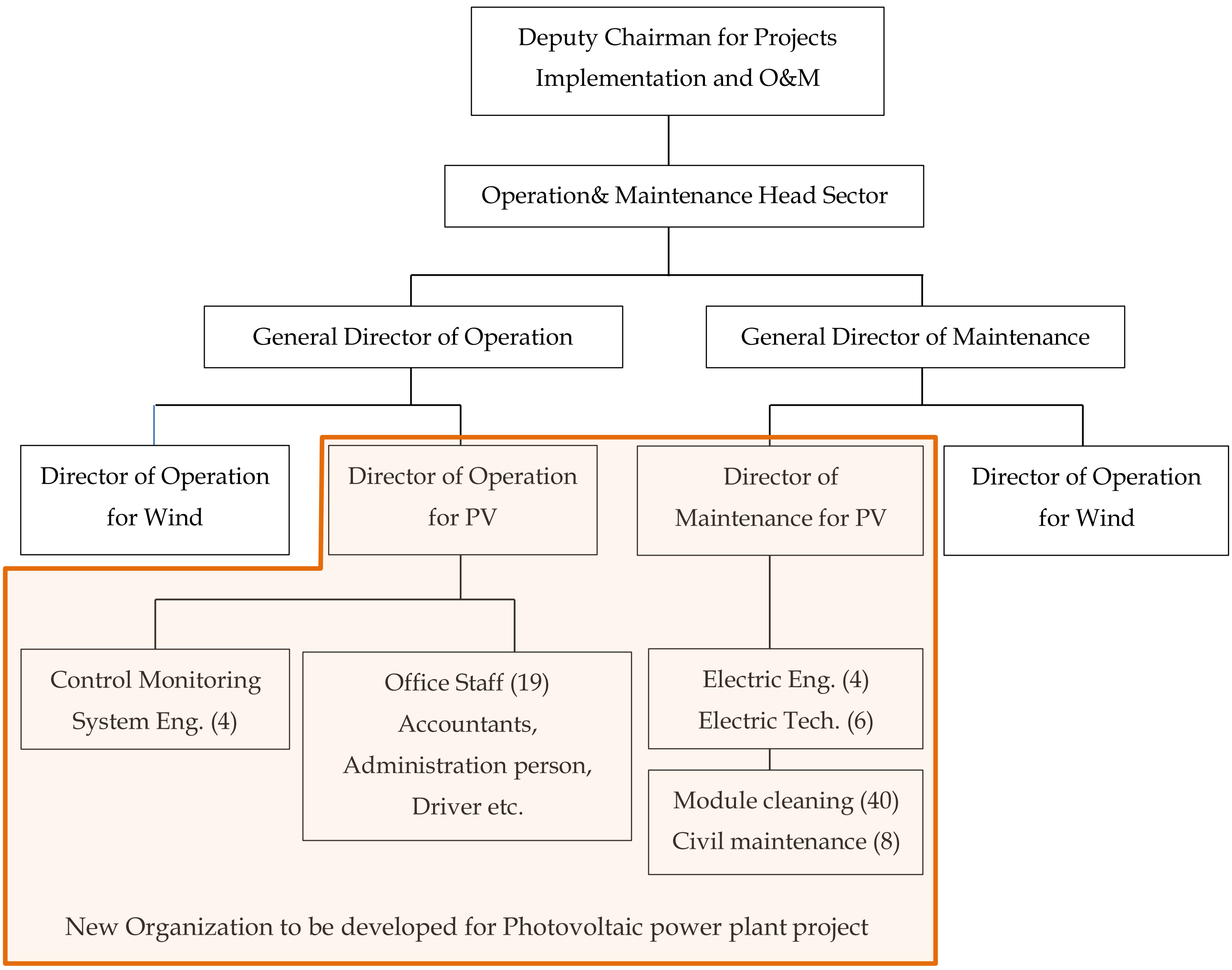


Fig.5-2-1 O&M Structure for Photovoltaic Power Plant Project

Functions and responsibilities for the operation department and maintenance department are expected to be as follows (since this is the first large scale PV power project in NREA, no clear idea is yet decided. Then the followings are just expectations based on wind power plants projects):

a) Operation Department

- ✓ Monitoring control system (SCADA system) that will be installed under this project in the control room.
- ✓ Follow up data collection, data entry and deal with these data in terms of analysis (including fault analysis) and develop periodic reports required.
- ✓ Control the operation and shutdown of each inverter, if necessary.
- ✓ Periodical maintenance for SCADA/control system.
- ✓ Repair and maintenance of electronic cards and hardware in the control room
- ✓ Fix communication faults.
- ✓ Follow up and coordination with maintenance teams.
- ✓ Guide and operation for the information center.

b) Maintenance Department

- ✓ Develop strategy for the periodical maintenance based on recommended maintenance procedures to be developed by the Contractor/supplier.
- ✓ Execute periodical maintenance and emergency maintenance (in case, any faults are found)
- ✓ Record maintenance actions taken and develop reports required.
- ✓ Maintain the information center including necessary repairing works.
- ✓ As part of the maintenance, Maintenance Department will take the following actions for the used equipment such as batteries and PV modules:
  - ■ Maintenance Department will replace batteries, PV modules and other equipment deem to be required to replace when such equipment are found defected or aged in accordance with O&M manuals to be developed by the Contractor or NREA or if Maintenance Department judges that such equipment have any faults and can not be used any more.
  - ■ Subsidiary stores of NREA in Hurghada officially inform the General Authority for the Governmental Services of the availability of such used/returned equipment.
  - ■ Then the said authority (General Authority for the Governmental Services) will announce for an auction for selling such equipment to certified concerned entities for recycling.
  - ■ The said authority will follow the process until such entities winning the auction take the equipment from the store at the site for recycling and legal disposal.

3) The necessary number of working staff

In addition to the previously mentioned organization, working staff for PV module cleaning and civil work is required as O&M staff.

a) Staff for PV module cleaning

In order to avoid reduction of the power generation efficiency by the accumulation of dust on the PV module (called as "dust effect"), proper PV modules cleaning shall be planned.

Necessary number of working staff for cleaning for the 20MW PV modules in two weeks or one month is estimated. This cleaning interval is estimated by the actual situation of dirt condition of the PV module obtained from the measuring system installed by JICA (Refer to Clause 5, Section 2 of Chapter 3 as well).

Situation of the dust effect for 3 measured periods are shown in Fig.5-2-2. According to this figure, the Team estimated that the dust effect level for 2 weeks is approx. 3-4% and for month it is approx. 5-8%.

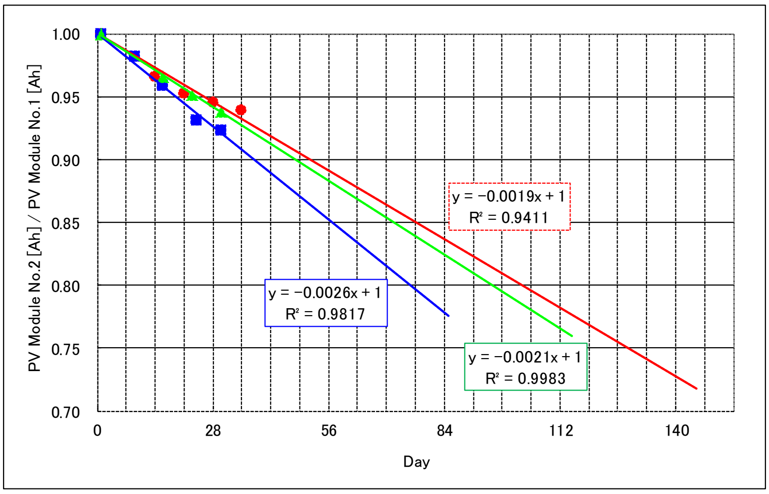


Fig.5-2-2 Measured dust effect (between left days and decreased output current from PV module)

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

Table 5-2-1 Dust effect for energy production

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%

For recommending proper cleaning method for this project site, the following actions were taken:

- ✓ NREA and the Team visited a grid connected PV power plant in Cairo which is the first private PV power plant in Egypt. Capacity of this PV power plant is 600kW including 100kW 2 axis tracking system. Based on the experience of this site, PV modules are cleaned by using high pressure water (cleaning period is depending on the panel dirt condition, as explained by them). This cleaning work requires 600 liter of water for each 25kW modules.

- ✓ In addition, NREA's Kuraymat solar thermal plant is also using high pressure water for clean-up mirrors.
- ✓ The Team made test cleaning work for the PV modules of the measuring system and found the following items:
  - Wiping with dry cloth required a lot of time and effort
  - Wiping with wet cloth made ingrained dust spread out on the surface of the PV modules
  - Washing with high pressure water sprayer and wiping by dry cloth after drying up, can easily remove the ingrained dust (see Fig. 5-2-3).

Fig. 5-2-3 Cleaning method by high pressure water sprayer

Taking the above into account, NREA and the Team agreed to use high pressure water sprayer for cleaning the PV modules of this project with minimum 1 month interval.

In case using this method (high pressure water sprayer) and cleaning interval is assumed to be once a month, requirement of resources are as follows;

- ✓ Number of PV modules:

Table 5-2-2 Number of module

	Output energy for one module (Example)	Capacity	Number of module
MLTF	128W	20MW	143,040

- ✓ Water for cleaning: according to the above cleaning test which was done by the Team, required water for cleaning one PV module provided by JICA at the site (CIS type, size is 1,257*977mm), 0.5-1.0 liter is required. Based on this water requirement of the cleaning test and for mass cleaning with high efficiency, the Team estimated that approx. 100t of water /month (for cleaning once a month) is required.

- ✓ Human resource: 2 men x 1 team can clean 1,000kW arrays of PV modules per month, thus 2 men x 20 teams = 40 men per months is required for whole PV modules.

In addition to the above periodical PV module cleaning, the Team recommended that special cleaning is to be carried out for the PV modules when NREA staff finds that the PV modules are dirty, especially after sandstorms.

b) Staff for civil works

In addition to the above, civil maintenance team for removing sand dust accumulated in drainage, fence wall will be required for this project. Two teams of which each team will be consisted of 4 persons is expected to be required for these works.

Considering the above, necessary number of working staff is shown in the Table 5-2-3.

Table 5-2-3 Necessary Number of Working Staff

	Cleaning Interval	Necessary number of working staff	Necessary amount of water
PV module cleaning	1month	20 team-40 staff	100t / month
Civil maintenance	Depend on the situation	2 team-8 staff	-

In total, the necessary number of working staff for cleaning shall be 48 staffs as minimum.

Chapter 6: Environmental and Social Considerations

Chapter 6 Environmental and Social Consideration

Section 1 Policy, Legal, and Administrative Framework

Clause 1 EIA law, regulation and guideline

Basic policy of EIA in Egypt is stipulated in the Environment Law 4/1994 and its executive regulations. Detail EIA procedures and requirements are elaborated in Guidelines of Principles and Procedures for Environmental Impact Assessment 2nd Edition (EEAA, 2009).

The project was categorized in "C" by EEAA on 24th February 2011. Then the project has to follow the procedure of category "C". Category "C" projects require a full EIA including public scoping at the early stages of the EIA and a public disclosure activity during draft EIA stage.

For category "C" project, a detailed full EIA study is required to fulfill the requirements described in the guideline according to the following contents:

- Executive summary
- Policy, legal and administrative framework
- Description of the project
- Description of the environment
- Identification and analysis of Impacts
- Analysis of alternatives
- Public consultation
- Environmental management plan
- List of references
- Annexes include (not limited to):
  - List of consultants participating in the study and their role
  - Lists of attendees in public consultation meetings
  - Agenda of public consultation meetings

Clause 2 JICA's Guidelines for Environmental and Social Considerations

This project is categorized in "C" by JICA classification. Then this project has to fulfill the requirement of category "C" stipulated in JICA GUIDELINES FOR ENVIRONMENTAL AND SOCIAL CONSIDERATIONS (JICA, 2010). The category "C" project does not require either EIA or IEE.

Even though, as this project is categorized in C, it requires EIA to be conducted. This is because JICA guideline also requires the compliance with the laws or standards related to the environment in the governments of host countries.

Screening Format of JICA's Guidelines for Environmental and Social Considerations as well as JICA's environmental checklist for other electric generation is attached in Appendix 6-1.

Clause 3 Process of the EIA work

The Public Consultation of EIA scoping has been done in January 2012 and the Public Consultation of draft ESIA has been held in October 2012, both of them took place in Hurghada. The ESIA report will be submitted to EEAA in December 2012. The progress of EIA procedure is shown in the following Table 6-1-3-1.

Table 6-1-3-1 Progress of the EIA work

Items	*Timing and work*
i) Preparation of the Public Consultation Plan	Public Consultation Plan was prepared by NREA and discussed with EEAA on 10th October 2011.
ii) Public Consultation during EIA Scoping	Individual scoping meetings were conducted on 10-11 January, 2012 in Hurghada. Public Scoping meeting was held on 28th February, 2012 in Hurghada.
iii) Baseline Survey	- Baseline Noise measurements were carried out on 4th October, 2011 at four locations (one within the project site and three at surrounding receptors around the site) - Baseline Air measurements carried out on 4th October, 2011 for parameters related to the construction activities of the project (PM_{10}, CO, NO_2, SO_2) at four locations (one within the project site and three at surrounding receptors around the site) - Detail topographic survey was carried out from 6th to 11th July 2012. - Literature survey was carried out from October 2011 to February 2012.
iv) Impact Assessment	Impact assessment was carried out from March 2012 to June 2012.
v) Mitigation Planning	Mitigation Planning was carried out from July to August 2012.

vi) Environmental Management Planning	Environmental Management Plan was carried out from July to August 2012.
vii) Preparation of a draft ESIA report	Draft ESIA report was prepared in September 2012.
viii) Public Consultation on the Draft ESIA Report	Public Consultation was held on 9th October 2012 in Hurghada.
ix) Preparation of the Final ESIA Report	The Final ESIA Report is expected to be submitted to EEAA in December 2012.

Section 2 Scoping

Clause 1 Anticipated issues

Based on the project design and baseline information, the following impacts are scoped. Comments of EEAA, result of individual consultation and public consultations are taken into consideration for the scoping.
Detail scoping results are shown in Table 6-2-1.

- Dust by construction vehicles and delivery vehicles
- Noise by construction vehicles, delivery vehicles, transformers, and inverters
- Waste will be produced by used PV panels and Batteries
- Water use for panel cleaning might decrease water resources
- Soil contamination by the waste from the project
- Flood water impacts (might shift the panels)
- Possibility of growth of local employment (positive impact)
- Aesthetic impacts

All of the scoped items shall be conducted on impact assessment.

