

**DETAILED PROJECT REPORT
FOR
GRID INTERACTIVE ROOF TOP SOLAR
PHOTOVOLTAIC POWER PLANT AT
SEWA BHAWAN**



**CENTRAL ELECTRICITY AUTHORITY
SEWA BHAWAN, NEW DELHI
December, 2009**

**GRID INTERACTIVE ROOF TOP SOLAR PHOTOVOLTAIC POWER PLANT
AT SEWA BHAWAN, R.K. PURAM, NEW DELHI**

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GRID INTERACTIVE ROOF TOP SOLAR PHOTOVOLTAIC POWER PLANT AT SEWA BHAWAN, R.K. PURAM, NEW DELHI

Executive summary

The proposed Roof Top Solar Photovoltaic Power Plant at Sewa Bhawan would utilize vacant area of about 375 sq. m. available on the terrace of the north wing of the building. The SPV power plant with proposed capacity of 25 kW_p would be connected to grid. No battery storage has been provided. It would meet partial load of the building during working days and feed the surplus power available to the grid during week end and holidays. The grid connected SPV project would be a demonstration plant to harness renewable energy and the data on generation would be utilized for analysis of the various aspects of operation as also that of availability of power.

The 25 kW_p SPV power plant is estimated to afford annual energy feed of 42 MWh considering efficiency of the solar module as 16%, Inverter/ Power Conditioning Unit (PCU) as 94% and losses as 3% in the DC and AC system. The Plant would operate at an annual capacity utilization factor of 19%. The energy available from the Plant would vary from a minimum of 3.33 MWh during the month of January to a maximum of 4.13 MWh during the month of March.

The SPV Power Plant is estimated to cost Rs. 42.5 lakhs based on the normative cost of Rs. 17 Crores per MW adopted by CERC notification dated 16th September 2009. The tariff for sale of electricity has been worked out adopting the parameters given in the CERC notification and energy generation as presented in this report.

Adopting normative cost estimate and capacity utilization factor, the levelised tariff works out as Rs 18.45 per unit.

GRID INTERACTIVE ROOF TOP SOLAR PHOTOVOLTAIC POWER PLANT AT SEWA BHAWAN, R.K. PURAM, NEW DELHI

Salient features

1. Location

i	State	NCT Delhi
ii	Locality	West Block area, R.K. Puram
iii	Name of Building	Sewa Bhawan
iv	Latitude	77° 12'
v	Longitude	28° 32'

2. Area for SPV Plant

i	Length	25.5m
ii	Width	13.0 m
iii	Location	Terrace of North Wing of Sewa Bhawan (Eastern side of terrace)

3. SPV Power Plant

i	Output	25 kW _p
ii	No. of modules	150
iii	No. of modules in series	5
iv	No. of parallel combination	30
v	DC BUS	1 No.

4. Technical details of a SPV Module

(a)	PV Module type	Poly crystalline
(b)	Physical Dimensions	
i	Length with frame	1580 mm
ii	Width with frame	795 mm
iii	Thickness	40 mm
(b)	Electrical Parameter	
i	Maximum Power Rating	170 kW _p
ii	Rated Current	5 A
iii	Rated Voltage	34 V
iv	Short Circuit Current	6 A
v	Open Circuit Voltage	42.8 V

5. Mounting Arrangement

i	Mounting	Fixed Type
ii	Surface azimuth angle of PV Module	180°
iii	Tilt angle(slope) of PV Module	28.32°

6. Inverter/ Power Conditioning Unit (PCU)

i	Number of units	1
ii	Rated Capacity	27 kWp
iii	Input Voltage range	170 V (Max.)
iv	Output Voltage	440 V AC
v	Frequency	50 Hz
vi	Efficiency	94%

5. Grid Connection Details

i	Electrical parameters for interconnection	440 V, 3Ph ,50 Hz
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6. Annual Energy Generation

i	Annual Energy	42 MWh
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7. Cost Estimate

i	Estimated Cost (Rs. Lakh)	42.5
ii	Cost per kW (Rs.Lakh)	1.7

8. Cost of Energy Generation

i	Levelised Tariff (Rs/kWh)	18.45
ii	Cost of Generation (Rs/kWh)	10.54

11. Construction Time

5 months

GRID INTERACTIVE ROOF TOP SOLAR PHOTOVOLTAIC POWER PLANT AT CEA HEADQUARTER AT SEWA BHAWAN, R.K. PURAM, NEW DELHI

1. INTRODUCTION:

Harnessing of non polluting renewable energy resources to control green house gases is receiving impetus from the government of India. The solar mission, which is part of the National Action Plan on Climate Change has been set up to promote the development and use of solar energy in for power generation and other uses with the ultimate objective of making solar energy competitive with fossil-based energy options. The solar photovoltaic device systems for power generation had been deployed in the various parts in the country for electrification where the grid connectivity is either not feasible or not cost effective as also some times in conjunction with diesel based generating stations in isolated places and communication transmitters at remote locations. With the downward trend in the cost of solar energy and appreciation for the need for development of solar power, solar power projects have recently been implemented. A significant part of the large potential of solar energy in the country could be developed by promoting grid connected solar photovoltaic power systems of varying sizes as per the need and affordability coupled with ensuring adequate return on investment. It has been proposed to set up a 25 kWp grid connected solar photovoltaic power plant on the roof top terrace of the north wing of Sewa Bhawn as a pilot project.

The 25 kWp SPV system at roof-top of Sewa Bhawan, is estimated to afford annual energy generation of 42 MWh and operate at a capacity factor of 19%. The SPV system estimated to cost Rs. 42.5 lakhs would have a levelised tariff of Rs. 18.45 Per kWh base on CERC norms.

2. LOCATION:

Sewa Bhawan is situated in the West Block area at R.K.Puram in New Delhi bounded by inner ring road (Mahatma Gandhi road) in the north and outer ring road in the south and the Bhikaji Cama place on the east. Sewa Bhawan houses the head office of Central Electricity Authority, Central Water

Commission, Bureau of Energy Efficiency (BEE), Registrar office of census and sub-offices of CPWD. The location of the site is shown in the **Exhibit – I**.

3. SITE DESCRIPTION:

The Sewa Bhawan has two wings known as north wing and south wing. The lay out of the rooftop terrace is shown in the **Exhibit – II**. The terrace on the north block has communication antennas and an area of about 375 sq meters is vacant which could be used for SPV installation of 25 kWp. The terrace of the south wing having an area of about 1000 sq. meters is vacant and could also be used for larger size SPV installation. It is proposed to utilize the vacant area available on the north wing for installation of 25 kWp which could serve as a grid connected demonstration system and could be used for collection of data for analysis on the of availability of solar power. The development on the south wing terrace could be taken up later.

4. EXISTING POWER SUPPLY ARRANGEMENTS:

4.1. BRPL Supply

Electrical Power requirement for Sewa Bhawan is met from two sources of BRPL viz Main supply from sub-station Sector-1 and sub-station Sector-9, R. K. Puram. The power received at 11 kV level is stepped down to .4 kV by 4 Nos. dry type 11/ 0.4 kV, 4x1600 kVA distribution transformers located at the S/S in the ground floor of the Sewa Bhawan building. The load of north wing where the office of CEA is located is fed from transformers (TR-3 & TR-4). The maximum load for CEA is to be around 1-1.2 MW (1600 -1800 Amp). A 4x600 kVA capacitor bank has also been provided to improve the power factor.

