Indian Journal of Science and Technology, *Vol 10(27), DOI: 10.17485/ijst/2017/v10i27/111510, July 2017*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Installation and Commissioning of a 100 kW Rooftop Solar PV Power Plant

Akhilesh A. Nimje* and Pankaj R. Sawarkar

*Department of Electrical Engineering, Institute of Technology, Nirma University, Gujarat – 382481, Ahmedabad, India; akhilesh.nimje@nirmauni.ac.in
Department of Electrical Engineering, Ramdeobaba College of Engineering and Management, Nagpur – 440013, Maharashtra, India; sawarkarp@rknec.edu

Abstract

Objectives: The grid connected rooftop solar photovoltaic system is gaining momentum. The feasibility study of its installation, testing, commissioning and grid connectivity issues is a must. The analysis of economic benefits in comparison with electricity charges as per utility and the payback period is prime requirement. The objective is to integrate solar power with grid and share a greater portion of solar power for the local use and contribute the solar power installed capacity of the nation **Methods/Statistical Analysis**: The paper gives a comprehensive study of site information, plant architecture, layout, single line diagram and test results prior to commissioning. An operation and maintenance sheet has been maintained to track the various parameters such as voltage, current and power both on DC and AC mains for individual inverters. The average V_{DC}, I_{DC} and P_{DC} has been found to be 620 volts, 32 Amps, 20 kW respectively from 11 am to 4 pm on bright sunny days. Similarly, V_{AC}, I_{AC} and P_{AC} were noted to be 440 volts, 27 Amps, 20 kW respectively.**Findings:** During light loading in the institute, the power flow from solar to grid was evidenced through net meters installed by the utility. This relieved the institute management to pay heavy electricity charges. The electricity charge by the utility for HT consumer was Rs.10 per kWh whereas the solar charges were paid at the rate of Rs. 6.4. This resulted in a significant cost saving. **Application/Improvements:** The power taken from grid during 11 am to 4 pm has been reduced from an average 45 kWh to 12 kWh per hour. The scheme is well suited for large commercial complex, residential buildings and offices. It can be implemented with battery back up in remote villages which has poor access to electricity.

Keywords: I5-6 Words, Drawn from Title, Word Representing the Work

1. Introduction

Electricity is the backbone of industrialization and has become an integral part of mankind. Its increasing usage pattern by all sectors has necessitated to augment the generation since independence. The drastic increase in generation capacity of 1465 MW (1947) to 315426.32 MW (as on 28 Feb 2017) is the growth index that has eased and improved the quality of life. The thermal power stations have greater share of 189047.88 MW in electricity production in India but suffer from CO_2 emission. Power system engineer's exercise on optimal resource utilization for electricity production with minimum emission of CO_2, but its greater content due to other sources such as vehicles, plants, factories leads to global warming[1]. The researchers have focused their attention to introduce novel methods of electricity generation that fulfills the power demand, maintain reliability in terms of uninterrupted power supply, increase the efficiency and reduce carbon di-oxide. These include small hydropower (4333.86 MW), wind-power (28700.44 MW), bio-mass and cogeneration (7856.94 MW), waste to energy (114.08 MW) and solar (9012.69 MW) as on 31 Dec 2016.Of these several methods, solar power is an attractive option because it is a natural source and freely available. Solar power generation with its associated technologies has

**Author for correspondence*

advanced few steps ahead in last several decades. It is believed and investigated since last four decades that solar energy in space free from the weather conditions is quite different from that on the earth[2]. There are two ways of harnessing electricity from solar energy namely through concentrating solar collectors and converting this heat into electricity using a typical thermal power generating unit. This is known as solar thermal power generation. The other way is by using solar cells to convert the radiation from the sun directly to electricity. This is called solar photovoltaic (PV) power generation. Sunlight can be converted to electricity due to the photovoltaic effect discovered in 1839 by Edmund Becquerel a French scientist. There are three variations in solar PV generation. They are stand alone, hybrid and grid connected[3].

The installation of on-grid solar plant serves several advantages in commercial complexes, educational institutions whereas off-grid solar installations have been proved successful in remote areas. Guru Nanak Institutions, Nagpur spread over a geographical belt of 12.5 acres has two educational institutions of which the connected load is 125 kVA. The institute receives electricity from an express feeder at 11 kV through a step down transformer 11 kV/0.44 kV, 200 kVA. The annual electricity consumption is approximately 1,80,000 kWh (average monthly consumption 15,000 kWh) which costs around Rs. 22 lac annually. The energy charges were Rs. 10.8 (August 2015). The cost of energy generation using solar was Rs. 6.4. This has necessitated bringing down the electricity consumption from the grid and extract as much as possible from the solar installation. Since the installation was grid connected, it saved quite a large expenditure which would have been otherwise spent onenergy storage using batteries and its maintenance. The planning of rooftop solar installation needs careful study of the site information, plant architecture, layout, structural analysis and its economic benefits.