Table 6-2-1 Potential / Residual Impacts Matrix

		Environmental Attributes[1]								
Activities (Sources of impacts)	**Aspects**	**Physical Environment**				**Biological Env.**	**Socio-economic**			
		Air Quality	**Noise level**	**Soil**	**Ground water Resource**	**Terrestrial life**	**Transpor-tation**	**Employ-ment**	**Aesthetic Impact**	**Waste**
Construction Phase										
Site leveling Civil Works Steel erection Equipment erection Electrical and instrumentation Mechanical completion Pre-commissioning	• Labor	NA	NA	NA	NA	NA	NA	+	NA	NA
	• Dust Emissions	$-/I_m$	NA	NA	NA	$-/I_m$	NA	NA	NA	NA
	• Emissions (vehicles, equipment & material)	$-/I_m$	NA	NA	NA	$-/I_m$	NA	NA	NA	NA
	• Noise (vehicles & equipment)	NA	$-/I_m$	NA	NA	NA	NA	NA	NA	NA
	• Construction Waste (including generation of solid and liquid municipal waste)	NA	NA	NA	NA	NA	NA	+	NA	$-/I_m$
	• Transportation	NA	NA	NA	NA	NA	$-/I_m$	NA	NA	NA
	• Spills (vehicles & equipment)	NA	NA	$-/I_m$	NA	NA	NA	NA	NA	NA
	• Sewage	NA	NA	$-/I_m$	NA	NA	NA	NA	NA	NA
Operation Phase										
Activities related to Workforce	• Labor employment	NA	NA	NA	NA	NA	NA	+	NA	NA
	• Municipal Solid Waste	NA	NA	$-/I_m$	NA	NA	NA	NA	NA	$-I_m$
	• Sewage	NA	NA	$-/I_m$	NA	NA	NA	NA	NA	NA
Cleaning	• Cleaning Modules	$-/I_m$	NA	NA	$-/I_d$	NA	NA	NA	NA	NA
Project existence	• Existence of the structure	NA	NA	NA	NA	$-/I_m$	NA	NA	$-/I_m$	NA
Maintenance	• Maintenance equipment	NA	NA	NA	NA	NA	NA	NA	NA	NA
Waste	• Waste of panels and butteries	NA	NA	$-/I_m$	NA	NA	NA	NA	NA	$-/I_m$
Transformers and inverters	• Noise from transformers and inverters	NA	$-/I_{d,m}$	NA	NA	NA	NA	NA	NA	NA

[1](-): Negative impact(+): positive impact $I_{d:}$ minor residual impacts acceptable after design integrated mitigation
I_m: minor residual impacts acceptable after mitigation through management NA: Not applicable

Section 3 Baseline survey items and survey method

Baseline survey was conducted for 8 items, such as Air quality, Noise, Flood, Metrological conditions, Flora, Fauna, Land use, and Landscape. Site survey is conducted on Air quality, noise, land use and landscape in October 2011. The survey items and survey methods are shown in the following table. Survey results are shown in Baseline Report (Annex1 of ESIA report in Appendix 6-2) and Topographic Survey Report (Annex 2 of ESIA report in Appendix 6-2).

Table 6-3-1 Survey items and survey methods

Items	*Method*	*Area/points*	*Time*
Air quality	Literature review and field measurements	Four locations (one inside the project area and three at surrounding locations)	4th October, 2011
Noise	Field measurements	Four locations (one inside the project area and three at surrounding locations)	4th October, 2011
Flood	Literature review and utilization of modeling (Digital Elevation (DEM) and Watershed Modeling (WMS) simulation)		
Topographic measurement	Total station and GPS	In and around the project site 2km	6 to 11 July 2012
Metrological conditions	Literature review	Hurghada Station data	
Flora	Literature review	Hurghada	
Fauna	Literature review	Hurghada	
Land use	Literature survey and site visits	Hurghada	4th October, 2011
Landscape	Literature survey and site visits	Hurghada	4th October, 2011

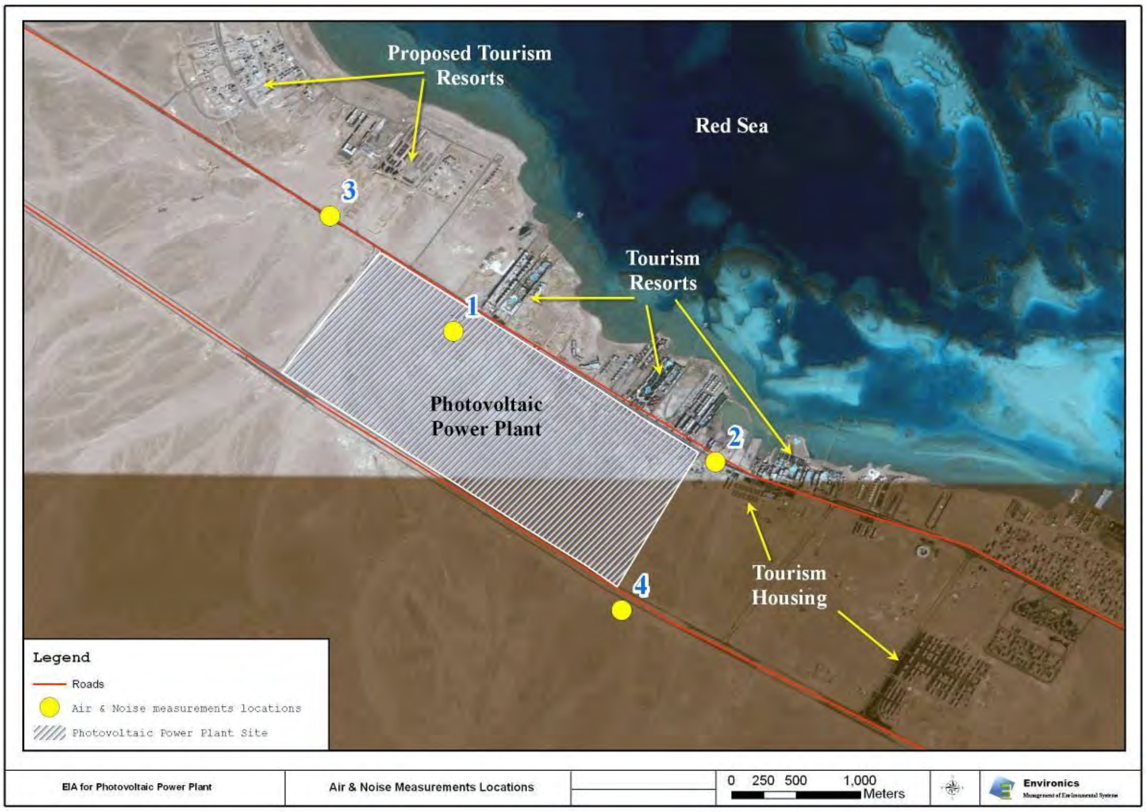


Fig. 6-3-1 Location of the survey points

Table 6-3-2 Description of Measurement Locations

Location No.	Position	Description of the Location
1	27°18'55.24"N 33°42'14.00"E	Inside the site of the Photovoltaic Power Plant
2	27°18'22.52"N 33°43'19.83"E	Residential compounds with low traffic near the tourist resorts
3	27°19'24.16"N 33°41'43.18"E	Downwind measuring point (Roads)
4	27°17'45.23"N 33°42'56.24"E	Upwind measuring point (Roads)

Section 4 Impact Assessment and Mitigation

The following is a brief explanation of the impact assessment and mitigation. ESIA report (Appendix 6-2) shows the detail explanation.

Clause 1 Physical Environment

The following is a brief explanation of the impact assessment and mitigation.

(1) Air Quality

Construction activities may result in minor, localized, short term, air quality deterioration in the form of dust/particulate matter, and emissions from soil leveling, construction equipment and transport vehicles. Air Emissions from mechanical construction equipment may result in potential impacts due to the localized increase in concentration of nitrogen oxides, sulfur oxides and carbon monoxide.

Such impacts will occur for relatively short duration and will affect mainly the workplace environment. Impact on public health is unlikely due to the fact that there are no nearby residential areas to the site.

Mitigation Measures

The PV project will ensure that contractors will carry out the necessary measures to minimize impacts. This is to be included in the contractor's scope of work (contract). Possible measures include:

- Dust suppression measures at the site through limit driving speed
- Maintaining machinery and vehicles in good working conditions to minimize fugitive emissions
- Frequent inspection of all construction equipment will be carried out to minimize fugitive emissions

(2) Noise

Construction phase

The use of construction equipment may result in localized, short term, increase in noise levels. Table 6-4-1-1 shows typical noise levels, in decibels, expected at various distances from construction machinery. It is not expected that noise from the construction activities would pose impacts on the neighboring areas.

Table 6-4-1-1 Average Noise Levels from Construction Equipment

Equipment Type	Distance from Noise Source (dBA)		
	10m	50m	100m
Crane	72	58	52
Bulldozer	74	60	54
Generator	76	62	56
Backhoe	79	65	59

Operation phase

Noise during operation can result mainly from the transformers and inverters (four 500 kV Invertors and one 2,000 kW Transformer). The transformers, switchgears, LV switchgears and protection relays are contained in an enclosure (Kiosk or container box) with restricted access.

Noise levels, expected from the different equipment as shown in the table 6-4-1-2 below, are less than the allowable limits of law 4/1994.

Table 6-4-1-2 Expected noise levels from

Noise source	No / Size	Noise level (dBA)	Location
500kV Inverters	4 invertors 0.5m(w) x 0.5m(h)	75dB	Inside the inverter room
2,000 kW Transformer	One transformer 3m(w) x 2m(d) x 2m(h)	64dB	Outside transformer room

Mitigation Measures

- When construction equipment are used, such as during site excavation, earth moving, and land grading, workers will be provided with the necessary Personal Protective Equipment (PPEs) to minimize possible impacts from noise speed.
- Maintaining machinery and vehicles in good working conditions to minimize noise generation.
- Potential noise generating machines and equipment are designed to meet statutory regulations concerning noise.
- Acoustic enclosures are installed for casings of all noise generating equipment, wherever possible.

(3) Soil Contamination

The activities carried out during construction phase are unlikely to result in soil contamination that will need future decontamination and clean-up activities. Moreover, during construction contracts with different contractors will include requirements for periodic inspection of equipment and machinery which will contribute to minimizing spills and leaks. Wastes generated during construction including municipal and construction waste will be collected by an approved contractor to be disposed of at designated landfill sites.

(4) Water Resource

The project will use about $100m^3$/month (less than $4m^3$/day) for panel cleaning. The required water quantity will be provided through the city network. The water consumption will not put significant load on the water resources in the area.

Clause 2 Biological Environment

Important species of conservation value do not occur within the project site and its close hinterland as the area has experienced intensive anthropogenic changes due to the establishment of the wind farm and the large number of touristic villages and resorts along the coast. The most important ecological feature of the area is its location along a major flyway for Palearctic migrant birds. However, the PV project does not have any impact on the flyway of the birds as it does not include any elevated structures.

Construction phase

The project area represents a small part of the vast coastal desert plain and it is not considered a critical habitat. Gaseous emissions, noise from construction machinery are short term and their impacts are considered insignificant.

Operation phase

As mentioned above, the project does not include activities that would affect the wildlife in the area. Moreover, the PV modules are non-reflecting surfaces, to enable maximum solar radiation absorption, thus it will not have any disturbing reflective adverse impacts

Mitigation Measures

- Implement mitigation measures to reduce emissions and noise, as detailed in previous sections.
- Avoid working at night and using high energy lights.
- Use native floral species as much as possible for landscaping.
- Develop, implement and update a waste management plan to include waste collection, storage, transport and disposal in an environmentally sustainable manner.

Clause 3 Social Environment

(1) Employment

Construction phase

The construction phase of the project will provide employment opportunities for an average of 250 workers. Priority will be given to the community local workforce during labor selection to further enhance positive impact on the local community.

Operation phase

The project has the potential to decrease unemployment levels in the area by creating employment opportunities. Moreover, it would provide an opportunity for education, training and technology transfer to the Egyptian context related to Solar Energy. This is expected to contribute significantly to disseminating the project in other areas in Egypt.

(2) Transportation

Main roads are expected to be used for transportation of equipment and construction gear to the project site. About 100 000 PV modules are required for this project; these will be imported from abroad through Alexandria or El Ein El Sokhna Port. In addition to the transformers, inverters, switch gears which will be acquired from the Egyptian Markets, mainly from Cairo, as well as steel and concrete which will acquired from local agents. Imported components will be transported from the ports via the highways. An average of 2,500 trucks of various sizes will be required for transportation of all project components distributed throughout its construction period, which is about 20 months. Thus it is not expected to have significant impacts on the roads network in the area during the project’s construction period (expected average number of trucks = 10 trucks/day)

(3) Aesthetic Impact

The project is to be located within the wind farm area owned by NREA. The PV panels are not installed at significant heights that could be easily seen from the surroundings. Thus, it is not expected that the aesthetic impacts are significant.

(4) Flood

During the baseline study, a few wadis were confirmed in the project site and flooding risk is moderate (See Annex 1 and Annex 2 of ESIA report in Appendix 6-2). In order to grasp i) water flow, ii) geometry conditions surround the project site, iii) necessity of flood protection structures, etc., the topographic survey was made (See Annex 2 of ESIA report in Appendix 6-2).

After the topographic survey and analysis, it was concluded as follows:

- The study results indicated low value of flood intensity.
- The PV site could resist impacts of the potentially expected floods according to 100 year return period.
- Optimal recommended protection strategy for the PV site is to be addressed in the foundation design of the modules.

Section 5 Public Consultation

Clause 1 Scoping Stage

As part of the comprehensive ESIA, a process of public scoping was carried out for identification of environmental concerns of different stakeholders regarding the proposed project. Accordingly, individual scoping meetings were conducted with key stakeholders in Cairo and Hurghada during January 2012. Following the individual meetings a public scoping meeting was organized in February 2012 to present the stages of the EIA and allow for additional interaction between the different stakeholders as well as with the project team. The main issues raised at the public consultation are Method of cleaning panels, Waste management, Noise, and Flash flood. Followings are the main concerns raised at the Public Consultation and individual consultations.

- Some cleaning panel methods such as, Mechanical cleaning, anti-repulsion coating material, and fine brushing, are suggested from some participants.
- Amount of water for cleaning panels are inquired.
- Assessment of the waste water of cleaning panels is requested.
- Assessment of waste panels and waste batteries are requested.
- Impact of noise on surround communities is raised as anxious issues.
- Impact of electromagnetic waves on the people is requested to be assessed.
- Potential impacts of flash flood are raised as anxious issues.

- The numbers of potential job opportunities that will be provided by the project are inquired.

Annex 3 of Appendix 6-2 provides description of the results of the individual scoping meetings. Annex 4 of Appendix 6-2 provides Minutes of Meeting of the public consultation.

Clause 2 Draft EIA Stage

Public consultation was held at Hurghada on 9th October 2012 to consult the stakeholders about the draft ESIA report. Following issues are discussed at the public consultation. The final ESIA report is under preparation referring to the result of the discussion.

- Project location and technology including:
  - Selection of Hurghada for establishing the project and alternative locations
  - Impact on the electricity grid
  - Panel cleaning method

- Impacts of the project on the environment
  - Water sources and wastewater management
  - Waste management
  - Transportation of project components
  - Impact on work place

- Impacts of the environment on the project
  - Flash flood impact
  - Impacts of dust
  - Impacts of high temperature

- Socio- economic aspects
  - Employment and training
  - Aesthetic impacts

Chapter 7: CDM (Clean Development Mechanism)

Chapter 7 CDM (Clean Development Mechanism)

Section 1 DNA (Designated National Authority) and CDM project approval procedures

Clause 1 Establishment of DNA in Egypt

The Arab Republic of Egypt signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and Kyoto Protocol in 1997 and ratified it in 2005.
The Egyptian Environmental Affairs Agency (EEAA) of the Ministry of State for Environmental Affairs (MSEA) took a lead for building a CDM structure. Ministerial Decree No.42 was declared by the Ministry of State for Environmental Affairs, and the CDM Designated National Authority (DNA) was established in EEAA on 14th March 2005.