The Sub-station at Sewa Bhawan is operated and maintained by officers and operators of CPWD. The changeover of power supply from main to alternate is, however, under the control of BRPL.

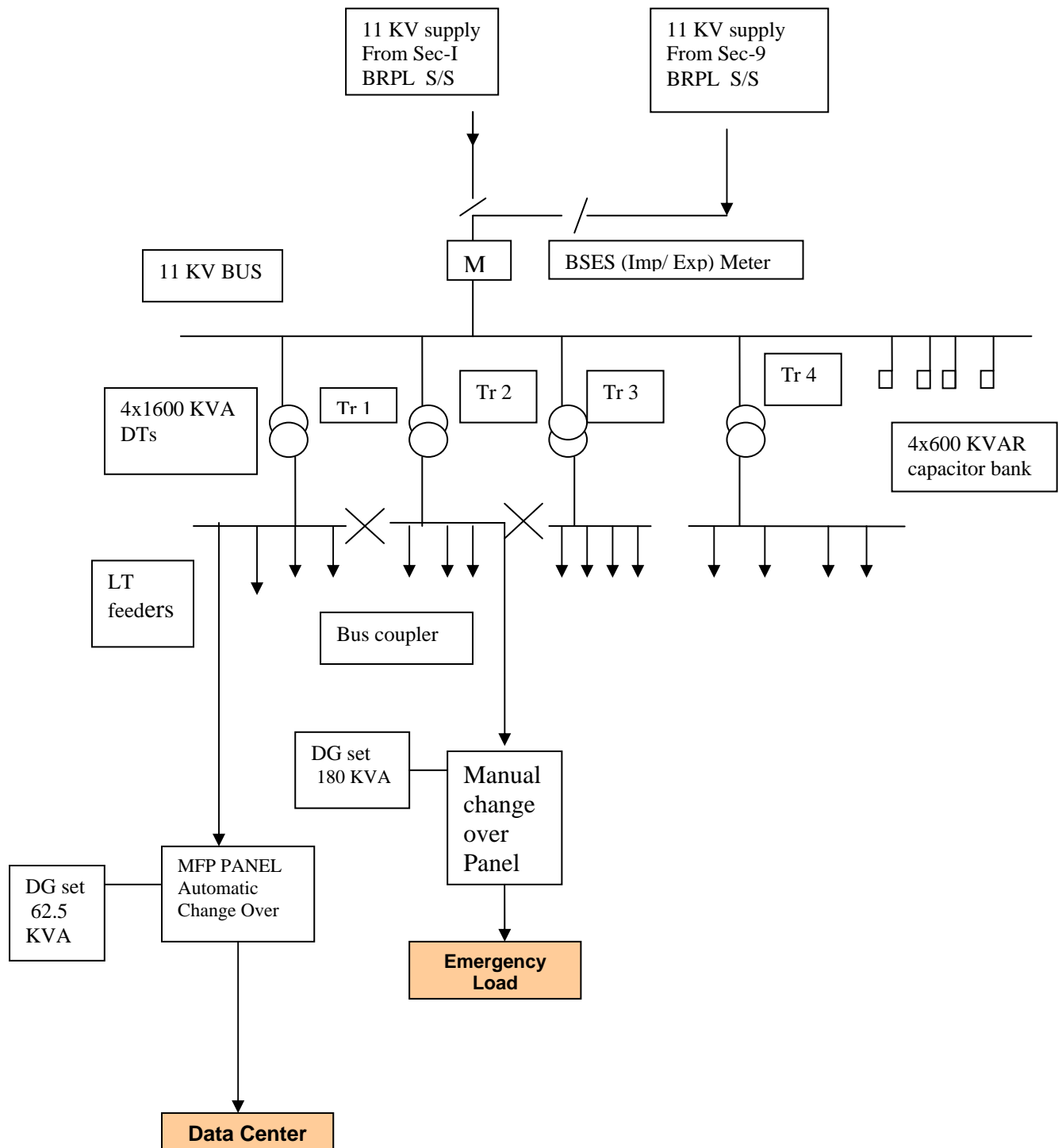
4.2. Emergency Power Supply

DG set of 1x180 kVA capacity has been installed for providing back up supply to important services like lifts, corridor lights, chairman & Members office and essential lighting in the building during the period of load shedding.

A 62.5 kVA DG set has also been installed to provide standby supply to the Data Centre located on the 3rd floor and Servers of Network Operation Control (NOC) Centre of NIC located on the 5th floor in the event of failure of Mains power supply. This DG set has been arranged on hire-purchase basis and its O&M is carried out by the vendor itself.

4.3. LV Distribution System

The load of CEA is fed from transformer (Tr-3 &Tr-4) through LT feeders. LT system is maintained by CPWD. The single line diagram of the supply system is given below.



5. FUNCTIONAL DESCRIPTION OF SPV POWER SYSTEM:

- 5.1 The solar PV system shall be designed with either mono/ poly crystalline silicon modules or using thin film photovoltaic cells or any other superior technology having higher efficiency.
- 5.2 Three key elements in a solar cell form the basis of their manufacturing technology. The first is the semiconductor, which absorbs light and converts it into electron-hole pairs. The second is the semiconductor junction, which separates the photo-generated carriers (electrons and holes), and the third

is the contacts on the front and back of the cell that allow the current to flow to the external circuit. The two main categories of technology are defined by the choice of the semiconductor: either crystalline silicon in a wafer form or thin films of other materials.

5.3 The grid interactive roof top solar PV system generally comprises the following equipment.

- i. SPV Power Source
- ii. Inverter (PCU)
- iii. Mounting Structure
- iv. AC and DC Cables
- v. Earthing equipment /material
- vi. Junction Boxes or combiners
- vii. Instruments and protection equipments

5.4 Photovoltaic solar system use the light available from the sun to generate electricity and feed this into the main electricity grid or load as the case may be. The PV panels convert the light reaching them into DC power. The amount of power they produce is roughly proportional to the intensity and the angle of the light reaching them. They are therefore positioned to take maximum advantage of available sunlight within siting constraints. Maximum power is obtained when the panels are able to 'track' the sun's movements during the day and the various seasons. However, these tracking mechanisms tend to add a fair bit to the cost of the system, so a most of installations either have fixed panels or compromise by incorporating some limited manual adjustments, which take into account the different 'elevations' of the sun at various times of the year. The best elevations vary with the latitude of the load location.

5.5 The power generating capacity of a photovoltaic system is denoted in Kilowatt peak (measured at standard test conditions of solar radiation of 1000 W per m^2). A common rule of thumb is that average power is equal to 20% of peak power, so that each peak kilowatt of solar array output power corresponds to energy production of 4.8 kWh per day (24 hours x 1 kW x 20% = 4.8 kWh)

5.6 Solar photovoltaic modules can be developed in various combinations depending upon the requirements of the voltage and power output to be taken from the solar plant. No. of cells and modules may vary depending upon the manufacturer prudent practice.