2. Site Information, Plant Architecture and Layout

2.1 Site Information

The institute is situated in Kalameshwar area with latitude: 21.2321°N, Longitude: 78.9180°E, Altitude: 1040 feet. The annual average wind speed is 3.58 meter per second (source: www.synergyenviron.com). Annual average solar radiation is 5.09 kWh/m^2/day. Though the area is surrounded by industrial belt but is has no such problem of fumes, smoke, dust etc. This has necessitated to go for solar PV plant as the maintenance would be minimum. The initial survey was performed by the author on all buildings T1, T2, M1 and M2. After careful survey of all the buildings, structural analysis and feasibility study, finally T1 and M1 buildings were selected for rooftop installation. The average shadow free space requirement for solar installation in 12 m^2/kW. Thus, the rooftop requirement for a 100 kW solar PV plant is approximately 1200 m^2. The area is estimated considering the sufficient space between the solar panels between the row arrays for maintenance purpose[4]. The panels have been installed with a tilt angle of 17° on both the buildings. The inverters were installed on fourth floor of T1 building which was easily accessible.

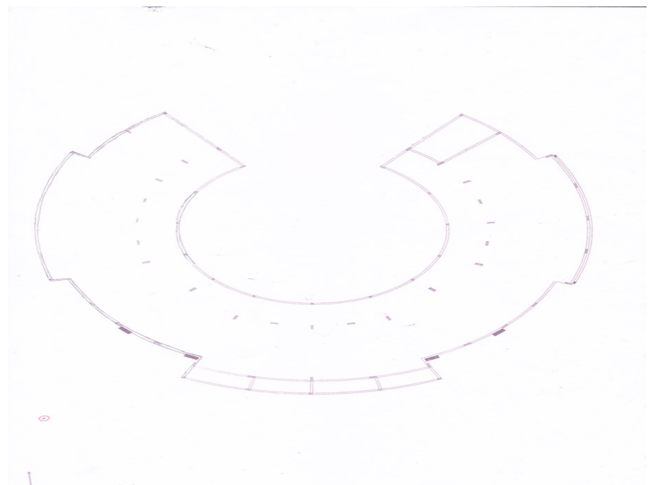

Figure 1. Top View GNIET.

2.2 Plant Architecture

There were few constraints of shadow effects which prevented the author to have the complete installation of 100 kW in one building. Therefore, half of the installation (50 kW) were done on T1 building Figure 1 and the other half (50 kW) on M1 building Figure 2. The plant uses four number of grid connected inverters (Model 867R023, 850 Volts, 25 Amp, +55°C, 1000 Volts max, Three Phase AC, 460 Volts Line to Neutral, 50/60 Hz, 23 kVA, Made in Hungry). There were 6 pair of terminals of which 4 pairs were used in each inverter and the rest two were kept standby for future expansion. During day time, when the solar module energy is less compared to energy required by the institute (load), the excess energy required is drawn from the grid[4]. Figure

3 shows the cable layout between T1 and M1 buildings. Figure 4 shows the single line diagram of electrical layout. The string voltages on open circuit before grid connectivity have been reported in Table 1 and Table 2. Technical specifications of solar panel and inverter are given in Table 3 and Table 4.

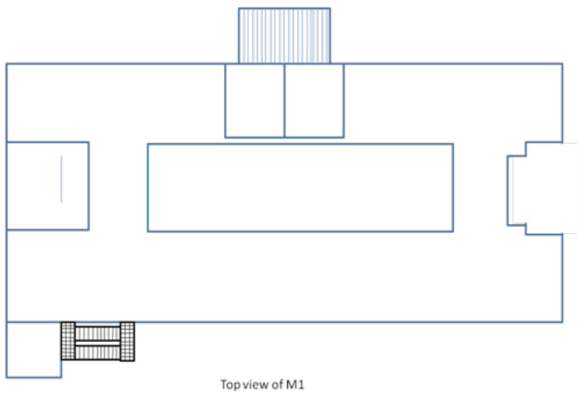

Figure 2. Top View GNIT 1 (M1).

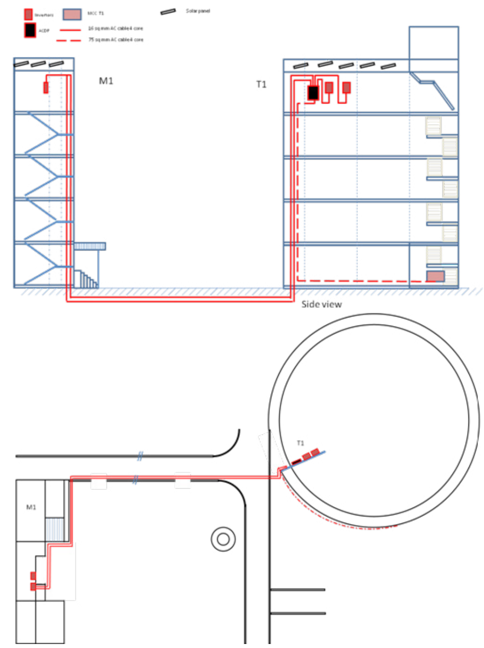

Figure 3. Cable Layout between GNIET1 and GNIT1 (M1).