Clause 2 DNA structures

In 2009, EEAA established the Central Department of Climate Change Fig. 7-1-2-1 shows the organizational structure of the Central Department of Climate Change. CDM Project Department of General Department for Mitigation and CDM is in charge of CDM project approval. Mitigation plan in Egypt includes the following areas;

- New and renewable energies
- Improve energy efficiency
- Recycling and waste treatment
- Fuel switching to natural gas
- Reduce the burning of gas associated with oil production
- Reduce leakage and wastage of natural gas in the oil sect.

CDM committee composed of Council for CDM and CDM bureau. Council for CDM is headed by the Minister of MSEA and is composed of the following permanent members representing all relevant governmental departments, as well as private and associative sectors.

- 6 representatives from relevant department of MSEA
- 1 representative from each of the followings:
  - ✓ Ministry of Foreign Affairs
  - ✓ Ministry of International Cooperation
  - ✓ Ministry of Electricity & Energy
  - ✓ Ministry of Transportation

- ✓ Ministry of Trade & Industry
- ✓ Ministry of Agriculture & Land Reclamation
- ✓ Ministry of Petroleum
- ✓ Ministry of Investment
- ✓ Ministry of Finance

■ 1 representative from NGO

CDM bureau includes seven members;

■ 5 representatives from MSEA

■ 1 representative from each of the followings:

- ✓ Ministry of Electricity & Energy
- ✓ Ministry of Trade & Industry

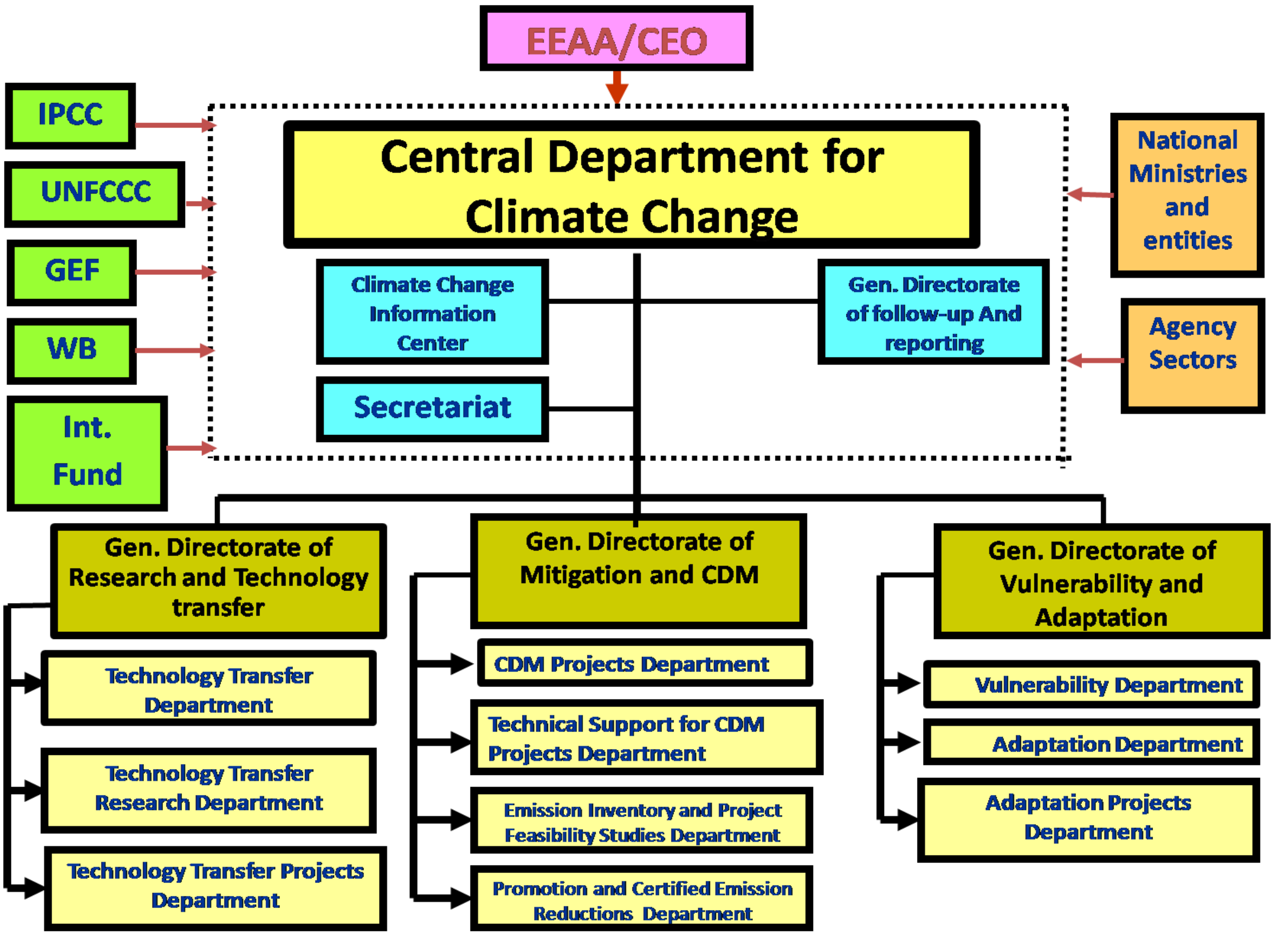


Fig. 7-1-2-1 Organizational structure of Central Department for Climate Change

Clause 3 CDM project approval procedures

Fig. 7-1-3-1 shows CDM project approval procedures. Project participants must submit a letter to notice "CDM consideration" to DNA and CDM EB (48th CDM EB decision).

Project proponents are required to submit PINs (Project Idea Note) with three (3) letters to confirm contribution to sustainable development, voluntary participation, and no diversion of ODA to DNA. Formulas of the letters are shown in Appendix 7-1 ~ 3 and draft PIN is as attached in Appendix 7-4. CDM bureau will review the proposed PINs and issue "No objection letter", if the proposal is compliance with additionality and sustainable development criteria. Once project proponents receive "No objection letter", they must submit PDD with draft validation report, which is provided by DOE, within nine (9) months of issuance of the letter.

The council for CDM reviews PDD to confirm that the project has the national approval for voluntary participation of Egypt in the CDM activity, and will certify that the project activities contribute to sustainable development of the country. Following the decision made by the Council, DNA will issue a letter of approval to the project proponents.

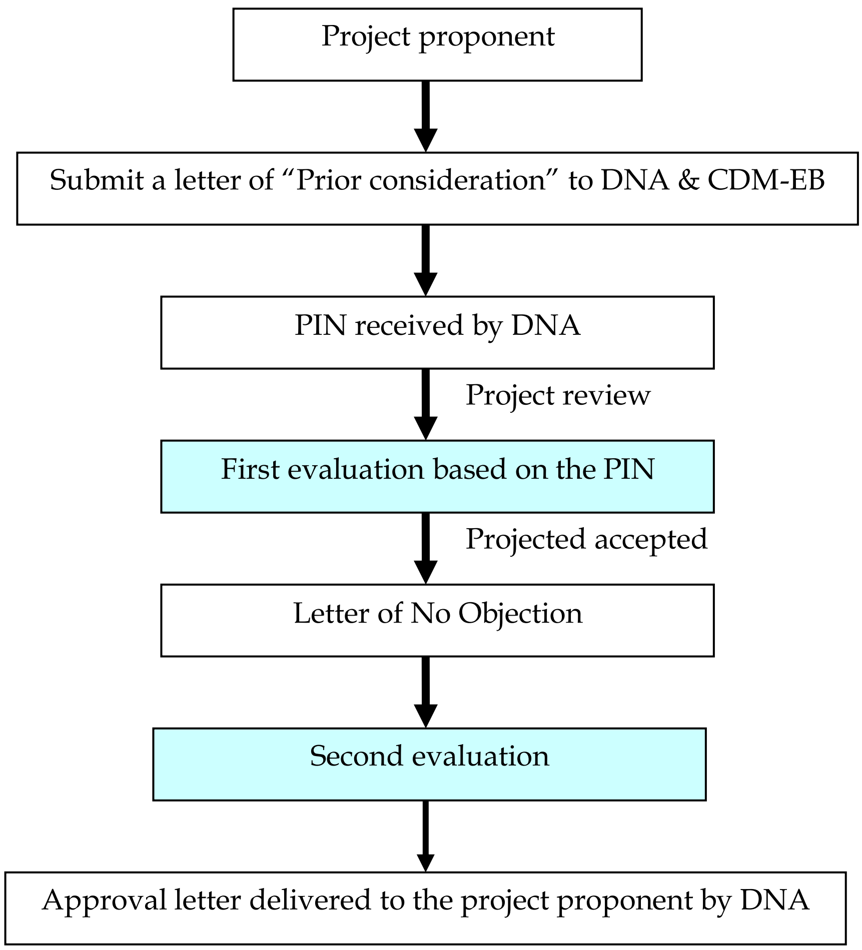


Fig. 7-1-3-1 Approval and evaluation of Egyptian CDM projects

Clause 4 Accepted projects

According to the information from Egyptian DNA, shown in Table 7-1-4-1, 11 projects (including one project requesting for registration) are registered to CDM-EB, 9 projects are approved by DNA, 34 projects are accepted (No objection letter) by DNA.

Table 7-1-4-1 Egyptian CDM Project Portfolio (Updated July, 2011)

Project	CERs	Date of L.No.Objec.	Date of L. of Appr.	EB-CDM Registration
1. Zafarana Wind Power Plant Project 120 MW (NREA– Japan)	248,609	11/4/2005	1/6/2006	22 /7/ 07
2. Zafarana 8 - Wind Power Plant Project, Arab Republic of Egypt 120 MW (NREA-Denmark)	209,714	10/9/2005	27/11/2007 and reissued to rename the project in 13 /7/ 2009	23/9/2010
3. Zafarana 85 MW Wind Power Plant Project in the Arab Republic of Egypt (NREA– Spain)	154,772	10/5/2006	13/7/2009	Request for Registration
4. Zafarana KfW IV Wind Farm Project 80 MW (NREA-Germany)	171,500	10/5/2006	27/12/2008	2 /3/ 2010
5. Gulf El Zeit Wind Power Farm Project 120 MW (up to 400 MW) – Italgen Egypt	250,000	7/3/2010		
6. 200 MW Wind Farm at the Gulf of El Zayt (NREA- Germany – EC – EIB)	481,800	19/1/2011		
7. Demitta Barrage Small Hydropower Project	47,058	10/9/2005		
8. Assuit Barrage Hydropower Project	134,330	25/5/2011		
9. Jatropha Luxor Project – submitted by JatroSolutions GmbH – Private sector / consulting firm	7800 (first 10 years) 2300 (the rest 20 years)	26/7/2010		
10. Onyx Alexandria Landfill Gas Capture and Flaring Project	370,903	4/1/2006	1/6/2006	15/12/06
11. Land Filling and Processing Services for Southern Zone in Cairo	76,652	25/1/2007	27/11/2007	At Validation (Corrective action or clarification has been requested)

12. Abu Zabal Landfill Gas Recovery and Flaring/Destruction	94,819	1/6/2007	7/3/2010	
13. Biogas Generation from Waste Water Treatment and Utilization for Heat Generation by Indorama Organics (Egypt) Co.S.A.E. in Beni Suef, Egypt	20,000	13/7/2009		
14. Egypt Vehicle Scrapping and Recycling (POA)	Total 26,703,000	7/3/2010	6/2010	2/6/ 2011
15. Emissions reduction through partial substitution of fossil fuels with renewable plantation biomass and biomass residues in CEMEX Assuit Cement Plant	204,693	10/5/2006	2/6/2008	17/1/2011
16. Egyptian Brick Factory GHG Reduction Project	430,350	14/9/2006	25/1/2007	14/7/2010
17. Sinai for Cement	120,000	4/1/2006		
18. Equipment Replacement & Fuel Switching, Dyeing Material & Chemicals (ISMADYE) Co.	13,000	14/9/2006		
19. Fuel Switching from Mazout to Natural Gas in Misr Fine Spinning & Weaving and Misr Beida	45,051	13/7/2009	7/3/2010	19/1/2011
20. Fuel Switching at the National Cement Co. (NCC), Egypt	306,454	25/1/2007	13/7/2009	
21. Reduce the Share of Clinker in the Production of a blended Cement type at the National Cement Co. (NCC)	66,197	25/1/2007	13/7/2009	
22. Fuel Switching from Mazout to Natural Gas in General Co. for Paper Industry (RAKTA)	18,134	2/6/2008		
23. Fuel Switching to Cleaner Fuel in the Egyptian Starch & Glucose Manufacturing Co. (Tourah Plant)	11,358	2/6/2008		
24. Fuel Switching to Alternative Fuel in Kattameya and Helwan Cement Plants	188,000	2/6/2008		

25. Fuel Switching from Mazout to Natural Gas in the Egyptian Sugar and Integrated Industries Co. at Abu Kurkas Factory	57,200	27/12/2008		
26. Fuel Switching from Mazout to Natural Gas in the Egyptian Sugar and Integrated Industries Company (ESIIC) / Kom Ombo Factory Project	21,513	26/7/2010		
27. Fuel Switching from Mazout to Natural Gas in the Egyptian Sugar and Integrated Industries Company (ESIIC) / Guirga Factory Project	11,187	26/7/2010		
28. Fuel Switching from Mazout to Natural Gas in the Egyptian Sugar and Integrated Industries Company (ESIIC) / Naga Hammadi Factory Project	7,314	26/7/2010		
29. Fuel Switching from Mazout to Natural Gas in the Egyptian Sugar and Integrated Industries Company (ESIIC) / Deshna Factory Project	27,536	26/7/2010		
30. Fuel Switching from Mazout to Natural Gas in the Egyptian Sugar and Integrated Industries Company (ESIIC) / Qus Factory Project	44,747	26/7/2010		
31. Fuel Switching from Mazout to Natural Gas in the Egyptian Sugar and Integrated Industries Company (ESIIC) / Armant Factory Project	30,118	26/7/2010		
32. Fuel Switching from Mazout to Natural Gas in the Egyptian Sugar and Integrated Industries Company (ESIIC) / Idfu Factory Project	27,536	26/7/2010		
33. Fuel Switching from Mazot to Alternative Fuels (Partial) at Amreyah Cement Company	57,414	26/7/2010		
34. Fuel Switching from Mazout to Natural Gas proposed by Quena Paper Industrial Co. QPIC	77,000	25/5/2011		