5.7 **Inverter**

- i. The DC power produced is fed to inverter for conversion into AC.
- ii. The output of the inverter must synchronize automatically its AC output to the exact AC voltage and frequency of the grid.
- iii. Inverter Efficiency of 94% is considered in the PV system.

5.8 Protection and Controls:

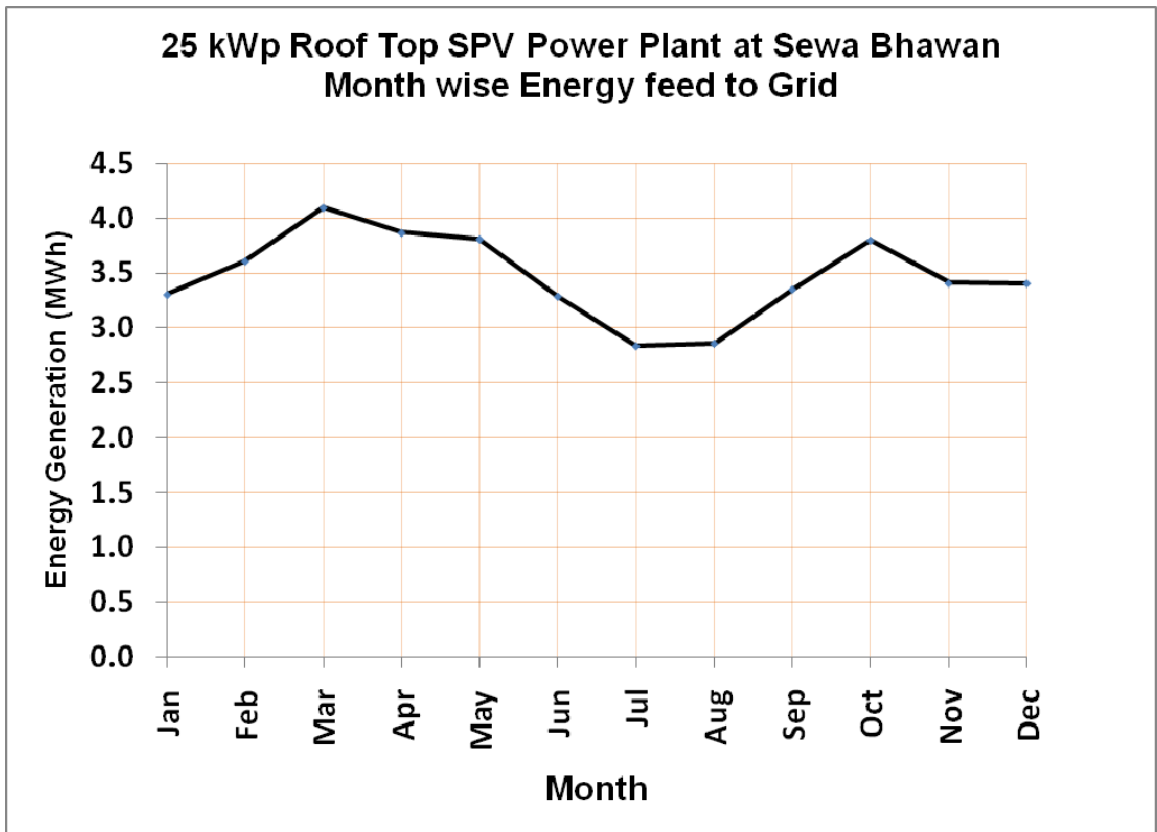
- i. Inverter shall be provided with islanding protection to isolate it from the grid in case of no supply, under voltage and over voltage conditions so that in no case there is any chance of accident.
- ii. In addition to above, PV systems shall be provided with adequate rating fuses, fuses on inverter input side (DC) as well as output side (AC) side for overload and short circuit protection and disconnecting switches to isolate the DC and AC system for maintenances are needed.
- iii. Fuses of adequate rating shall also be provided in each solar array module to protect them against short circuit.

6. ARRANGEMENT :

The general layout arrangement of the SPV panels is shown in the drawing given at **Exhibit – III** and installation details of the panels are shown in the **Exhibit - IV**.

7. ANNUAL ENERGY GENERATION:

The annual energy generation from the SPV power plant has been worked out based on the data on mean global solar radiant exposure over Delhi at Safdarjung. The mean global solar radiant exposure varies from 3.72 kWh/m² /day in the month of December to 7.08 kWh/m² /day in the month of May. The month-wise mean global solar radiant exposure is given at **Annex-I**. Considering the efficiency of PV module at 16% and temperature coefficient of 4.4 % per °C, the annual energy generation feed into the grid is estimated as 42 MWh. This takes into consideration an efficiency of the Power Conditioning Unit (PCU) as 94% and losses in the DC and AC system as 3% each up to the point of interconnection. The month wise energy generation during the year is given at **Annex-II** and shown below.



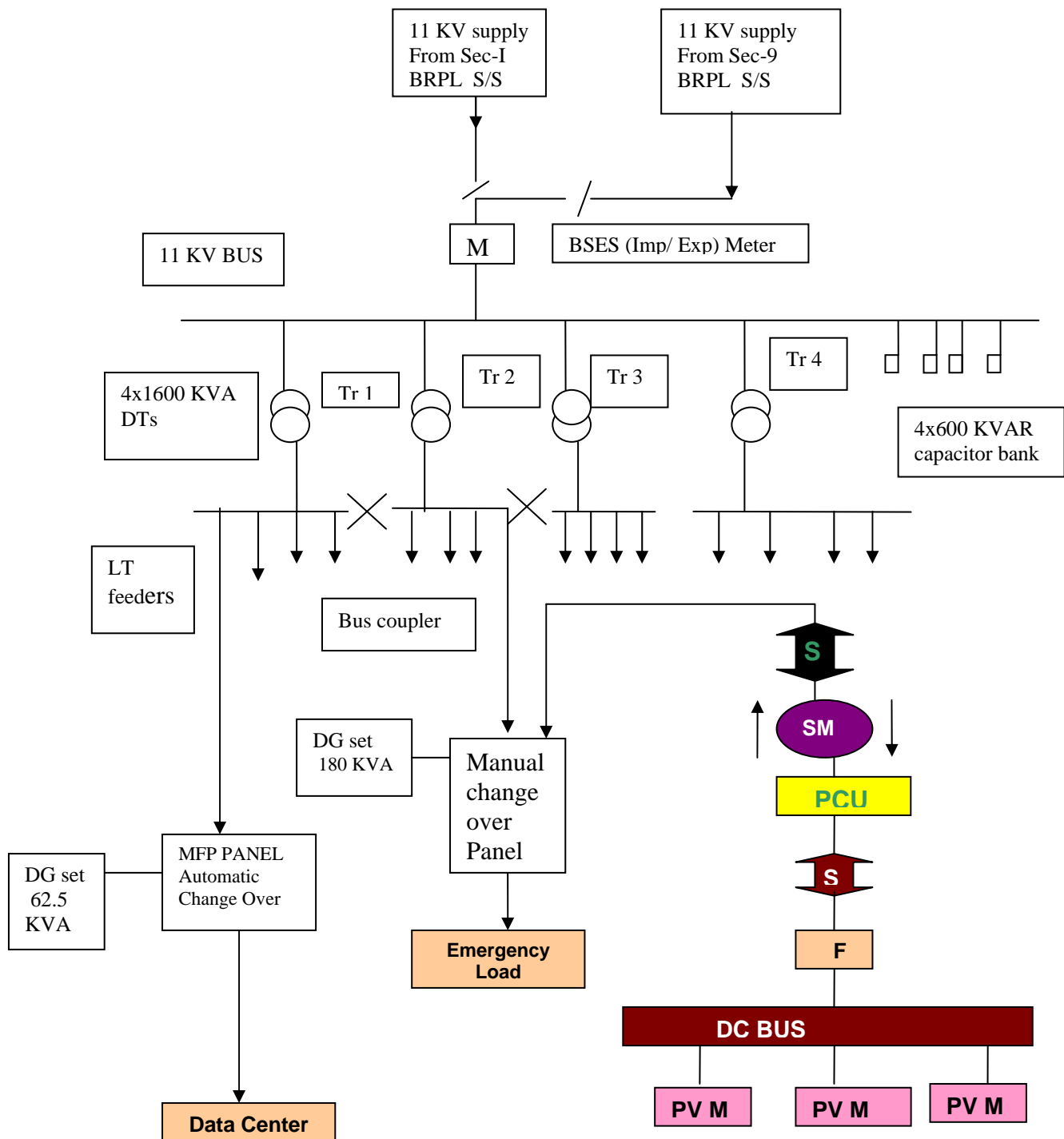
The energy available from the Plant would vary from a minimum of 3.33 MWh during the month of January to a maximum of 4.13 MWh during the month of March .