Table 1. String Voltage Test Report of T1 Building on 16/08/2015

Sr. no.	String No.	Distribution of panel	No. of panels	Voltage	Invertors
01	String 1	Row 1 Row 2	21	836 V DC	Inverter 01
02	String 2	Row 2 Row 3	21	830 V DC	
03	String 3	Row 4 Row 5	21	833 V DC	
04	String 4	Row 6 Row 7	21	845 V DC	
05	String 5	Row 8 Row 9 Row 10	21	862 V DC	Inverter 02
06	String 6	Row 11 Row 12 Row 13	21	863 V DC	
07	String 7	Row 13 Row 14	21	863 V DC	
08	String 8	Row 15 Row 16	21	866 V DC	

Table 2. String Voltage Test Report of M1 Building on 10/08/2015

Sr. no.	String No.	Distribution of panel	No. of panels	Voltage	Invertors
01	String 1	Row 1 Row 2	18	727 V DC	Inverter 03
02	String 2	Row 2 Row 3 Row 4	19	732 V DC	
03	String 3	Row 4 Row 5 Row 6	17	736 V DC	
04	String 4	Row 6 Row 7 Row 8	17	728 V DC	
05	String 5	Row 8 Row 9 Row 10	17	736 V DC	
06	String 6	Row 11 Row 12 Row 13	12	859 V DC	Inverter 04
07	String 7	Row 13 Row 14 Row 15	19	820 V DC	
08	String 8	Row 16 Row 17 Row 18	20	836 V DC	
09	String 9	Row 19	20	846 V DC	

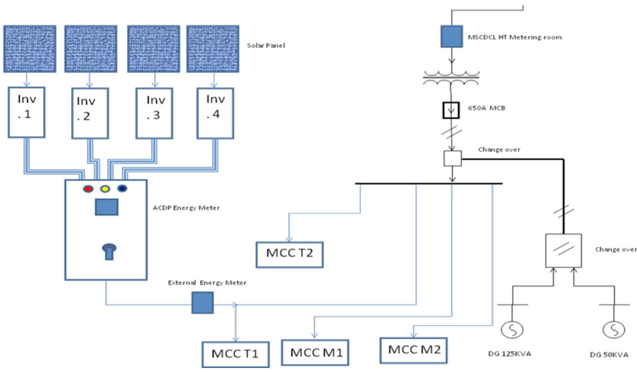

Figure 4. Single Line Diagram.

Table 3. Technical Specification of Solar Panel

S No	Particular	Details
1	Make	Rene Sola Jiangau Ltd.
2	Hot Line	+86 510 87128055, +86 21 64072288
3	Model Type	Jc295m-24/Ab
4	Maximum Power (Pmax)	295 Watts
5	Open Circuit Voltage (Voc)	44.7 Volts
6	Max. Power Voltage (Vmp)	36.3 Volts
7	Max. System Voltage	1000 Volts Dc
8	Dimension (L×W×H)	1956×992×40 mm
9	Power Tolerance	0 /+5 Watts
10	Short Circuit Current (Isc)	8.62 Amp
11	Max. Power Current (Imp)	8.13 Amp
12	Weight	27 Kg

Table 4. Technical Specification of Inverter

S.No.	**Particulars**	**Details**
1	Make	Advanced Energy
2	Hot Line	+49 7123 969-202
3	Name of Product	Photo Voltaic String Inverter
4	Model Type	867r023 .010 Ae_3tl-23-Mv-Iec Hw00
5	DC Max. Input Voltage	1000 Volts
6	DC Mpp Range	575-850 Volts
7	DC Max Input Current Per Input Pair	25 Amp
8	Operating Temperature Range	-25. +55°C
9	Enclosure	Ip65
10	Over Voltage Category DC / AC	ii / iii
11	Ac Nominal Operating Voltage	3 Phase AC 460 volts +N
12	Ac Nominal Operating Frequency	50 / 60 Hz
13	Ac Rated Power	23 kVA
14	Ac Max. Active Power @ Cos Phi = 1	23 kW
15	Ac Max. Output Current	3 × 29.2 Amp
16	Made In	Hungary
Serial No of Inverter		
Sr. No.	**Inverter No.**	**Inverter Serial No.**
01	Inverter No. 01	080167852
02	Inverter No. 02	080167854
03	Inverter No. 03	080167850
04	Inverter No. 04	080167837