35. "Fuel Switching from Mazout to Natural Gas", proposed by Misr Edfu Pulp Writing and Printing Paper Company (MEPPCO)	49,000	25/5/2011		
36. Fuel Switch from Heavy Fuel Oil (Mazout) to Natural Gas in Misr Cement / Qena plant	108,000	25/5/2011		
37. Biomass Bases Steam and Power Generation by Indorama Organics (Egypt) Co.S.A.E. in Beni Suef, Egypt	70,000	13/7/2009		
38. Al-Sindian 13 MW Natural Gas based Cogeneration Package Project, Egypt	24,541	4/1/2006	25/1/2007	
39. Waste Gas-based Cogeneration Project at Alexandria Carbon Black Co., Egypt	109,514	Approved	27/11/2007	26/7/2008
40. Waste heat recovery based Cogeneration project at Abu Zaabal Fertilizers and Chemicals Company	54,679	2/6/2008	2/6/2008	
41. Waste Heat Recovery for Gas Turbine Generators Project	31,096	27/12/2008	11/4/2011	
42. Power Generation by Utilizing Coke Oven Gas of Al-Nasr Co. for Coke & Chemicals	68,477	27/12/2008		
43. Energy efficiency measures at MRI-Mansoura unit	4000	26/7/2010		
44. Gas Flare Recovery in Suez Oil Processing Company	120,000	26/7/2010	11/4/2011	
45. Street Lighting Project – North Cairo Electricity Distribution Company	75,000	26/7/2010		
46. Waste Heat Recovery and Utilization for Power Generation at the TITAN Cement Plant in Beni Suef		Pipeline		
47. Waste Heat Recovery Projects for Gas Turbine Generators proposed by KHALDA Petroleum Co.	73,000	19/1/2011		
48. Catalytic N2O destruction project in the tail gas of the Nitric Acid Plant of Abu Qir Fertilizer Co.	1,065,881	26/4/2005	1/6/2006	07/10/2006

49. Delta Fertilizers N2O Abatement	242,000	25/1/2007		
50. Semadco Fertilizers N20 Abatement	275,265	31/10/2010	11/4/2011	
51. N2O abatement at KIMA	115,553	25/5/2011		
52. Flared Gas Recovery System	60,740	27/12/2008		
53. Producing Liquefied CO2 With Production Capacity of 2.5 ton/hour	43,200	13/7/2009		
54. Shifting from Traditional Open-Pit Method to Mechanized Charcoal Production Program in Egypt, EEAA	36,000	31/10/2010		
55. Introduction of Hot Direct reduced Iron (DRI) into Electric ARC Furnace (EAF)	106,000	19/1/2011		

❖ Abbreviations:

CERs : Certified Emission Reductions
PIN : Project Idea Note
PDD : Project Design Document
L. No. Obj .: Letter of No Objection
L.o. A : Letter of Approval
Accepted : Get letter of no objection
Approved : Get letter of Approval
Pipeline : In the phase of preparing Project Idea Note
Registered : Registration in the CDM-EB

Section 2 Estimation of GHG emission reductions

Clause 1 Identification of an applicable CDM baseline and monitoring methodology

The project is a grid-connected renewable power generation project activity that installs a new power plant at a site where no renewable power plant was operated prior to the implementation of the project activity (Greenfield plant). The project activity is the installation of a solar power plant. Therefore ACM0002/Version12.1.0 "Consolidated baseline methodology for grid-connected electricity generation from renewable sources" is the applicable baseline and monitoring methodology for the project activity.

Clause 2 Project boundary

The spatial extent of the project boundary includes the project plant and all power plants connected physically to the electricity system that CDM project power is connected to. In Egypt, all power plants are connected to the Egyptian Unified Electric grid (the national grid). The project will be physically connected to the national grid. NERA has confirmed that all its information sources indicated that none of the major Egyptian transmission lines are operated at 90 % or more of its rated capacity during 90 % or more of the hours of a year. Further, electricity spot markets do not yet exist in Egypt. Therefore the relevant electricity system for the project is the Egyptian Unified Electric grid.

Clause 3 Project emissions

The project is the installation of a solar power plant. Therefore project emissions (PEy);

PEy = 0.

Clause 4 Baseline emissions

Baseline emissions include only CO_2 emissions from electricity generation in fossil fuel fired power plants that are displaced due to the project activity. The methodology assumes that all project electricity generation above baseline levels would have been generated by existing grid-connected power plants and the addition of new grid-connected power plants. The baseline emissions (BEy) are to be calculated as follows:

$BEy = EG_{PJ, y} \times EF_{grid.CM, y}$

Where,

BEy	= Baseline emissions in year y (tCO2/yr)
$EG_{PJ, y}$	= Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity in year y (MWh/yr)
$EF_{grid.CM, y}$	= Combined margin CO2 emission factor for grid connected power generation in year y calculated using the latest version of the "Tool to calculate the emission factor for an electricity system" (tCO2/MWh)

The combined margin (CM) CO2 emission factor for the Egyptian Unified Electric grid is calculated according to the following explanation (details of the calculation are shown in Appendix 7-5):

(1) Operating margin (OM) emission factor

The low-cost/must-run resources constitutes 11.8 % in average of five most recent years in the Egyptian Unified Electric grid which is less than 50 % of the total gird generation. Therefore the simple OM method is chosen to calculate the OM emission factor. The simple OM emission factor is calculated as the generation-weighted average CO_2 emissions per unit net electricity generation (tCO_2/MWh) of all generation power plants serving the system, not including low-cost/must-run power plants/units. There are two options to calculate simple OM emission factor. Option B: Based on the total net electricity generation of all power plants serving the system and the fuel types and total fuel consumption of the project electricity system, is chosen to calculate the simple OM emission factor, because fuel consumption data by type of fuel which is necessary to calculate CO_2 emission factor of each power unit is not available in Egypt. The OM emission factor is calculated based on the data taken from the annual reports of the Egyptian Electricity Holding Company (EEHC) for the business year 2007/2008, 2008/2009 and 2009/2010. The result of calculation of the OM emission factor is shown in the Table below.

Table 7-2-4-1 OM emission factors (tCO_2/MWh) in recent three years

	2007/2008	2008/2009	2009/2010
OM emission factor	0.536	0.539	0.533
3 years average OM emission factor	0.536		

(2) Build margin (BM) emission factor

The sample group of power units *m* used to calculate the BM emission factor should be determined as per the following procedure:

(a) Identify the set of five power units, excluding power units registered as CDM project activities, that started to supply electricity to the grid most recently ($SET_{5\text{-units}}$) and determine their annual electricity generation ($AEG_{SET\text{-}5\text{-units}}$, in MWh);

(b) Determine the annual electricity generation of the project electricity system, excluding power units registered as CDM project activities (AEG_{total}, in MWh). Identify the set of power units, excluding power units registered as CDM project activities, that started to supply electricity to the grid most recently and that comprise 20% of AEG_{total} (if 20% falls on part of the generation of a unit, the generation of that unit is fully included in the calculation) ($SET_{\geq 20\%}$) and determine their annual electricity generation ($AEG_{SET\text{-}\geq 20\%}$, in MWh);

(c) From $SET_{5\text{-units}}$ and $SET_{\geq 20\%}$ select the set of power units that comprises the larger annual electricity generation (SET_{sample});

The following table shows the sample group of power units to calculate BM emission factor of the Egyptian Unified Electric grid.

Table 7-2-4-2 Sample group of power plants to calculate BM emission factor

Power plant name	Type of power generation	Commissioning year	Rated capacity (MW)	Net generated power (GWh)	Percentage (%)
El-Atf	CC	2009	500	2,991	
Sidi Kir	CC	2009	500	3,080	
Nubaria 1-3	CC	2005-2009	2000	11,515	
Kuriemat 3	CC	2009	500	2,784	
Kuriemat 2	CC	2007-2009	750	5,035	19.0%
Talkha 750	CC	2006-2008	750	4,347	22.3%
Cairo North	CC	2005-2008	1500	9,346	29.3%
Total net generated power (GWh), excluding CDM projects				133,461	

The result of calculation of the BM emission factor is shown in the table below.

Table 7-2-4-3 BM emission factor

Power plant name	Net generated power (GWh) $EG_{m,y}$	Emission factor (tCO_2/MWh) $EE_{EL, m, y}$	CO2 emissions (tCO_2)	BM emission factor (tCO_2/MWh)
El-Atf	2,991	0.491	1,468,581	
Sidi Kir	3,080	0.554	1,706,486	
Nubaria 1-3	11,515	0.418	4,813,228	
Kuriemat 3	2,784	0.617	1,717,728	
Kuriemat 2	5,035	0.343	1,726,936	
Talkha 750	4,347	0.410	1,782,270	
Cairo North	9,346	0.384	3,588,941	
Total	39,098		16,804,171	0.430

(3) Combined margin (CM) emission factor

Default value of the weighting of OM and BM of PV power generation is 0.75 and 0.25.

Thus combined margin emission factor ($EF_{grid.CM, y}$) is shown in the table below.

Table 7-2-4-4 Combined margin emission factor ($EF_{grid.CM, y}$)

	OM	BM	CM
Weighting of OM and BM	0.75	0.25	
Emission factor (tCO_2/MWh)	0.536	0.430	0.510

Clause 5 Leakage

No leakage emissions are considered.

Clause 6 Emission reductions

Emission reductions are calculated as follows, because the emissions of this project are zero as described in Clause 3:

ERy = BEy

Where:

ERy = Emission reductions in year y (tCO2e/yr)

BEy = Baseline emissions in year y (tCO2/yr)

BEy is calculated to multiply $EG_{PJ,y}$ by $EF_{grid.CM,y}$

Accordingly, ERy is calculated as follows:

Table 7-2-6-1 shows estimation of emission reduction in the first year and Table 7-2-6-2 shows estimation of emission reductions and CDM revenues for 20 years.

Table 7-2-6-1 Estimation of emission reduction in the first year

Type of PV panel (Capacity)	Multilayer(Tandem) (20MW)
EG_{PJ} by PV panel (MWh)	(a) 35,910
Loss of 2MW battery in year*1 (MWh)	(b) 780
EG_{PJ} (Net) (MWh)	(c)=(a)-(b) 35,130
$EF_{grid.CM,y}$	(d) 0.510 tCO_2/MWh
ER_y (tCO_2/year)	(e)=(c)×(d) 17,916

(*1)Loss of the battery in year : 3MWh*2 × 260days (exclude Saturdays and Sundays in a year)

(*2) Charge and discharge loss of 2MW Sodium-Sulfur battery : 12MWh-9MWh = 3MWh/time

Table 7-2-6-2 Estimation of emission reductions

year	EG_{PJ} (Net) [MWh/year]	ER_y *1 [tCO_2/year]
1	35,130	17,916
2	34,591	17,641
3	34,052	17,367
4	33,513	17,092
5	32,974	16,817
6	32,435	16,542
7	31,896	16,267
8	31,357	15,992
9	30,818	15,717
10	30,279	15,442
11	30,279	15,442
12	30,279	15,442
13	30,279	15,442
14	30,279	15,442
15	30,279	15,442
16	30,279	15,442
17	30,279	15,442
18	30,279	15,442
19	30,279	15,442
20	30,279	15,442
Total	629,835	321,216
Average	31,492	16,061

(*1) ER_y [tCO_2/year]= EG_{pj}(Net)[MWh/year] × $EF_{grid.CM,y}$ (0.510)[tCO_2/MWh]

Chapter 8: Impact of the Project

Chapter 8 Impact of the Project

Section 1 Operation and Effect Indicators

1) Basic theory for the selection of Operation & Effect Indicators

Standardized Operation & Effect Indicators prepared by JICA is shown in Table 8-1-1.

In order to appropriately express the situation of operation and effectiveness of the Project at the post evaluation stage, the Team takes into consideration that the indicators must reflect the purpose of the Project and it should be easily obtainable.

Therefore, the Team established indicators in consideration with the following points:

- The indicators should be in accordance with the project purpose
- The indicators should be easily obtainable

The Team confirmed the suitability of the indicators in reflecting the following Project purposes:

- To supply power from the PV power generation system.
- To supply generated power to the peak load time through battery storage system.

2) Analysis of operation and effect indicators based on standardized one

- Utilized factor
  The purpose of this indicator is to grasp the amount of energy supply.
- Unplanned outage hours (due to equipment outage)
  The purpose of this indicator is to grasp the proper O&M works.
- Unplanned outage hours (due to external reason)
  The purpose of this indicator is to grasp the appropriateness of equipment in accordance to the climate condition.
- Planned maintenance outage
  In case of PV power plant, electrical equipment particularly inverter requires periodical maintenance work with outage.
- Maximum output power
  The purpose of this indicator is to grasp the deterioration ratio of the PV modules.
- Net Electric Energy Production
  This index is important to grasp the degree of financial benefit. It can measure appropriateness of O&M works, equipment, design and construction works.

■ CO_2 reduction Volume (t-CO_2)

It is possible to use Net Electric Energy Production for this index.

Table 8-1-1 Operation and Effect Indicator for Power Distribution (Standardized by JICA)

Operation Indicator

Category	Name	Policy and method of establishing the indicator	Target	Purpose	Remarks
Basic	Utilization factor	Annual energy production (MWh) / (regulated capacity (MW) x annual days) x 100	Predicted values by F/S etc.	To grasp the equipment and O&M condition.	Considering with condition of solar radiation
Basic	Unplanned outage hours (due to equipment outage)	Data acquisition from operation record	Should be 0	To grasp the degree of O&M performance and network condition.	
Auxiliary	Unplanned outage hours (due to external reason)	from operation record	Should be 0	To grasp the proper equipment for actual climate condition.	
Auxiliary	Planned maintenance outage	from operation record	Refer from maintenance plan	To grasp the situation of proper O&M works.	
Auxiliary	Maximum output power (kW)	from operation record	Predicted values by technical data, etc.	To grasp the actual situation of deteriorate ratio.	

Effect Indicator

Category	Name	Policy and method of establishing the indicator	Target	Purpose	Remarks
Basic	Net Electric Energy Production	From operation record	Predicted values by F/S etc.	To grasp the sustainable operation condition of the plant.	
Basic	CO_2 reduction Volume (t-CO_2)	Net Electric Energy Production x unit exhausting amount of CO_2	Predicted values by F/S etc.	ditto	

3) Proposed operation and effect indicators

In consideration of the above, the Team proposed operation and effect indicators shown in Table 8-1-2.

Table 8-1-2 Proposed Operation and Effect Indicators

Category	Name	Target
Basic	Utilization factor	32,272MWh/(20MW x8,760h)x100=18.4%
	Unplanned outage hours (due to equipment outage)	0 hr.
Auxiliary	Unplanned outage hours (due to external reason)	0 hr.
	Planned maintenance outage	1day / year For each equipment
	Maximum output power (kW)	20MW
Basic	Net Electric Energy Production	32,272 MWh/year
	CO_2 reduction Volume (t-CO_2)	16,458 tCO_2/year

4) Locations for data to be obtained

The above data can be obtained from the control system which will be installed the PV power plant under this project.

Section 2 Qualitative Analysis

In addition to the above, following qualitative effects are expected by this project.

Since large scale PV power plant requires huge land area, thus this will be conspicuous for general public;

- Recognitions of renewable energy resource for students, general public.
- Sight-seeing resource for tourists.

This will be a first large scale PV power plant in Egypt;

- Training resource for O&M for the other expected similar projects.
- Sample design and construction works for the other expected similar projects.

- Large scale solar power will boost the awareness towards natural energy having them contribute to energy efficiency.
- Employment creation on fields of construction and maintenance.
- Courses for training operation and maintenance skills for PV power and having its technology advanced will bring chances for participating in similar projects in neighboring countries.
- Information center (exhibition house) for large scale PV power will be contributing to understand to general public and demonstrating to neighboring countries how Egypt is leading this field. Thus technology transfer from Egypt to neighboring countries is expected.

Section 3 Economic and Financial Analysis

Clause 1 Implementation Schedule and Costs

1) Implementation Schedule

The schedule of construction works for the project is indicated in Table 3-6-2. According to the schedule, the project, including consulting services, manufacturing and installing of photovoltaic module, cable wiring and connection and inverter works etc., will be carried out over duration of 67 months.