The annual capacity utilization factor works out as 19.2%. The month wise capacity utilization factor is also shown in the **Annex-III**.

8. INTEGRATION OF PV POWER WITH GRID:

- 8.1 The out put power from SPV would be fed to the inverter which converts DC produced by SPV array to AC and feeds it into the main electricity grid after synchronization. In case of grid failure, or low or high voltage, solar PV system shall be out of synchronization and shall be disconnected from the grid. Once the DG set comes into service PV system shall again be synchronized with DG supply and load requirement would be met to the extent of availability of power.

- 8.2 Inverter shall have the software and controls capable of operating the complete system for safe and efficient operation and includes the Islanding protection, Over voltage/ under voltage protection, Ground fault /short circuit protection system, communication equipment such as modems, web box etc, DC reverse polarity protection, Grid monitoring of all the phases & pole sensitive residual current monitoring unit, protection against voltage fluctuations in the grid & protection against internal faults in the power conditioner, operational errors and switching transients etc.
- 8.3 The out put power from inverter would be fed to the panel of 180 KVA DG set at CPWD S/S at Sewa Bhawan. The solar power would be used locally in Sewa Bhawan on working days to the extent of load in the building and the generation over and above the requirement of the building would be fed into the grid. On the week end and other holidays, almost the entire energy from the SPV module would be fed into the grid. The connection of the grid connected SPV power plant with the existing power supply system is shown in the diagram below.



9. METERING SCHEME:

9.1 The above project is demonstration project as such measurement is proposed to be carried out on small intervals. It is proposed to measure the Solar Gross Generation on 15 minute interval basis besides measurement of DC battery voltages, DC current, AC system voltages and current, frequency, Total harmonics current and voltage distortion etc.

9.2 An Import/Export meter has already been installed by BSES at the entry point of 11kV incoming underground cable for metering for billing purpose which would also serve the purpose of registering the net export and import to the grid. A meter would also be installed at the out put side of the inverter to register the energy output from the SPV power plant. The meter would have necessary registers for recording and storing the information on 15 minutes time interval basis. The operational data of the SPV power plant shall be used for analysis.

10. POWER QUALITY REQUIREMENTS:

10.1 **DC Injection into the grid:** The injection of DC power into the grid shall be avoided by using an isolation transformer at the output of the inverter. It is proposed to limit DC injection within 1% of the rated current of the inverter as per IEC 61727.

10.2 Harmonics on AC side

- i. Harmonic distortion is caused principally by non-linear load such as rectifiers and arc furnaces and can affect the operation of a supply system and can cause overloading of equipments such as capacitors, or even resonance with the system leading to overstressing (excessive voltage & current). Other effects are interference with telephone circuits and broadcasting, metering errors, overheating of rotating machines due to increased iron losses (eddy current effects), overheating of delta connected winding of transformer due to excessive third harmonics or excessive exciting current.
- ii. The limits for harmonics shall be as stipulated in the CEA Regulations on grid connectivity which are as follows:
 - a. Total Voltage harmonic Distortion= 5%
 - b. Individual Voltage harmonics Distortion=3%
 - c. Total Current harmonic Distortion=8%

10.3 **Voltage Unbalance-**The Voltage Unbalance at 33 kV and above shall not exceed 3.0%

10.4 Voltage Fluctuations

- (i) The permissible limit of voltage fluctuation for step changes which may occur repetitively is 1.5%.
- (ii) For occasional fluctuations other than step changes the maximum permissible limits is 3%.
- (iii) The limits prescribed in (i) and (ii) above shall come into force not later than five years from the date of publication of these regulations in the Official Gazette.

11. COMMUNICATION INTERFACE:

11.1 The project envisages a communication interface which shall be able to support (These facilities are being provided as this is a demonstration project)

- Real time data logging
- Event logging
- Supervisory control
- Operational modes
- Set point editing

11.2 Communication System shall be an integral part of inverter. All current values, previous values up to 40 days and the average values of major parameters shall be available on the digital bus.

11.3 The following parameters shall be measured, displayed and recorded/logged. Daily plotting of graphs for various parameter shall also be available on demand. (These facilities are being provided as this is a demonstration project)

- i) 15 minute, Daily, monthly & Annual energy generated by the solar system (kWh)
- ii) Solar system temperature
- iii) Ambient temperature
- iv) Solar irradiation/isolation
- v) AC and DC side voltage and currents
- vi) Power factor on AC side
- vii) DC injection into the grid (one time measurement at the time of installation)
- viii) Total Current Harmonics distortion in the AC side
- ix) Total Voltage Harmonic distortion in AC side
- x) Efficiency of the inverter
- xi) Solar system efficiency
- xii) Display of I-V curve of the solar system
- xiii) Any other parameter considered necessary by supplier of the solar PV system based on prudent practice.

11.4 Data logger system and the software for study of effect of various environmental & grid parameters on energy generated by the solar system and various analysis would be required to be provided.

11.5 The communication interface shall be suitable to be connected to local computer and also remotely via the Web using either a standard modem or a GSM / WIFI modem.

12. ESTIMATES OF COST:

Based on the normative cost adopted by CERC the cost is estimated as Rs.42.5 Lakh.