3. Design

Total number of modules: 340 Nos.
Open Circuit voltage of Inverter: 46 Volts
Panel voltage (V_{OC}): 38 Volts
Number of panels connected in series: 21 Nos
Panel working voltage: 38 Volts
Series panel working voltage = 800 Volts
Total power output of each inverter = 295 Watts
Dead Load on Rooftop
Weight of single solar panel: 1×27 Kg = 27 kg
Weight of single Iron stand: 4×1 Kg = 04 kg
Weight of single concrete: 3×4 Kg = 12 kg
Total Weight of complete panel = 43 kg
Length of Panel: 1956 mm = 1.956 m
Width of Panel: 992mm = 0.992 m
Thickness : 40mm = 0.04 m
Area of concrete = 6”×6”= 36 sq. inch = 0.9144 m^2
Total area of concrete = 4× 0.9144 m^2 = 3.6576 m^2
Weight of complete panel per meter sq. = 43 kg/3.6576 m^2 =12.76 Kg/ m^2

4. Guidelines for Solar Plant Connectivity with Distribution Licensee’s Network

Once the solar plant has been installed, it is informed to the concerned utility with an application downloaded from website, duly filled, technical details of the plant along with the requisite processing fee. The installation may be connected at 230/240 volts single phase, 400/415 volts or 11000 volts three phase depending upon the size of solar plant. The concerned utility officials conduct a technical feasibility study within 15 days from the date of registration of the application on AC voltage level at which the connectivity is sought, sanctioned load/ contract demand, rated output AC voltage of the proposed rooftop solar PV System and the available cumulative capacity of relevant distribution transformer. The applicant is given a time of 15 days or longer to rectify the deficiencies if required[5]. However, if the plant is found technically feasible, the utility conveys its approval for connectivity with the grid. The applicant submits the test reports received from the manufacturer with request for testing and commissioning of rooftop solar PV system. The eligible consumer and utility enters into a Net Metering Connection Agreement in the prescribed format. The utility upon completion of testing within 10 days installs net metering equipment and synchronize the PV system thereafter asper guidelines specified by Central Electricity Authority (CEA). The isolation switch between solar system and the utility is installed for carrying repair and maintenance work when required. The design, installation, maintenance and operation of solar system shall be undertaken conducive to the safety of both consumer and Licensee's network. If at any time, the Licensee determines that the eligible consumer's PV system is causing damage to the Licensee's consumers and its assets, the consumer shall disconnect the solar system with the Licensee's network. The consumer shall undertake corrective measures at his own expense prior to re-connection.

5. Economic Benefits

The energy generated through solar system, its utilization for local load and feeding back to the grid is recorded by net metering (bidirectional) installed by the utility after careful assessment of protection system and ensuring that no part of the utility is affected by the solar generation. In case of any fault within the solar system, it has to be disconnected from the main bus so as to prevent any harmful effects to the utility. Installation of such plants not only benefits the consumer but also augments the solar generation of the nation. It thus benefits both utility in terms of solar power capacity addition and the consumer with reduced energy charges.

6. Conclusion

The installation of 100 kW solar power generation plant at Guru Nanak Institutions, Nagpur not only provides a self-sustaining way of producing power from renewable energy source (i.e. sun) but also provides economic benefits. From the bill assessment, it was found that the energy demand as well as the energy charges decreased after the installation of solar panel. There is a considerable amount of savings and the payback period has been estimated to be about 10-12 years. Net metering enables the user to sell the excess energy back to the utility grid. Thus the installation of such a renewable power generation plant not only helps in achieving economic benefits but also reduces impact on the environment by reducing pollution, and implications due to climate change.

7. References

1. Nimje AA, Ali SM. Solar Power Connectivity Using Transmission Superhighway: Smart Grid. Proceedings of International Congress on Renewable Energy, 2010 (ICORE 2010), Tradeshow, Chandigarh, India: 2010 Dec; 2(10): 1–6.
2. Dighade HM, Nimje AA. Wireless Power Transmission Using Satellite Based Solar Power System. International Journal of Application or Innovation in Engineering and Management (IJAIEM). 2013 Oct; 2(10): 1–6. .
3. Gon Chaudhari SP. India's First MW Level Solar PV Power Plant, My Dream Project. Managing Director, WBGEDCL. 2016.p. 1–215.
4. Francis PT, Oommen AA, Abhijith A, Rajan AR, Muralidharan VS. Performance Assessment of 100 kW Solar Power Plant Installed at Mar Baselios College of Engineering and Technology. International Journal of Emerging Technology and Advanced Engineering. 2014 June; 4(6): 1–6.
5. ANNEXURE – I Procedure for Application for Connectivity of Rooftop Solar PV System with Distribution Licensee›s Network. 2016 Nov.p. 1–6.