The main mile stones are as follows:

- Commencement of consulting services: estimated as August 2013
- Commencement of construction works: estimated as April 2015
- Completion of construction works (up to Taking Over and Acceptance Certificate (TOAC)): estimated as November 2016
- Warranty period: 24 months after TOAC

2) Implementation Costs

Economic and financial analysis is conducted using estimated construction costs as described in Table 8-3-2.

a) Conditions

Costs of implementation work for the project were estimated in consideration of the following:

- Implementation schedule: as shown in Table 3-6-2
- Taxes: customs duties and sales tax (equivalent to VAT) are considered
- Price escalation: 2.1% for foreign currency and 8.8% for local currency are considered
- Administration cost is considered (assumed as 10 % of the project cost)
- Physical Contingency: 5%

Based on the above conditions, the following ratios of the costs allocation shown in Table 8-3-1 are applied to this analysis.

Table 8-3-1 Allocation of Costs

Category	2013	2014	2015	2016	2017	2018
Lot1 (Construction of 20MW PV Power Plant including necessary equipment)	0%	0%	40.0%	50.0%	5.0%	5.0%
Lot2 (Installation of 2MW High Performance Battery including necessary equipment)	0%	0%	40.0%	50.0%	5.0%	5.0%
Consulting services	20.0%	25.0%	25.0%	25.0%	3.0%	2.0%

Source; Prepared by the Team based on provided data

b) Breakdown of implementation costs

The implementation costs and those arranged per year are presented in Tables 8-3-2 and Table 8-3-3, respectively.

Table 8-3-2 Costs for the Project

Category			Foreign Currency (Million USD) (Million JP Yen)	Local Currency (Million USD) (Million LE)	Total (Million USD)
A	**Cost for Sub-Projects**				
	1	Construction of 20MW PV Power Plant including necessary equipment incl. 2MW battery	46.68 (3,847.71)	18.61 (112.24)	65.29
Total of A. Cost for Sub-Projects			46.68 (3,847.71)	18.61 (112)	65.29
B	**Contingency**				
	1	Price Escalation (2.1% for F/C, 8.8% for L/C)	3.79 (312.41)	6.98 (42.08)	10.77
	2	Physical Contingency (5%)	2.52 (208.05)	1.28 (7.71)	3.80
Total of B. Contingency			6.31 (520.46)	8.26 (49.8)	14.57
C	Consulting Services		11.69 (963.92)	2.96 (17.85)	14.65
	1	Price Escalation (2.1% for F/C, 8.8% for L/C)	0.68 (56.30)	0.78 (4.73)	1.47
	2	Physical Contingency (5%)	0.62 (50.94)	0.19 (1.13)	0.81
Total of C.			12.99 (1,071.16)	3.93 (23.71)	16.93
D	Interest During Construction and Commitment Charge		1.80 (148.70)	0.00 (.)	1.80
E	Total of the Eligible Portion (A+B+C+D)		67.79 (5,588.04)	30.80 (185.74)	98.59
F	Owner's Administration cost (5% of (A+B))		0 (0.00)	3.99 (24.08)	3.99
G	Land Acquisition & Compensation		0.00 (0.00)	0.00 (.)	0.00
H	Contingency		0.00 (0.00)	1.79 (10.76)	1.79
	1	Price Escalation (2.1% for F/C, 8.8% for L/C)	(0.00)	1.51 (9.11)	1.51
	2	Physical Contingency (5%)	(0.00)	0.28 (1.66)	0.28
I	Taxes (sales: 10% for all and custom duties: 0% for foreign materials)		(0.00)	7.99 (48.16)	
J	Grand Total		67.79 (5,588.04)	44.57 (268.75)	112.36

Note:

- All the above cost are reference for budget purpose only and may be changed as per discussion with JICA.
- exchange rate:

USD - JP Yen: Exchange Rate April 2012 provided by JICA 82.43
USD - LE: Exchange Rate April 2012 provided by JICA 6.03

Table 8-3-3 Costs per Year

(Million US$)

No.	Item	Total			2013			2014			2015			2016			2017			2018		
		F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
A. ELIGIBLE PORTION																						
1	Construction of 20MW PV Power Plant including necessary equipment incl. 2MW battery	46.678	18.614	65.292							18.671	7.445	26.116	23.339	9.307	32.646	2.334	0.931	3.265	2.334	0.931	3.265
2																						
3																						
4																						
5	Total (1-4)	46.678	18.614	65.292							18.671	7.445	26.116	23.339	9.307	32.646	2.334	0.931	3.265	2.334	0.931	3.265
6	Price Escalation	3.790	6.979	10.769							1.201	2.144	3.345	2.023	3.734	5.757	0.256	0.488	0.744	0.310	0.613	0.923
7	Physical Contingency	2.524	1.279	3.803							0.994	0.479	1.473	1.268	0.652	1.920	0.130	0.071	0.201	0.132	0.077	0.209
8	Total (5+6+7)	52.992	26.872	79.864							20.866	10.068	30.934	26.630	13.693	40.323	2.720	1.490	4.210	2.776	1.621	4.397
9	Consulting Service	11.693	2.960	14.653	2.339	0.592	2.931	2.923	0.740	3.663	2.923	0.740	3.663	2.923	0.740	3.663	0.351	0.089	0.440	0.234	0.059	0.293
10	Price Escalation	0.683	0.784	1.467	0.049	0.052	0.101	0.124	0.136	0.260	0.188	0.213	0.401	0.253	0.297	0.550	0.038	0.047	0.085	0.031	0.039	0.070
11	Physical Contingency	0.618	0.188	0.806	0.119	0.032	0.151	0.152	0.044	0.196	0.156	0.048	0.204	0.159	0.052	0.211	0.019	0.007	0.026	0.013	0.005	0.018
12	Total (9+10+11)	12.994	3.932	16.926	2.507	0.676	3.183	3.199	0.920	4.119	3.267	1.001	4.268	3.335	1.089	4.424	0.408	0.143	0.551	0.278	0.103	0.381
13	**A. Total (8+12)**	65.986	30.804	96.790	2.507	0.676	3.183	3.199	0.920	4.119	24.133	11.069	35.202	29.965	14.782	44.747	3.128	1.633	4.761	3.054	1.724	4.778
B. NON ELIGIBLE PORTION																						
14	Land acquisition & Compensation																					
15	Price Escalation																					
16	Physical Contingency																					
17	Total (14+15+16)																					
18	Administration cost		3.994	3.994								1.547	1.547		2.016	2.016		0.211	0.211		0.220	0.220
19	Price Escalation		1.510	1.510								0.445	0.445		0.809	0.809		0.111	0.111		0.145	0.145
20	Physical Contingency		0.275	0.275								0.100	0.100		0.141	0.141		0.016	0.016		0.018	0.018
21	Total (18+19+20)		5.779	5.779								2.092	2.092		2.966	2.966		0.338	0.338		0.383	0.383
22	VAT		2.687	2.687								1.007	1.007		1.369	1.369		0.149	0.149		0.162	0.162
23	CD		5.300	5.300								2.087	2.087		2.663	2.663		0.272	0.272		0.278	0.278
24	**B. Total (21+22+23)**		13.766	13.766								5.186	5.186		6.998	6.998		0.759	0.759		0.823	0.823
25	**Total (A+B)**	65.986	44.570	110.556	2.507	0.676	3.183	3.199	0.920	4.119	24.133	16.255	40.388	29.965	21.780	51.745	3.128	2.392	5.520	3.054	2.547	5.601
26	**IDC**	1.400		1.400				0.016		0.016	0.173		0.173	0.368		0.368	0.410		0.410	0.433		0.433
27	Commitment Charge	0.404		0.404	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067
28	**Grand TOTAL (25+26+27)**	67.790	44.570	112.360	2.574	0.676	3.250	3.282	0.920	4.202	24.373	16.255	40.628	30.400	21.780	52.180	3.605	2.392	5.997	3.554	2.547	6.101

29	**Financial Costs**	61.917	35.297	97.214	2.525	0.624	3.149	3.142	0.784	3.926	22.811	13.453	36.264	27.756	16.940	44.696	2.901	1.746	4.647	2.780	1.750	4.530

Note 28-6-10-15-19-26

30	**Economic Costs**	63.317	25.153	88.470	2.525	0.565	3.090	3.158	0.710	3.868	22.984	9.541	32.525	28.124	11.903	40.027	3.311	1.223	4.534	3.213	1.211	4.424

Nore: for FC=28-6-10-15-19-22-23
for LC=(5+9)*SCF+7+11+16+18+20 SCF= 0.90

Clause 2 Economic Analysis

1) Economic Evaluation

The economic analysis appraises the project under study in terms of an entire national economy by comparing and measuring its economic costs and benefits converted into international prices. In other words, the economic analysis is the process of evaluating the extent of economic effects on the national economy as a result of the implementation of the project.

The economic evaluation is conducted according to the following procedures:

- Definition and quantification of economic costs and benefits
- Comparison of economic costs and benefits
- Calculation and evaluation of the Economic Internal Rate of Return

Comparisons are carried out by converting all future economic costs and benefits emerging during the operational life of the project into Net Present Values (NPV), by applying the discounted cash flow method. When the present value of the economic costs (C) is equal to the present value of the economic benefits (B), or B/C=1, the discount rate used to calculate these present values is known as the Economic Internal Rate of Return (EIRR).

The discount rate (for capital establishment) for this project is set at 4% which is lower than the rate used by international lender organizations such as the World Bank and the Asian Development Bank.

This project is challenging to promote photovoltaic power plant which is an environmentally friendly technology and renewable resource but it is costly. High level of IRR cannot be expected from this project but at the same time this project is worth implementing because of its nature and characteristics. Comparative low level of IRR means that this project will not be implemented under commercial basis. Therefore, this project needs to be carried out with governmental and international assistance.

This project will be financed by borrowings: JICA STEP loan and local loan. It is expected that IRR of the project should be more than the interest rate of the loan.

Table 8-3-4 Average interest rate of the loan (JICA loan and local loan)

	Costs USD Mil.	Outside of loan USD Mil.	Loan amounts USD Mil.	Interest rate %	Remarks
JICA loan	67.79		67.79	0.10	*1
Local loan*3	44.57	3.99	40.58	11.00	*2
Total			108.37	4.18	weighted average

*1 Rate for STEP loan
*2 Commercial bank prime lending rate in Egypt, Source: http://www.indexmundi.com/
*3 Amount of the local loan will be varied depending on JICA's loan conditions. Refer to Section 5 of Chapter 3.

Average interest rate for the project is estimated as 4.18% as shown in Table 8-3-4. IRR for the project should be higher than interest ratio of the loan and the Team did not take into account the profit of the implementing agency because the implementation agency of this project "NREA" is a governmental agency and as a purpose of governmental body it is not pursuit of profit like private body. Therefore, discount rate of IRR shall be 4.2% adding some buffer to the estimated rate.

2) Economic Benefits and Costs

The "economic benefits" of a construction of power station project are, from the perspective of the national economy, the output emerging from the implementation of the project, such as the increase of power generation.

In line with the above interpretation, the "economic costs" of such power plant construction project are, from the perspective of the national economy, all costs associated with the implementation of the project, including construction costs, operation, maintenance and administration costs, fuel expenses and other costs related to the implementation works.

The economic benefits and economic costs of this study are as follows:

- Economic benefits:
  - ✓ Increase of fuel export by substituting power resources from fossil energy to renewable energy.
  - ✓ Increase of fuel export due to reducing operation of inefficient Hurghada thermal plant by supplying power from high performance batteries at energy consumption peak time.
  - ✓ CER sales increase by utilization of renewable energy
  - ✓ Reduction of transmission line losses
- Economic costs: costs for implementation of this project

3) Project Life and Operation Period

Economic costs and benefits are calculated over the whole life of the project. The first year of the project is assumed as the first allocation of the project costs to the installation of equipment and machineries. The last year of the project life refers to the year when the operation and maintenance of the project facilities come to an end.

The average operation period of the equipment and systems of this project is assumed to be 20 years, starting after the four years which are required to complete the installation of the main equipment and systems (2014 to 2017).

4) Scope and Objectives of the Economic Evaluation

The construction of power plant and the installation of equipment (such as high performance battery, inverter, and transformer) regarded as one part of the power generation system, is one and only project within the whole power generation of the nation. Thus, it is generally difficult to define the benefits associated with the implementation of only one power plant construction project of this kind.

The reasons that drive the implementation of this project are:

- Power demand in Egypt has been growing rapidly in recent years.
- Present Egyptian energy structure is relied on a fossil energy. Fossil energy resources are assumed to be depleted in near future, and cost might increase.
- To cope with power demand expansion, 7th five year plan (2012/13 to 2016/17) includes execution of 12,400 MW of generating capacity from 11,100 MW during the plan years and 1,300 MW to be commissioned during 2017/2018.
- The government of Egypt set ambitious targets to reach 20% of the energy generated by 2020 from renewable sources. Where hydro power represents 5.8%, wind 12% and 2.2% from other renewable sources, especially solar energy.
- EEHC/EETC and NREA cooperate with purchase of energy generated from renewable projects at reasonable price to encourage the use of renewable energy.
- Although current Egyptian electrical laws and legislations are not considering the development of renewable energy, Egypt ERA assumes three business models of renewable energy development for direction of new renewable energy laws. One of them is development by NREA, and the others are developments by private sector.
- Egypt has strong density of solar radiation, thus there is high potential for using solar energy.

5) Economic Benefits

Main purpose of this project is to construct a 20 MW photovoltaic power plant in Hurghada and generate power. Power generation is the base for estimating both financial and economic benefits.

Power production differs from type of photovoltaic module. Characteristics and generating efficiency of each photovoltaic module are stated in Chapter 3. One type of photovoltaic modules “Multi-Layer Thin Film (MLTF)” will be installed for the project. Estimated power generation by photovoltaic modules is stated in Table 8-3-5, including the case with the battery.

The battery is assumed to be used for 260 days per year (week day only) taking into account prolong life time of the battery (minimizing charging- discharging times).

Energy production will decrease by installation of the battery as it described in Table 8-3-5 because certain ratio of power will be lost during battery charge and discharge. Power will be lost when electricity passes inverter at the time of charge and discharge and certain power will remain in battery which cannot be discharged. Therefore, totally, 25% of power will be lost during charge and discharge.[1]

Table 8-3-5 Energy production during project years

year	MLTF 20MW [MWh/year]	MLTF 20MW with 2MW battery [MWh/year]
1	35,910	35,130
2	35,371	34,591
3	34,832	34,052
4	34,293	33,513
5	33,754	32,974
6	33,215	32,435
7	32,676	31,896
8	32,137	31,357
9	31,598	30,818
10	31,059	30,279
11	31,059	30,279
12	31,059	30,279
13	31,059	30,279
14	31,059	30,279
15	31,059	30,279
16	31,059	30,279
17	31,059	30,279
18	31,059	30,279
19	31,059	30,279
20	31,059	30,279
Total	645,435	629,835
Average	32,272	31,492

Source: prepared by the Team based on provided data

[1] Charging-discharging loss is assumed to be 0.75 considering battery loss(DC side, 0.87 for Lead battery) and Inverter losses (0.93 x 0.93 for both direction) .

A) Increase of fuel export by substituting power resources from fossil energy to renewable energy.