13. PHASING OF EXPENDITURE:

The implementation of the SPV Power Plant could be achieved in a period of 5-6 months. The indirect expenditure would therefore be in the year in which the plant is to be installed.

14. COST OF ENERGY GENERATION & TARIFF:

The Tariff for the sale of energy from the SVP Power Plant at Sewa Bhawan has been worked out considering that equity ratio of 70:30. The interest rate on the loan has been adopted as 12.79 % based on the prime landing rate (PLR) as per CERC. The salvage value of the project has been considered at 10% and the depreciation has been based on the differential depreciation approach as per the CERC Notification dated 16th September, 2009. The depreciation of 7% has been adopted during the 1st 10 years and based on straight-line method for remaining useful life. The interest rate on the working capital has been adopted as 13.79 % based on the prime lending rate of CERC. The working capital has been worked out based on the CERC norms. The O & M expenses have been adopted at the rate of Rs.9 lakh / MW for the first year operation and escalated @ 5.72% / annum. The data sheet indicating the various parameters adopted in the computation of the Tariff as per CERC norms is enclosed as **Annex-IV**.

The computations for tariff have been made in the Performa template given in the CERC Notification. The computations are enclosed at **Annex-V**.

The cost of generation at different discount rates using discounted cash flow studies works out as under.

15. BILL OF MATERIAL

The bill of material is enclosed in **Annex.VI**.

16. IMPLEMENTATION OF WORK:

The solar panel and other associated equipment are indigenously manufactured in the country. The implementation of the plant could, therefore, be achieved in 5 to 6 months. The work would be awarded through limited tender on turn key basis to selected companies having experience in the design engineering, testing & commissioning of SPV system in India like BHEL, CEL, TATA SOLAR BP, Moser Bear, etc.

17. CONSTRUCTION SCHEDULE:

A construction schedule for the installation of 25 kWp Power Plant at Sewa Bhawan indicating the various activities is enclosed as **Annex-VII**

**Mean Global Solar Radiant Exposure
Safdarjung, New Delhi**

Month	Daily solar radiation - horizontal
	kWh/m ² /d
Jan	3.75
Feb	5.03
Mar	6.00
Apr	6.75
May	7.08
Jun	6.47
Jul	5.14
Aug	4.92
Sep	5.50
Oct	5.22
Nov	4.19
Dec	3.72
Annual	5.31

25 kWp Roof Top SPV at Sewa Bhawan

Pattern of Energy Generation

Month	Export to Grid (MWh)
Jan	3.333
Feb	3.641
Mar	4.133
Apr	3.903
May	3.844
Jun	3.316
Jul	2.859
Aug	2.883
Sep	3.382
Oct	3.833
Nov	3.437
Dec	3.436
Annual	42.00

Assumption:

Losses in DC circuit	3%
Converter efficiency	92%
Lossess in AC circuit	3%

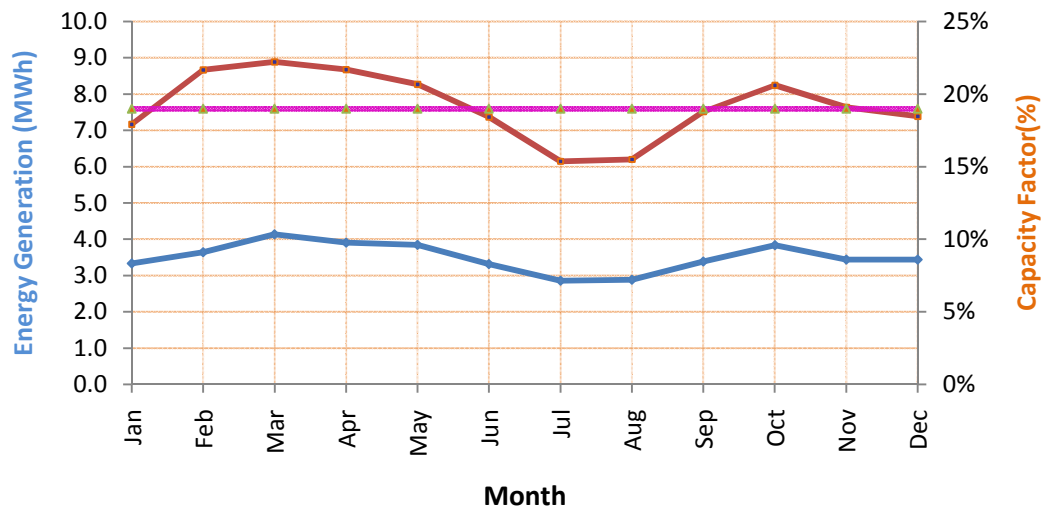
25 kWp Roof Top SPV at Sewa Bhawan

Capacity Utilisation Factor

Month	Capacity Utilisation Factor (%)
Jan	17.9%
Feb	21.7%
Mar	22.2%
Apr	21.7%
May	20.7%
Jun	18.4%
Jul	15.4%
Aug	15.5%
Sep	18.8%
Oct	20.6%
Nov	19.1%
Dec	18.5%
Annual	19.2%

25 kWp Photovoltaic Roof Top Power Plant Pattern of Energy Generation & Capacity Factor

Annex-III



Tariff determination for SPV System

As per CERC notification No L-7/186(201)/2009-CERC dated 16th September 2009

Sl No	Parameter	Value
1	Useful Life of Solar PV System (Year)	25
2	Capital Cost (Rs Lakhs/MW) - normative	1700
3	Capacity Utilisation factor (%) - normative	19
4	O&M Charges (Rs Lakhs/MW)	9
5	Escalation (%)	5.72
6	Tariff Period (Year)	25
7	Debt (%)	70
8	Equity (%)	30
9	Salvage Value (%)	10
10	Loan Tennure (Year)	10
11	Interest rate (%)	11.75
12	Depreciation first 10 year (%)	7
13	Depreciation 10-25 year (%)	1.33
14	Working Capital (Rs Lakhs)	
14(a)	O&M (Rs Lakhs)	one month
14(b)	Receivable (Rs Lakhs)	two months
14(c)	Maintenance Spare (Rs Lakhs)	15% of O&M expenses
15	Interest on working capital	13%
Project Specific		
1	Capital Cost (Rs Lakhs)	45
2	Annual Energy (MWh)	42

Annex-V

NAME OF PROJECT:
Based on CERC Regulation 2009

INPUT DATA SOLAR PV POWER PROJECT

Capital cost	0.425	Crores	Debt	70.00%	Int.Rate	14.29%	p.a. (PLR +150 BP)
Debt	0.30	Crores	Equity	30.00%	Rep.Period	10.00	years
Equity	0.13	Crores			O&M	9.00	Lakhs / MW
					O&M Esc.	5.72%	p.a.
					Int.W/C	13.79%	p.a.
Plant Life	25.00	Years			Maint. spares	15.00%	of O&M
					Spares Escl.	5.72%	
Capacity	0.025	MW			ROE (base rate)	19.00%	24%
Aux consumption	0.00%				Discount Rate %	16.60	
PLF	19.00%				Depreciati rate	7.00%	p.a. for 1st 10 years
Deprecn.(90% Cap. Cost)	0.38	Crores			Discount Rate	16.6030	
Derecn.(First 10 years)	0.30	Crores			(based on cost of capital)		
Tax Rate(30%+10%+3%)	33.99%						
Minimum Alt. Tax.	17.00%						
RoE for 19% for 1st	10	Years					
Generation	0.04	MU					
Net Gen.	0.04	MU					
					Loan	Int.Rate	Rep. Period
					Debt Pack. I	0.30	14.29%
							10.00
					Debt Pack.II	0.00	0.00
							0.00

12.79% PLR as per CERC

CALCULATION OF FIXED COST

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Int. paymt(Debt Pkg I)																									
opening balance	0.30	0.27	0.24	0.21	0.18	0.15	0.12	0.09	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Normative Loan repayment	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
closing Balance	0.27	0.24	0.21	0.18	0.15	0.12	0.09	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Charged	0.27	0.24	0.21	0.18	0.15	0.12	0.09	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
interest payment	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Int. paymt(Debt Pkg II)																									
opening balance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Repayment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
closing Balance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
interest payment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Interest	Rs Cr.	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Working Capital																									
O&M (1 month)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spares	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Receivables 2months	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total w/c	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Interest on W/C Rs. Crs.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

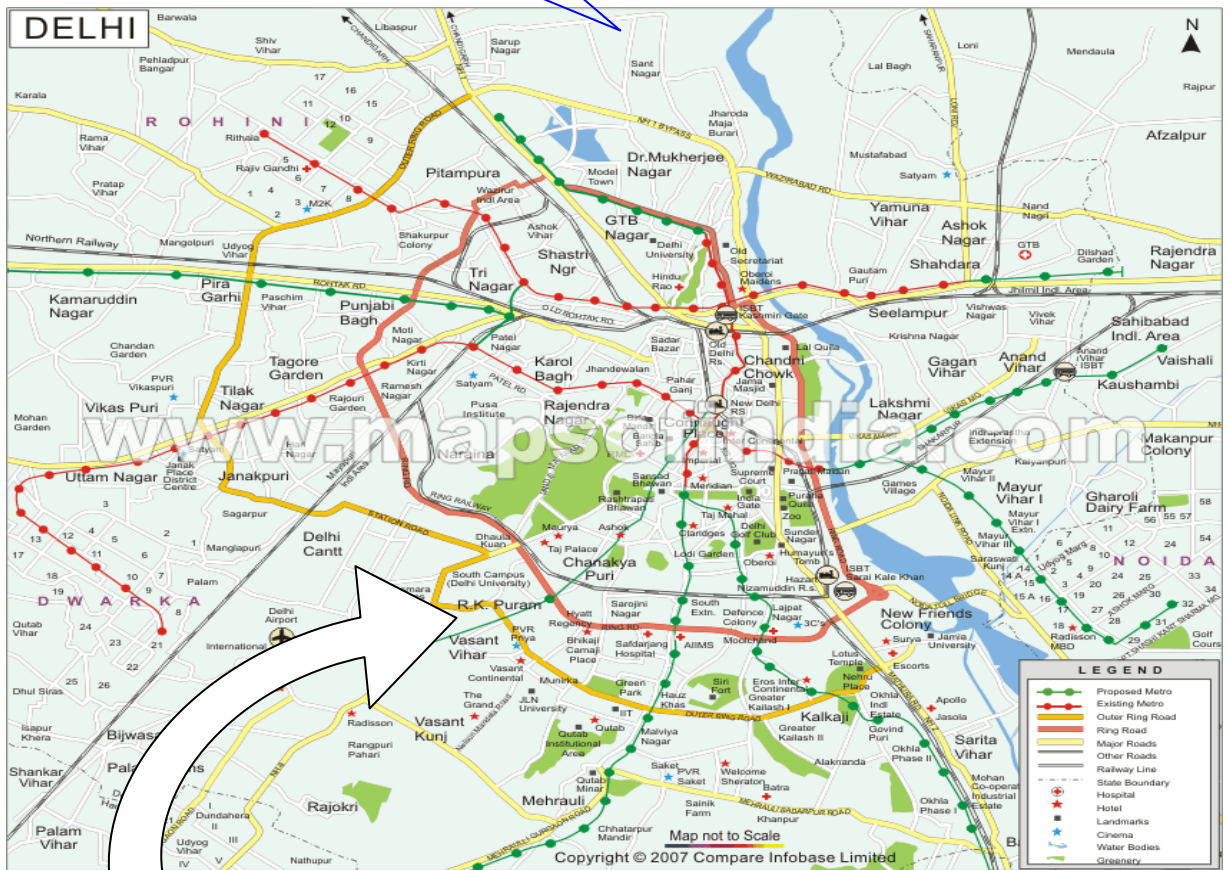
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Annual Fixed Cost																									
Interest payment	Rs. Crs.	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Rs/kwh	9.706	8.684	7.663	6.641	5.619	4.598	3.576	2.554	1.533	0.511	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Depreciation (CERC)	Rs. Crs.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Rs/kwh	7.150	7.150	7.150	7.150	7.150	7.150	7.150	7.150	7.150	1.362	1.362	1.362	1.362	1.362	1.362	1.362	1.362	1.362	1.362	1.362	1.362	1.362	1.362	1.362
O&M	Rs. Crs.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Rs/kwh	0.541	0.572	0.604	0.639	0.675	0.714	0.755	0.798	0.844	0.892	0.944	0.998	1.056	1.116	1.180	1.250	1.321	1.397	1.477	1.561	1.655	1.750	1.850	1.956
Return on Equity	Rs. Crs.	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	Rs/kwh	5.822	5.822	5.822	5.822	5.822	5.822	5.822	5.822	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354	7.354
Interest on W/C	Rs. Crs.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Rs/kwh	0.564	0.542	0.520	0.497	0.475	0.454	0.432	0.410	0.389	0.368	0.258	0.261	0.265	0.268	0.272	0.276	0.280	0.284	0.288	0.293	0.298	0.304	0.309	0.315
Total Fixed cost	Rs. Crs.	0.099	0.095	0.091	0.086	0.082	0.078	0.074	0.070	0.065	0.061	0.041	0.042	0.042	0.042	0.042	0.043	0.043	0.043	0.044	0.044	0.044	0.045	0.045	0.046
	Rs/kWh	23.782	22.769	21.758	20.749	19.742	18.737	17.734	16.734	15.737	14.742	9.919	9.976	10.036	10.100	10.167	10.241	10.317	10.396	10.481	10.570	10.669	10.769	10.875	10.987
Discount Factor	16.60%	1	0.86	0.74	0.63	0.54	0.46	0.40	0.34	0.29	0.25	0.22	0.18	0.16	0.14	0.12	0.10	0.09	0.07	0.06	0.05	0.05	0.04	0.03	0.03
Discounted Cost (Rs/kWh)		23.782	19.527	16.003	13.088	10.679	8.693	7.056	5.710	4.605	3.700	2.135	1.841	1.589	1.371	1.184	1.023	0.883	0.764	0.660	0.571	0.494	0.428	0.371	0.321
Levelised Tariff		18.45																							
Discounted Annual Fixed Cost components (Rs. / kWh)																									
Return on Equity		5.822	4.993	4.282	3.672	3.149	2.701	2.316	1.987	1.704	1.461	1.583	1.357	1.164	0.998	0.856	0.734	0.630	0.540	0.463	0.397	0.341	0.292	0.251	0.215
Interest on Loan		9.706	7.448	5.636	4.189	3.040	2.133	1.423	0.872	0.448	0.128	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Depreciation		7.150	6.132	5.259	4.510	3.868	3.317	2.845	2.440	2.092	1.794	0.293	0.251	0.216	0.185	0.159	0.136	0.117	0.100	0.086	0.074	0.063	0.054	0.046	0.040
Interest on working capital		0.564	0.465	0.382	0.314	0.257	0.210	0.172	0.140	0.114	0.092	0.056	0.048	0.042	0.036	0.032	0.028	0.024	0.021	0.018	0.016	0.014	0.012	0.011	0.009
O&M expenses		0.541	0.490	0.445	0.403	0.365	0.331	0.300	0.272	0.247	0.224	0.203	0.184	0.167	0.152	0.137	0.125	0.113	0.103	0.093	0.084	0.077	0.070	0.063	0.05