Photovoltaic module does not consume fossil energy when it produces power. Therefore, it has effect of saving fuel compared with the case that same quantity of power is generated by thermal power plant with consumption of crude oil which could have been exported.

Based on energy production which is described in Table 8-3-5, saving crude oil is calculated by the followings:

- Based on fuel/consumption ratio in annual report of EEHC (2010/2011), weight of crude oil can be estimated.
- Price for crude oil is calculated using past price movement of this oil.

Based on the above procedure, saving crude oil in each year by the project is calculated and summarized in Table 8-3-8.

According to the Petroleum Association of Japan, price of imported crude oil for the past 16 years are as follows:

Table 8-3-6 Movement of imported crude oil price (CIF)

(USD/Barrel)

Year	Nominal Price	Real Price
1996	20.41	20.41
1997	20.72	20.29
1998	13.93	13.35
1999	17.08	16.03
2000	28.53	26.21
2001	25.28	22.73
2002	24.63	21.69
2003	29.22	25.19
2004	36.37	30.69
2005	51.11	42.22
2006	63.94	51.71
2007	69.41	54.96
2008	101.91	79.00
2009	60.67	46.04
2010	79.19	58.83
2011	108.75	79.10

Source: Petroleum Association of Japan

Real Price = Nominal Price – price escalation (2.1% compounded interest)

[Regression analysis of oil price]

Crude oil price have been increasing from the view of long term trends. The Team conducted a more precise estimation of future trends for crude oil price by

applying statistical method. Using the above data, the Team carried out a regression analysis and the price to be estimated by the linear model with the assumption that there is a strong correlation between time and oil price.
Slope of the regression line is computed by MS Excel function "SLOPE".
(Slope can be interpreted as an increasing amount per year)

From Table 8-3-6, slope from 1996 to 2011 is calculated as follows:
SLOPE (Y-axis data, X-axis data) = SLOPE (time line, oil price)
As a result of calculation, slope for nominal price is 5.78, and for real price is 4.00.

Prices until 2017 (base year for IRR calculation) are calculated in nominal price and prices after 2017 are calculated in real price. Price escalation used for calculation of real price is 2.1% (price escalation for foreign currency). This rate is same as the rate used in cost calculation (see Table 8-3-3).
Ceiling price is set at highest monthly average price for past 16 years: 135.14 USD/Barrel at July 2008 (Source: Petroleum Association of Japan). As a result, the estimated price reaches to the ceiling price before base year and the ceiling price shall be used for whole project years.
The table below shows the estimated crude oil export price from 2012 to 2037. The price reaches to the ceiling price before the base year and the ceiling price shall be applied for the rest of the project years.

Table 8-3-7 Movements of estimated crude oil price

(USD/Barrel)

Year	Price	Year	Price	Year	Price	Year	Price
2012	107.69	2019	135.14	2026	135.14	2033	135.14
2013	113.47	2020	135.14	2027	135.14	2034	135.14
2014	119.24	2021	135.14	2028	135.14	2035	135.14
2015	125.02	2022	135.14	2029	135.14	2036	135.14
2016	130.80	2023	135.14	2030	135.14	2037	135.14
2017	135.14	2024	135.14	2031	135.14		
2018	135.14	2025	135.14	2032	135.14		

Source: prepared by the Team based on provided data

Based on the above data and assumption, savings of crude oil by the project are calculated as follows.

Table 8-3-8 Saved crude oil calculation sheet

	Generation amounts	Fuel consumption rate	Fuel consumption		Price for crude oil	Savings
	MWh	(gm/kWh)	(ton)	(barrel)	(US$/B)	(US$10^3)
2017	35,130	208.4	7,321	51,174	135.14	6,916
2018	34,591	208.4	7,209	50,389	135.14	6,810
2019	34,052	208.4	7,096	49,604	135.14	6,703
2020	33,513	208.4	6,984	48,819	135.14	6,597
2021	32,974	208.4	6,872	48,034	135.14	6,491
2022	32,435	208.4	6,759	47,249	135.14	6,385
2023	31,896	208.4	6,647	46,463	135.14	6,279
2024	31,357	208.4	6,535	45,678	135.14	6,173
2025	30,818	208.4	6,422	44,893	135.14	6,067
2026	30,279	208.4	6,310	44,108	135.14	5,961
2027	30,279	208.4	6,310	44,108	135.14	5,961
2028	30,279	208.4	6,310	44,108	135.14	5,961
2029	30,279	208.4	6,310	44,108	135.14	5,961
2030	30,279	208.4	6,310	44,108	135.14	5,961
2031	30,279	208.4	6,310	44,108	135.14	5,961
2032	30,279	208.4	6,310	44,108	135.14	5,961
2033	30,279	208.4	6,310	44,108	135.14	5,961
2034	30,279	208.4	6,310	44,108	135.14	5,961
2035	30,279	208.4	6,310	44,108	135.14	5,961
2036	30,279	208.4	6,310	44,108	135.14	5,961
Total	629,835		131,258	917,491		123,990

Source: prepared by the Team based on provided data

Fuel consumption rate; 208.4 (average for thermal, excluding BOOT in EEHC annual report 2010/2011)

1 ton = 6.99 barrel

B) CER sales by using renewable resource.

CDM (Clean Development Mechanism) and CER (Certified Emission Reduction) are described in Chapter 7 “CDM”. According to Table 7-2-6-1, estimated emission reductions are as follows:

Table 8-3-9 Estimated CO2 Emission Reductions

	Energy Production (MWh)	CO_2 Emission factors (t/MWh)	Emission reduction (t)
2017	35,130	0.51	17,916
2018	34,591	0.51	17,641
2019	34,052	0.51	17,367
2020	33,513	0.51	17,092
2021	32,974	0.51	16,817
2022	32,435	0.51	16,542
2023	31,896	0.51	16,267
2024	31,357	0.51	15,992
2025	30,818	0.51	15,717
2026	30,279	0.51	15,442
2027	30,279	0.51	15,442
2028	30,279	0.51	15,442
2029	30,279	0.51	15,442
2030	30,279	0.51	15,442
2031	30,279	0.51	15,442
2032	30,279	0.51	15,442
2033	30,279	0.51	15,442
2034	30,279	0.51	15,442
2035	30,279	0.51	15,442
2036	30,279	0.51	15,442
Total	629,835		321,216

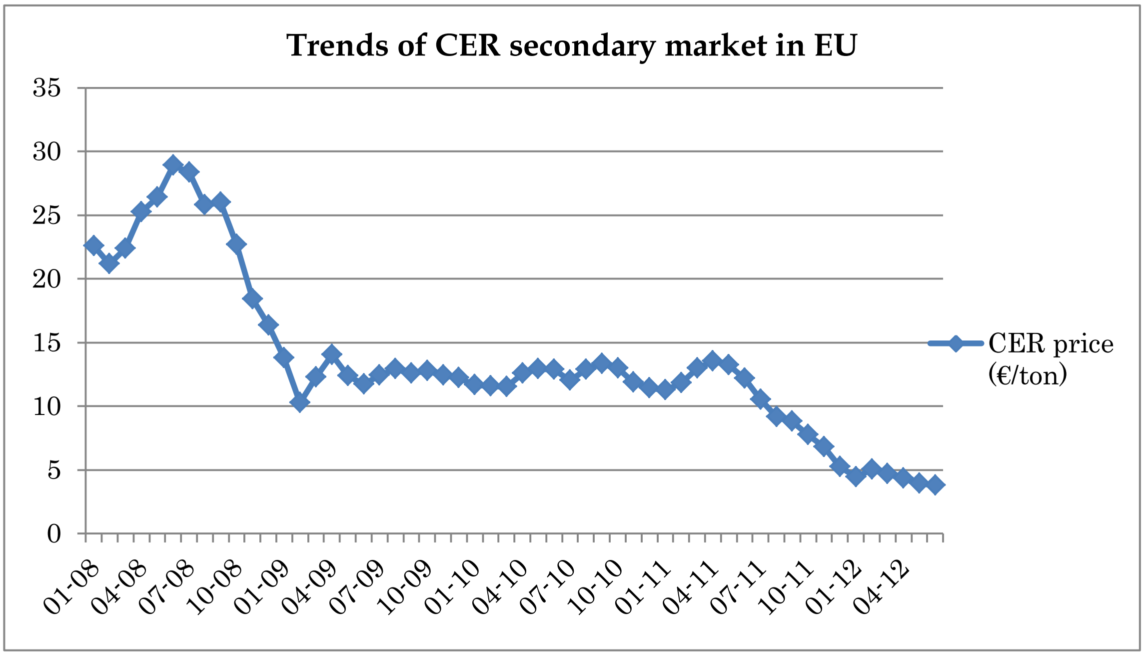
Source: prepared by the Team based on the provided data

Price data of ICE are used for estimating future price of CER because at present, more than 80% of carbon emissions are traded within EU area and ICE is a biggest emissions trading market in EU.

There are 2 types of market which deal with CER (CDM): primary market and secondary market. In the primary market, CERs are traded before obtaining the certification and in the secondary market, CERs are traded after obtaining the certification. Primary market has the risk of not being certified and purchased emission right may be lapsed. Therefore, the price of secondary market is adopted in this calculation.

Price trends of CER trading in ICE are described in the following chart. Emission trading was started in 2005 and the prices were increased since mid of 2008.

CER prices declined rapidly twice. The causes of this catastrophe were Lehman shock and euro financial crisis. Prices of CER were stable during the period after Lehman shock and before euro financial crisis.



Source: ICE homepage https://www.theice.com/

Fig. 8-3-1 Trends of secondary market in EU

There is an assumption on estimating future CER price that market mechanism work in emission trading market. This emission trading market is not oligopoly market, nor speculative market. CER price will not be influenced by certain party but CER price will be decided by demand and supply. CER price increased until mid of 2008, but as the market started just a few years ago and as the supplies were not large, the demand exceeded the supply in western European countries where environmental issue was crucial. Lehman shock and euro financial crisis attacked European economy bringing industrial production decline and decrease of CO_2 emission in line with economy situation. Thus, Europe lost its capacity to purchase emission credit. Accordingly, the demands for emission trading declined rapidly. During the period of between Lehman shock and euro financial crisis European economy were stable, hence CER price was also stable. As aforementioned, market mechanism worked in the market because the market reflected economic situation.

Future price is decided by future demands and future supply in the market where market mechanism is working. As for the demand side, demands for CER supposed to be increasing in the future. Dependency on thermal power is increasing in present western European countries due to rising anxiety to nuclear power. This tendency is apparent in the countries which decided to abolish nuclear power plants like German and Italy.

However, future economic situation in EU is still unclear. Euro crisis which started from Greece, spread to Spain, Portugal and Italy with no sign of economic recovery. Moreover, recession in Euro will continue in the future if Greece and/or Spain fail to reconstruct sound financial position. Economic condition will strongly affect emission market.

On the supply side, interests for renewable energy are increasing and utilization of renewable energy will be developed in the future in general. However, utilization of water resource is already developed in advanced countries and construction of dam may cause serious environmental issues, so that not so much development of hydro power can be expected. High costs prevent development of solar power and wind power to be prevailing in the countries where no feed-in-tariff system.

There is one another important uncertain factor for estimating trends of emission market. Framework for carbon emission after Kyoto protocol is undecided at present and price of CER will fluctuate according to new framework whether restriction will strengthen or weaken.

It seems that the potential fundamental factor of emission markets push the price up. However, uncertain factors like continual Euro crisis and new framework are strong and it is difficult to estimate future trends of CER price. Therefore, Team comes to conclusion to consider conservative and adopts past lowest price (average price in June 2012) for project period.

Table 8-3-10 Price of CER per ton

	2012 Jun
Average Price (Euro/t)	3.78
Average Exchange rate	0.8133
Average Price (USD/t)	4.65

Source of price in euro: ICE homepage https://www.theice.com/

Source of exchange rate: oanda.com historical currency converters

From Table 8-3-10, the Team applied an average price of 4.65USD/ton and the revenue from CER sales during the project period will be as shown in Table 8-3-11.

Table 8-3-11 Revenue from CER sales during project period

	Energy production (MWh)	CO_2 Emission factors (t/MWh)	Emission reduction (t)	CER price (USD/t)	Amounts 1000USD
2017	35,130	0.51	17,916	4.65	83
2018	34,591	0.51	17,641	4.65	82
2019	34,052	0.51	17,367	4.65	81
2020	33,513	0.51	17,092	4.65	79
2021	32,974	0.51	16,817	4.65	78
2022	32,435	0.51	16,542	4.65	77
2023	31,896	0.51	16,267	4.65	76
2024	31,357	0.51	15,992	4.65	74
2025	30,818	0.51	15,717	4.65	73
2026	30,279	0.51	15,442	4.65	72
2027	30,279	0.51	15,442	4.65	72
2028	30,279	0.51	15,442	4.65	72
2029	30,279	0.51	15,442	4.65	72
2030	30,279	0.51	15,442	4.65	72
2031	30,279	0.51	15,442	4.65	72
2032	30,279	0.51	15,442	4.65	72
2033	30,279	0.51	15,442	4.65	72
2034	30,279	0.51	15,442	4.65	72
2035	30,279	0.51	15,442	4.65	72
2036	30,279	0.51	15,442	4.65	72
Total	629,835		321,216		1,494

Source: prepared by the Team based on the provided data

C) Reduction of Transmission Losses by Connecting Power Line Directly to Distribution Line.

In usual case, power production companies transfer power to Egyptian Electricity Transmission Company (EETC) and EETC transfers power to Distribution companies. But in this project, as Hurghada photovoltaic power plant is located close to Hurghada city area and El Gouna, there is no need to connect to the transmission line while outward electricity line from the power plant will be connected to the distribution network of Canal Electricity Distribution Company (CEDC) directly.

Certain ratio of electricity will be lost when power passed through transmission lines. This transmission loss can be avoided in this project because generated power will be connected to distribution line directly and will not utilize electric grid.

Average transmission line loss from 2003/04 to 2010/11 in Egypt is 3.815%.