BILL OF MATERIAL FOR 25 KW SOLAR PV SYSTEM FOR SEWA BHAWAN

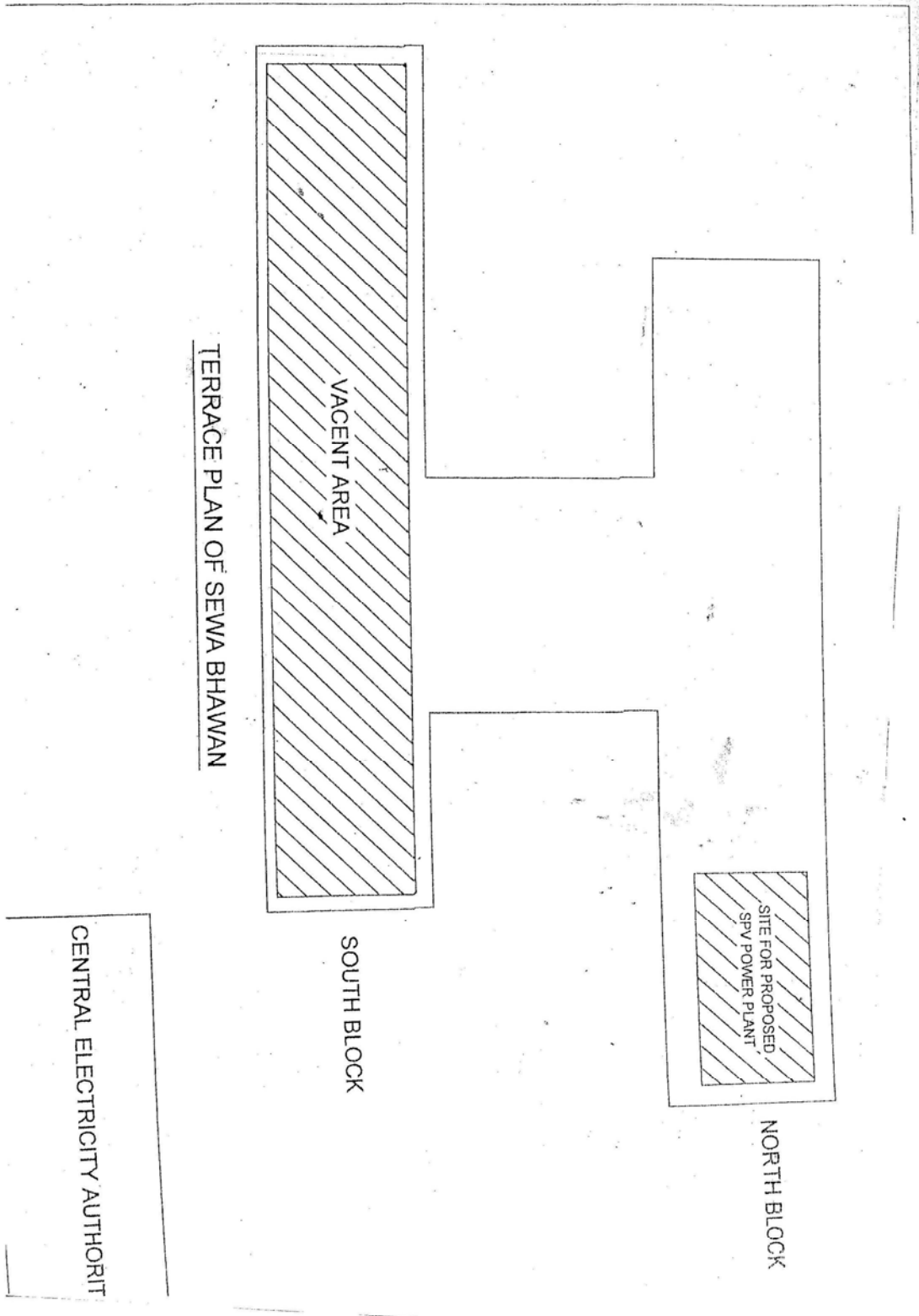
(5 module in series & 30 module in parallel)

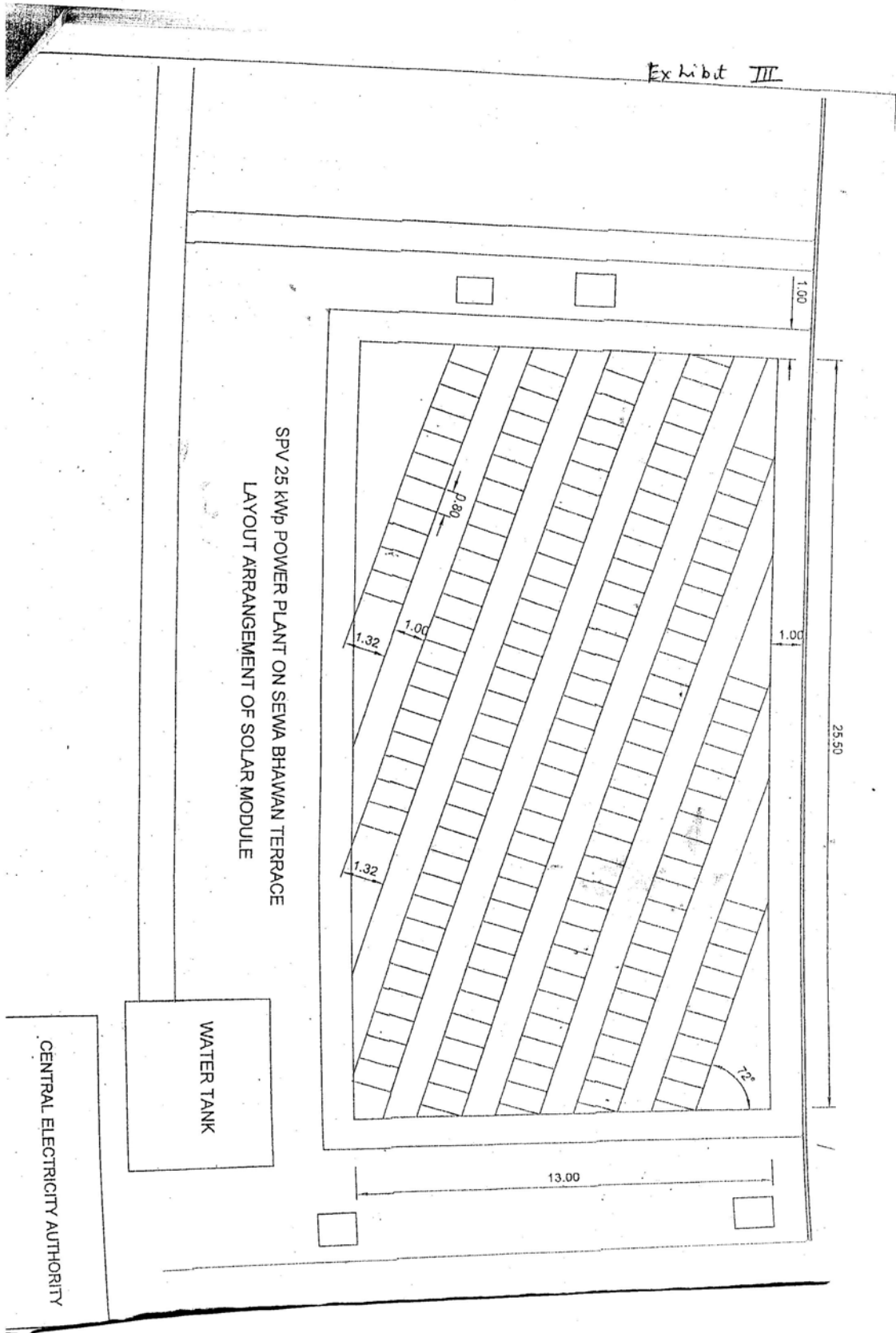
SI No	Component Name	Type and / or Model No	Description of Components	Quantity/ System
1	SPV Module	170 Wp or equivalent	@ 5 Amps/module Total DC current (30x5) = 150 Amps (AC O/p current = 32 Amps, 3 Ph)	sets of 150 nos SPV module (30 in parallel and 5 in series)
2	Structure	Module type	MS Hot dip galvanized steel	
3	Field Junction Box	Reputed make	Dust & water proof	5 nos of 40 Amps each
4	Main Junction Box	Reputed make 2x100 Amps	Dust & water proof	2 no
5	Grid-Tie Inverter Rating	180 V D/C – input 415 V AC - output	30 KW power rating with synchronizer & meter equipped with data logging facilities	1 no
6	Ground Fault Protection System		Included at inverter	1 No
7	Cordless Modem, Web Box etc		N A	1 set
8	Cables	Conforming to BIS	25 sq mm PVC cables	As per site conditions
9	Lightening Arresters			2 No
10	Earthing	Reputed make		2 sets

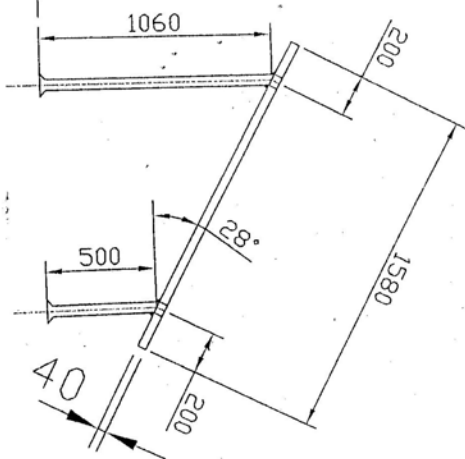
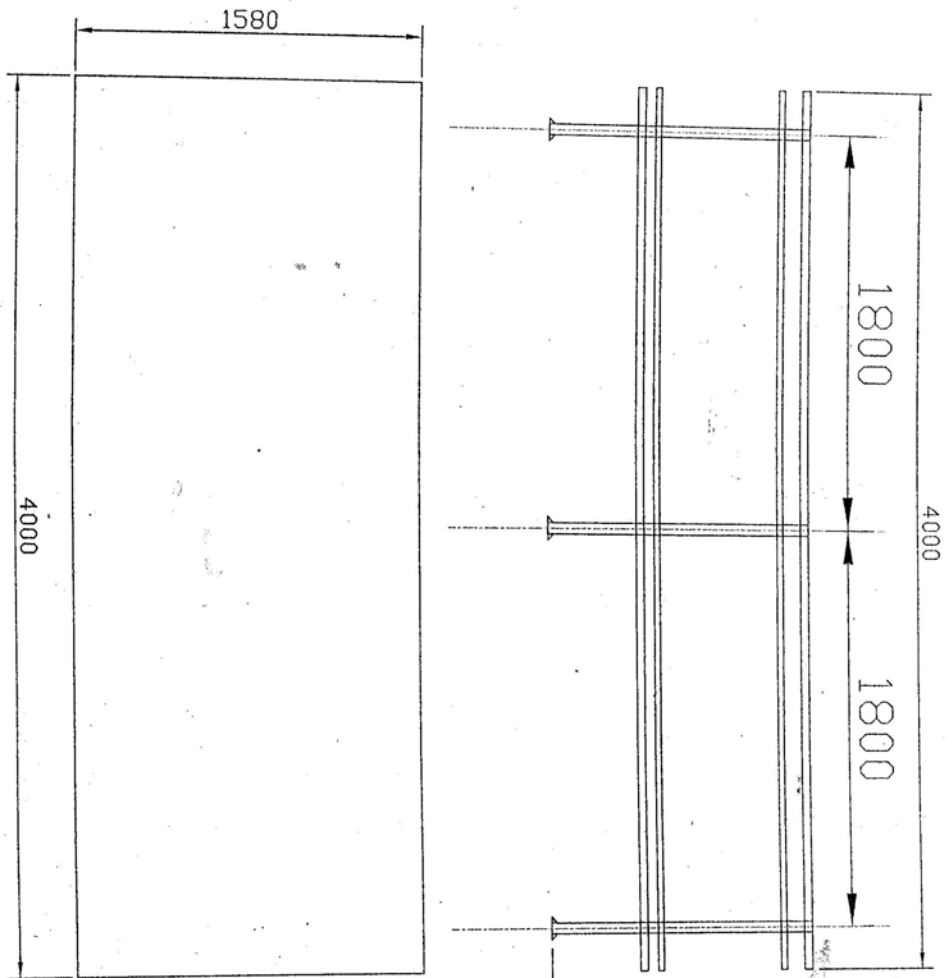
LOCATION MAP OF SEWA BHAWAN, R K PURAM, NEW DELHI



Sewa Bhawan, R K Puram, New Delhi
 (28° 34' 2.02")
 (77° 10' 44.93")







CENTRAL ELECTRICITY AUTHORITY
TENTATIVE PV MODULE STRUCTURE
5 Nos. x 170 Wp Array