Table 8-3-12 Loss reduction by bypassing transmission line

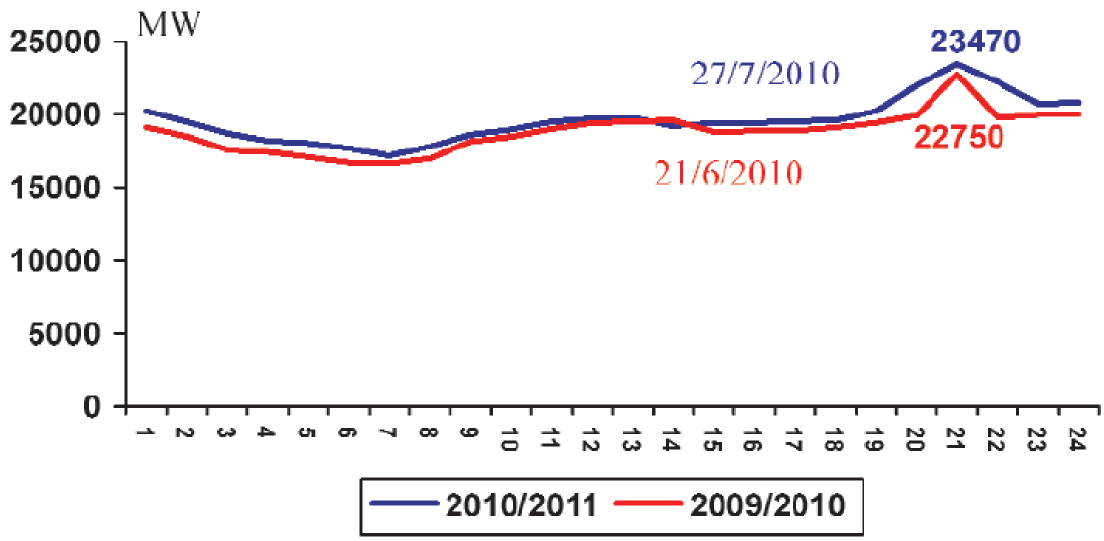
	Energy production MWh	Transmission loss ratio (%)	Loss Reduction (MWh)
2017	35,130	3.815%	1,340
2018	34,591	3.815%	1,320
2019	34,052	3.815%	1,299
2020	33,513	3.815%	1,279
2021	32,974	3.815%	1,258
2022	32,435	3.815%	1,237
2023	31,896	3.815%	1,217
2024	31,357	3.815%	1,196
2025	30,818	3.815%	1,176
2026	30,279	3.815%	1,155
2027	30,279	3.815%	1,155
2028	30,279	3.815%	1,155
2029	30,279	3.815%	1,155
2030	30,279	3.815%	1,155
2031	30,279	3.815%	1,155
2032	30,279	3.815%	1,155
2033	30,279	3.815%	1,155
2034	30,279	3.815%	1,155
2035	30,279	3.815%	1,155
2036	30,279	3.815%	1,155
Total	629,835		24,028

Source: prepared by the Team based on the provided data

According to EEHC's standard procedure, 2,000 USD /MWh is applied to loss reduction (as un-served energy cost) in economic analysis (This was explained by EEHC Head Sector for Cost Study, Commercial and Administration Affairs)
Assumptions and calculation of the un-served energy cost can be considered to be proper in general.
See Appendix 8-1 for details. Accordingly, the value is also applied to this study.

D) Increase of fuel export due to reduce operation of inefficient Hurghada thermal power plant by supplying power from high performance batteries at peak time.

Photovoltaic modules generate power in day time and stops at night time. On the other hand, energy consumption increases from evening and reach to peak at night in Egypt as shown in Fig. 8-3-2.



Source: EEHC annual report 2011

Fig. 8-3-2 Peak load curve 2009/2010 to 2010/2011

Therefore, more power is necessary at night in Egypt. To cope with this situation, 2 batteries (1 MW each, total 2 MW) shall be installed for this project. Battery charge energy during daytime and discharge at peak time at night.

Currently, an aged and inefficient thermal power plant is operated only at night time to cope with expanding demand at this time in Hurghada area. If enough quantity of power is supplied from the batteries, it is not necessary to operate the once-retired thermal plant. Capacities of batteries are not sufficient for substituting all generations of thermal plant but it can reduce operations of the aged thermal plants up to the capacity of 2 MW.

Thermal plant in Hurghada consumes great deal of fuel compared with average thermal plants in Egypt because it is old and the fuel can be saved if operations of inefficient thermal power plant are reduced.

Computation of oil saving effect is as follows;

Saved Fuel Consumption Rate

Total thermal average	208.4	at 2010/2011
Hurghada	427.6	at 2009/2010
Diff(Savings)	219.2	gm/kWh

*The above values are from the annual report of EEHC

Energy discharged from batteries

Battery capacity	2	MW
Operating Hours/day	6	Hour
Operating Days/year	260	Days
Discharge rate	75	%
Discharge energy	2,340	MWh

Energy saving

Energy discharged from batteries	2,340	MWh/Year
Saved rate	219.2	
gram to Barrel	6.99	
Oil Price (barrel)	135.14	USD/Barrel

Saving Effects	484.53	1000USD/Year

6) Economic Costs

Since the local currency portion of the economic costs is not regarded as an accurate reflection of the attributes of the economy (due to several circumstances such as the effect of control and legislation on prices), this amount cannot be evaluated or used directly as an economic cost.

Therefore, for the purpose of the economic analysis, it is necessary to convert the national market costs to economic costs referenced to the international market, by applying conversion factors.

A) Foreign Currency

The foreign currency portion of the implementation costs is expressed in terms of CIF (Cost, Insurance and Freight) FOB (Free on Board) prices, which can be included as economic costs since they are referenced to the international market. In the economic analysis of this project, the CIF prices are treated directly as international market prices.

B) Local Currency

As mentioned above, it is believed that the local market in developing countries is affected by several factors including internal price control, laws and regulations. This is the reason for the consideration that if the national market prices are treated as economic costs, they will not represent accurately those particularities of the economy applying to goods and services such as materials, consulting, etc.

Standard Conversion Factors (SCF) derived from ordinary import-export statistics are applied to costs of trading goods and used in the economic evaluation process in order to convert from national market prices into typical international market prices.

The SCF adopted for this analysis is 0.9. This factor was selected in consideration of examples of projects in other countries.

The following costs shall be eliminated from economic and financial costs:

- For economic cost: price escalation and taxes
- For financial cost: price escalation and interest during implementation

Table 8-3-13 summarizes economic costs calculated according to the above conditions. The detailed annual breakdown of costs is stipulated in Table 8-3-14.

Table 8-3-13 Project Economic Costs (USD Th.)

	2013	2014	2015	2016	2017	2018
Economic costs	3,090	3,868	32,525	40,027	4,534	4,424

Table 8-3-14 Economic Costs and Financial Costs

(Million US$)

No.	Item	Total			2013			2014			2015			2016			2017			2018		
		F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
	A. ELIGIBLE PORTION																					
1	Construction of 20MW PV Power Plant including necessary equipment incl. 2MW battery	46.678	18.614	65.292							18.671	7.445	26.116	23.339	9.307	32.646	2.334	0.931	3.265	2.334	0.931	3.265
2																						
3																						
4																						
5	Total (1-4)	46.678	18.614	65.292							18.671	7.445	26.116	23.339	9.307	32.646	2.334	0.931	3.265	2.334	0.931	3.265
6	Price Escalation	3.790	6.979	10.769							1.201	2.144	3.345	2.023	3.734	5.757	0.256	0.488	0.744	0.310	0.613	0.923
7	Physical Contingency	2.524	1.279	3.803							0.994	0.479	1.473	1.268	0.652	1.920	0.130	0.071	0.201	0.132	0.077	0.209
8	Total (5+6+7)	52.992	26.872	79.864							20.866	10.068	30.934	26.630	13.693	40.323	2.720	1.490	4.210	2.776	1.621	4.397
9	Consulting Service	11.693	2.960	14.653	2.339	0.592	2.931	2.923	0.740	3.663	2.923	0.740	3.663	2.923	0.740	3.663	0.351	0.089	0.440	0.234	0.059	0.293
10	Price Escalation	0.683	0.784	1.467	0.049	0.052	0.101	0.124	0.136	0.260	0.188	0.213	0.401	0.253	0.297	0.550	0.038	0.047	0.085	0.031	0.039	0.070
11	Physical Contingency	0.618	0.188	0.806	0.119	0.032	0.151	0.152	0.044	0.196	0.156	0.048	0.204	0.159	0.052	0.211	0.019	0.007	0.026	0.013	0.005	0.018
12	Total (9+10+11)	12.994	3.932	16.926	2.507	0.676	3.183	3.199	0.920	4.119	3.267	1.001	4.268	3.335	1.089	4.424	0.408	0.143	0.551	0.278	0.103	0.381
13	**A. Total (8+12)**	65.986	30.804	96.790	2.507	0.676	3.183	3.199	0.920	4.119	24.133	11.069	35.202	29.965	14.782	44.747	3.128	1.633	4.761	3.054	1.724	4.778
	B. NON ELIGIBLE PORTION																					
14	Land acquisition & Compensation																					
15	Price Escalation																					
16	Physical Contingency																					
17	Total (14+15+16)																					
18	Administration cost		3.994	3.994								1.547	1.547		2.016	2.016		0.211	0.211		0.220	0.220
19	Price Escalation		1.510	1.510								0.445	0.445		0.809	0.809		0.111	0.111		0.145	0.145
20	Physical Contingency		0.275	0.275								0.100	0.100		0.141	0.141		0.016	0.016		0.018	0.018
21	Total (18+19+20)		5.779	5.779								2.092	2.092		2.966	2.966		0.338	0.338		0.383	0.383
22	VAT		2.687	2.687								1.007	1.007		1.369	1.369		0.149	0.149		0.162	0.162
23	CD		5.300	5.300								2.087	2.087		2.663	2.663		0.272	0.272		0.278	0.278
24	**B. Total (21+22+23)**		13.766	13.766								5.186	5.186		6.998	6.998		0.759	0.759		0.823	0.823
25	**Total (A+B)**	65.986	44.570	110.556	2.507	0.676	3.183	3.199	0.920	4.119	24.133	16.255	40.388	29.965	21.780	51.745	3.128	2.392	5.520	3.054	2.547	5.601
26	**IDC**	1.400		1.400				0.016		0.016	0.173		0.173	0.368		0.368	0.410		0.410	0.433		0.433
27	Commitment Charge	0.404		0.404	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067	0.067		0.067
28	**Grand TOTAL (25+26+27)**	67.790	44.570	112.360	2.574	0.676	3.250	3.282	0.920	4.202	24.373	16.255	40.628	30.400	21.780	52.180	3.605	2.392	5.997	3.554	2.547	6.101
29	**Financial Costs**	61.917	35.297	97.214	2.525	0.624	3.149	3.142	0.784	3.926	22.811	13.453	36.264	27.756	16.940	44.696	2.901	1.746	4.647	2.780	1.750	4.530

Note 28-6-10-15-19-26

No.	Item	Total F/C	Total L/C	Total	2013 F/C	2013 L/C	2013 Total	2014 F/C	2014 L/C	2014 Total	2015 F/C	2015 L/C	2015 Total	2016 F/C	2016 L/C	2016 Total	2017 F/C	2017 L/C	2017 Total	2018 F/C	2018 L/C	2018 Total
30	**Economic Costs**	63.317	25.153	88.470	2.525	0.565	3.090	3.158	0.710	3.868	22.984	9.541	32.525	28.124	11.903	40.027	3.311	1.223	4.534	3.213	1.211	4.424

Nore: for FC=28-6-10-15-19-22-23
for LC=(5+9)*SCF+7+11+16+18+20 SCF= 0.90

7) Economic Evaluation Results

The economic evaluation of this project was based on the cash flow of economic costs and benefits analyzed during the process. Results are summarized in Table 8-3-15 and the outline is presented below.

In economic analysis, ratio between benefit and cost (B/C) is estimated from converted net present value of the benefits and the costs. Difference between the benefits and the costs (B-C) is also estimated by same manner.

The EIRR is calculated also, which is regarded as an important indicator to assess the feasibility of the project. This indicator is defined as follows:

$$\sum_{t=1}^{t=T} \frac{C_t}{(1+R)^t} = \sum_{t=1}^{t=T} \frac{B_t}{(1+R)^t}$$

Where,

T =Last year of the project life

Ct =Annual cash flow of the economic cost for this project at the year t

Bt =Annual benefit from the alternative project at the year t (savings from the Alternative project and sales income from the international interconnection)

R =Economic Internal Rate of Return

- Total economic costs = costs for implementation of this project, such as installation of photovoltaic modules and inverters, contingency, consulting fee, administration fee and land acquisition fee + maintenance costs for 20 years
- Total economic benefits = Increasing fuel export, increase of CER sales and reduction of transmission losses

The EIRR was calculated as 6.86% for the base case, as indicated in the following table.

Table 8-3-15 EIRR Calculation Sheet

Economic Internal Rate of Return

EIRR= 6.55%

Year Order	Year	Cost			Benefit												
					Fuel Saving by renewable energy			CER Trading			Reduction of Transmission line loss			Fuel Saving by using Butteries (iv)	Total B = (i)+(ii)+(iii) +(iv)	Net Cash Balance (B-C)	Accumulation
		Investment (1,000 $)	O&M (1,000$)	Total (C)	Electricity Production (MWh)	Crude oil price (USD/barrel)	Sub-Total 1,000USD. (i)	CO2 Saving Amounts (t)	Unit Costs (USD)	Sub-Total 1000USD (ii)	Loss Reduction (MWh)	Unit Cost (USD)	Sub-Total 1000USD (iii)				
	2013	3,090	0	3,090											0	-3,090	-3,090
	2014	3,868	0	3,868											0	-3,868	-6,958
	2015	32,525	0	32,525											0	-32,525	-39,482
	2016	40,027	0	40,027											0	-40,027	-79,510
1	2017	4,534	0	4,534	35,130	135.14	6,916	17,916	4.65	83	1,340	2,000.00	2,680	484.53	10,164	5,630	-73,880
2	2018	4,424	0	4,424	34,591	135.14	6,810	17,641	4.65	82	1,320	2,000.00	2,639	484.53	10,015	5,591	-68,288
3	2019		529	529	34,052	135.14	6,703	17,367	4.65	81	1,299	2,000.00	2,598	484.53	9,867	9,337	-58,951
4	2020		529	529	33,513	135.14	6,597	17,092	4.65	79	1,279	2,000.00	2,557	484.53	9,718	9,189	-49,762
5	2021		682	682	32,974	135.14	6,491	16,817	4.65	78	1,258	2,000.00	2,516	484.53	9,570	8,887	-40,874
6	2022		529	529	32,435	135.14	6,385	16,542	4.65	77	1,237	2,000.00	2,475	484.53	9,421	8,892	-31,982
7	2023		529	529	31,896	135.14	6,279	16,267	4.65	76	1,217	2,000.00	2,434	484.53	9,273	8,743	-23,239
8	2024		529	529	31,357	135.14	6,173	15,992	4.65	74	1,196	2,000.00	2,393	484.53	9,124	8,595	-14,644
9	2025		529	529	30,818	135.14	6,067	15,717	4.65	73	1,176	2,000.00	2,351	484.53	8,976	8,446	-6,197
10	2026		10,919	10,919	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	-2,091	-8,289
11	2027		529	529	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,298	9
12	2028		529	529	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,298	8,307
13	2029		529	529	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,298	16,605
14	2030		529	529	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,298	24,903
15	2031		786	786	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,041	32,944
16	2032		529	529	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,298	41,242
17	2033		529	529	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,298	49,540
18	2034		529	529	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,298	57,838
19	2035		529	529	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	8,298	66,136
20	2036		3,132	3,132	30,279	135.14	5,961	15,442	4.65	72	1,155	2,000.00	2,310	484.53	8,827	5,695	71,830
Total		88,470	22,932	111,400			123,990			1,494			48,056	9,691	183,230	71,830	

Condition of Discount Rate:	4.2%	
Net Present Value:	88,562	104,879
Benefit and Cost Ratio (B/C)		1.18425
Benefit and Cost Difference (B-C)		16,317

Table 8-3-16 Economic Evaluation Results

Case	EIRR (%)	B/C ratio	B-C (USD Th.)
Base case	6.55	1.18	16,317

As indicated earlier, the discount rate (for capital establishment) used for this project is 4.2%.

Because the calculated EIRR (6.55%) is higher than the discount rate (for capital establishment) of 4.2% assumed for Egypt, this project is feasible in the view of economy.

Consequently this project can have some feasibility from the economic perspective.

8) Economic Sensitivity Analysis

A sensitivity analysis was conducted to study the effect of some assumed variation involving the costs of construction materials, which show a relation to the economic situation in Egypt. In addition to the base case introduced above, a total of 8 cases were analyzed where the economic costs rise 5 or 10% and the economic benefits fall 5 or 10%.

Sensitivity analysis results are as follows:

Table 8-3-17 Results of EIRR Sensitivity Analysis

	Benefit		
Cost	Base case	-5%	-10%
Base case	6.55%	5.82%	5.07%
+5%	5.85%	5.14%	4.40%
+10%	5.20%	4.50%	3.78%

For the cases where the benefits fall 10% from the base case and the costs rise 10% from the base case, the EIRR is less than 4.2%; 3.78%. Other than this case, EIRR is more than 4.2% which can be interpreted as economically feasible.

Consequently this project can have some feasibility from the economic perspective unless both costs and benefit fluctuate more than 10%.

Clause 3 Financial Analysis

1) Financial Evaluation

A financial analysis appraises the degree of financial return of the project under study that is expected to earn and is carried out in terms of profitability for the owner.

The amount invested for the project is regarded as the "financial cost", and is evaluated in terms of market prices. Additionally, the benefit derived from this project is regarded as the "financial benefit", also evaluated in terms of market prices.

The financial costs and benefits derived during the operational life of the project are compared in terms of present values. When the present value of the financial costs (C) is equal to the present value of the financial benefits (B), or B/C=1, the discount rate used to calculate these present values is known as the Financial Internal Rate of Return (FIRR).

2) Financial Benefits and Costs

The financial benefits and costs of this study are as follows:

- Financial benefits:
  - ✓ Sales increase due to power production by photovoltaic power plant.
  - ✓ CER sales by using renewable resources.
  - ✓ Reducing operation costs of Hurghada thermal plant by supplying power from high performance batteries at peak load time.
- Financial costs: implementation costs of this project

3) Project Life and Operation Period

As described in "Clause 2 Economic Analysis," the operation period of this project is assumed to be 20 years, after the four years necessary to complete implementation of the facilities (2014 to 2017).

4) Scope and Objectives of the Financial Evaluation

The financial analysis is carried out in the view of financial independence of the executing agencies, and normally focused on cash flow of the income (financial benefits) and expense (financial costs), repayment of loans and balance sheet that summarizes benefits and costs of the project.

The evaluation will be made based on IRR (Internal rate of Return) in the same way as the economic analysis.

5) Financial Benefits

As mentioned before, the financial benefits are the revenue increase and cost saving by reduction of losses.

A) Sales increase due to power production by photovoltaic power plant (MWh).

Based on the above energy production (see Table 8-3-5), increase of power sales are calculated by following feed-in tariff.

(1) Base or rule for estimating feed-in tariff

German and Spain are the advanced countries for feed-in tariff program for solar power. IRR is an index for deciding feed-in tariff in both countries.

German IRR 7% (before taxation)

Spain IRR5.5-6.5% (after taxation)

Source: METI Hp

Taking into account that IRR is an important index for deciding investment and German and Spain adopted IRR as an index for computing feed-in tariff, the Team also adopted IRR for the index for calculating the feed-in tariff

(2) Proper IRR Level

The feed-in tariff scheme in German and Spain is that the Government purchases power from power producer (mainly private sector). Therefore, incentives and/or some profit for private sector may be included in the feed-in tariff for promoting this feed-in tariff mechanism. NREA is a Governmental agency and pursuit of profit is not a purpose of NREA, so the profit can be excluded when considering IRR.

Proper level of IRR shall be at a minimum level for implementing the project. The project shall be financed by loan and interest rate of the project shall be covered by the project. Minimum IRR rate shall be 4.2% resulting from former Table 8-3-4 with some buffer and feed-in tariff shall be 266.44USD/MWh from Table 8-3-18.

As 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. This calculation is shown in Appendix 8-2.

Table 8-3-18 Calculation of Feed in tariff

Financial Internal Rate of Return FIRR= 4.20%

Order	Year	Cost			Benefit			Net Cash Balance (B-C)	Accumulation
					Sales Increase due to Production Increase				
		Investment (1,000 $)	O&M (1,000$)	Total (C)	Electricity Production (MWh)	Feed-in tariff (USD)	Total 1,000USD. (B)		
	2014	3,149	0	3,149				-3,149	-3,149
	2015	3,926	0	3,926				-3,926	-7,075
	2016	36,264	0	36,264				-36,264	-43,339
	2017	44,696	0	44,696				-44,696	-88,035
1	2018	4,647	0	4,647	35,130	266.44	9,360	4,713	-83,322
2	2019	4,530	0	4,530	34,591	266.44	9,216	4,686	-78,636
3	2020		529	529	34,052	266.44	9,073	8,543	-70,092
4	2021		529	529	33,513	266.44	8,929	8,400	-61,692
5	2022		682	682	32,974	266.44	8,786	8,103	-53,589
6	2023		529	529	32,435	266.44	8,642	8,113	-45,477
7	2024		529	529	31,896	266.44	8,498	7,969	-37,508
8	2025		529	529	31,357	266.44	8,355	7,825	-29,683
9	2026		529	529	30,818	266.44	8,211	7,682	-22,001
10	2027		10,919	10,919	30,279	266.44	8,068	-2,851	-24,852
11	2028		529	529	30,279	266.44	8,068	7,538	-17,314
12	2029		529	529	30,279	266.44	8,068	7,538	-9,776
13	2030		529	529	30,279	266.44	8,068	7,538	-2,238
14	2031		529	529	30,279	266.44	8,068	7,538	5,300
15	2032		786	786	30,279	266.44	8,068	7,281	12,582
16	2033		529	529	30,279	266.44	8,068	7,538	20,120
17	2034		529	529	30,279	266.44	8,068	7,538	27,658
18	2035		529	529	30,279	266.44	8,068	7,538	35,196
19	2036		529	529	30,279	266.44	8,068	7,538	42,734
20	2037		3,132	3,132	30,279	266.44	8,068	4,935	47,669
Total		97,214	22,932	120,144			167,813	47,669	

Source: prepared by the Team based on the provided data

(3) Feasibility for feed-in tariff

EEHC/EETC may not set feed-in tariff up to the above level because EEHC cannot raise tariff for consumers rapidly. Instead, Egyptian Government is ready for setting Carbon Fund and this Fund compensates tariff difference.

The Team had discussion with the concerned officials of Egyptian electric utility and Consumer Protection Regulatory Agency for seeking their opinion on level of the feed-in tariff. Their opinion was that it is probable to compensate above level of feed-in tariff from Carbon Fund if necessary.

Therefore, the above level of feed-in tariff (including compensation form carbon fund and/or other kind of governmental assistance) can be achieved in the future.

B) CER sales by using renewable resources.

The way of calculation and the amount of benefits are the same as those of the economic benefits.

C) Reducing operation costs of Hurghada thermal power plant by supplying power from high performance batteries at peak load time.

Photovoltaic power system generates power during daytime. However, Energy consumption increases from evening and reach its peak at night in Egypt as stated previously.

An aged gas turbine power plant is operated only at night, to cope with peak load in Hurghada. If high performance storage batteries are implemented by the project, these batteries may be able to replace aged gas turbine power plant.

Table 8-3-19 Distributable energy from storage batteries

Rated capacity	1	MW
Storage capacity	6	MWh
Working days	260	Days
Unserved rate	25	%
Number of battery	2	
Distributable storage power	2,340	MWh

Source: prepared by the Team based on the provided data

Information on costs of gas turbine power plant was not available. Instead, production costs of 5 production companies' from 04/05 to 08/09 shown in Table 8-3-20 are taken into account.

Table 8-3-20 Movement of Production Costs of thermal plants in Egypt

Period	04/05	05/06	06/07	07/08	08/09
Production Costs (1000LE) *	4,513,957	5,428,289	6,114,432	6,888,018	7,606,428
Generated power (GWh) *	74,560	81,565	88,862	95,782	101,898
Costs per MWh (LE)	60.54	66.55	68.81	71.91	74.65
Exchange rate	6.02	5.75	5.79	5.74	5.64
Costs per MWh (USD)	10.06	11.57	11.88	12.53	13.24

* Total of Cairo, East delta, Middle delta, West delta and Upper Egypt production company.

Source of production costs: PL of each production company

Source of generated power: EEHC Annual report from 05/06 to 08/09

Source of Exchange rate: oanda.com historical currency converters

Yearly Increase rate: 0.795 USD/MWh

Production costs per MWh have been increased for these 5 years and this tendency will continue in the near future considering the trend of price escalation in Egypt.

Table 8-3-21 Estimation of costs per MWh

Year	Unit Price (USD)
09/10	14.04
10/11	14.83
11/12	15.63
12/13	16.42
13/14	17.22
14/15	18.01
15/16	18.81
16/17	19.60
17/18	20.40

Source: prepared by the Team based on the provided data

During the project period, estimated price at 17/18; 20.40 USD is applied for FIRR calculation because yearly increase rate of 0.795 USD/MWh is below the local price escalation for this project: 8.8%.

6) Financial Costs

The financial costs consisting of the total implementation costs of this project are indicated below:

A) Implementation Costs

The financial costs are formed by those expenses directly related to the implementation costs, including labor (skilled and unskilled), fuel, machinery, equipment, compensation fees, engineering fees, administration and operation fees, etc., together with those contingency costs related to technical aspects (contingency costs).

B) Administration costs and land acquisition costs

Administration costs are executing agency's administrative costs for performing this project. Land acquisition costs are not taken into account since the land is owned by the project owner.

C) VAT and Custom Duties

VAT (sales tax) is applied to all goods and services. And its rate is assumed as 10%.

In accordance with the Ministerial Decree, Custom Duties for imported materials /equipment to be used for new and renewable energy projects shall be zero.

D) Other costs

Commitment charge is considered.

Table 8-3-22 summarizes financial costs calculated according to the previously mentioned conditions.

The detailed annual breakdown of costs is stipulated in Table 8-3-14.

Table 8-3-22 Project Financial Costs (USD Th.)

	2013	2014	2015	2016	2017	2018
Financial costs	3,149	3,926	36,264	44,696	4,647	4,530

7) Financial Evaluation Results

The Financial evaluation of this project was based on the cash flow of financial costs and benefits analyzed during the process. Results are summarized in Tables 8-3-18 and the outline is presented below.

The relation between the benefit and cost are used in the financial analysis, such as B/C and B-C, which compare the present values of benefit and cost as a ratio and as a difference, respectively.

The FIRR, together with the Net Present Value (NPV) and the Benefit-Cost ratio (B/C), are important indicators to evaluate the financial feasibility of the project. The Financial Internal Rate of Return is defined as follows:

$$\sum_{t=1}^{t=T} \frac{Cf_t}{(1+Rf)^t} = \sum_{t=1}^{t=T} \frac{Bf_t}{(1+Rf)^t}$$

Where,

T = Last year of the project life

Cft = Annual cash flow of the financial cost for this project at the year t

Bft = Annual cash flow of the financial benefit for this project at the year (increase of electricity exchange income)

Rf = Financial Internal Rate of Return

Table 8-3-23 Financial Evaluation Results

Case	FIRR (%)	B/C ratio	B-C (USD Th.)
Base case	4.39	1.01	1,395

The FIRR of 4.39% calculated for this project is higher than the discount rate (for capital establishment) of 4.2%.

Table 8-3-24 FIRR Calculation Sheet

Financial Internal Rate of Return

FIRR= 4.39%

Year Order	Year	Cost			Benefit											
					Power Sales incresase			CER Trading			Operation Costs Reduction			Total B = (i)+(ii)+(iii)	Net Cash Balance (B-C)	Accumulation
		Investment (1,000 $)	O&M (1,000$)	Total (C)	Electricity Production (MWh)	Feed-in tariff (USD)	Sub-Total 1,000USD. (i)	CO2 Saving Amounts (t)	Unit Costs (USD)	Sub-Total 1000USD (ii)	Storaged Energy (MWh)	Unit Cost (USD)	Sub-Total 1000USD (iii)			
	2014	3,149	0	3,149										0	-3,149	-3,149
	2015	3,926	0	3,926										0	-3,926	-7,075
	2016	36,264	0	36,264										0	-36,264	-43,339
	2017	44,696	0	44,696										0	-44,696	-88,035
1	2018	4,647	0	4,647	35,130	266.44	9,360	17,916	4.65	83	2,340	20.40	48	9,491	4,844	-83,191
2	2019	4,530	0	4,530	34,591	266.44	9,216	17,641	4.65	82	2,340	20.40	48	9,346	4,816	-78,375
3	2020		529	529	34,052	266.44	9,073	17,367	4.65	81	2,340	20.40	48	9,201	8,672	-69,703
4	2021		529	529	33,513	266.44	8,929	17,092	4.65	79	2,340	20.40	48	9,056	8,527	-61,176
5	2022		682	682	32,974	266.44	8,786	16,817	4.65	78	2,340	20.40	48	8,912	8,229	-52,947
6	2023		529	529	32,435	266.44	8,642	16,542	4.65	77	2,340	20.40	48	8,767	8,237	-44,710
7	2024		529	529	31,896	266.44	8,498	16,267	4.65	76	2,340	20.40	48	8,622	8,092	-36,617
8	2025		529	529	31,357	266.44	8,355	15,992	4.65	74	2,340	20.40	48	8,477	7,947	-28,670
9	2026		529	529	30,818	266.44	8,211	15,717	4.65	73	2,340	20.40	48	8,332	7,803	-20,867
10	2027		10,919	10,919	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	-2,732	-23,599
11	2028		529	529	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,658	-15,941
12	2029		529	529	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,658	-8,284
13	2030		529	529	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,658	-626
14	2031		529	529	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,658	7,032
15	2032		786	786	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,401	14,432
16	2033		529	529	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,658	22,090
17	2034		529	529	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,658	29,747
18	2035		529	529	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,658	37,405
19	2036		529	529	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	7,658	45,063
20	2037		3,132	3,132	30,279	266.44	8,068	15,442	4.65	72	2,340	20.40	48	8,187	5,055	50,117
Total		97,212	22,932	120,144	629,835		167,813	321,216		1,494	46,800		955	170,262	50,117	

Condition of Discount Rate:	4.2%		
Net Present Value:	96,113	97,508	
Benefit and Cost Ratio (B/C)			1.01451
Benefit and Cost Difference (B-C)			1,395

8) Financial Sensitivity Analysis

Some variation is expected for the construction material costs and other items reflecting the economic situation in Egypt. Consequently the financial benefit calculated for the project will obviously be affected by such variation.

Taking into account the above and in addition to the base case introduced earlier, a total of 8 cases were analyzed where the financial benefits fall 5 and 10%, and the financial costs rise 5 and 10%. Results of this sensitivity analysis are as follows.

Table 8-3-25 Results of FIRR Sensitivity Analysis

	Benefit		
Cost	Base case	-5%	-10%
Base case	4.39%	3.71%	3.01%
+5%	3.75%	3.08%	2.39%
+10%	3.14%	2.49%	1.81%

Results of sensitivity analysis show that if costs or benefits change even 5% worse, there will be low feasibility. However, it should be taken into account that price escalation and contingency which are most important causes of the cost difference, is included in the financial costs. Moreover, in terms of benefits, assistance from carbon fund will not be fixed and further assistance can be expected if revenues are not enough.