Generation and Economics of 100kwp Roof-Top Grid Connected PV Plant

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Abstract

This paper gives the detailed study of generation and economics of 100 kwp grid connected roof top solar pv power plant. Total no of units Generated, no of units consumed at the site and no of units (kwh) exported to the grid recorded for two years. A comparison statement prepared with net savings, payback period and also recommendations made to extract more energy for better performance. Maximum power output both AC and DC side are measured.

Keywords: *Solar PV System, MPPT, Inverter.*

I. INTRODUCTION

Solar energy is gaining high popularity in India. It sets a target of installed capacity of 100GW (40 GW from roof top) by 2022 through MNRE (Ministry of New and Renewable Energy) and achieved 20GW by Jan 2018. The unit cost is Rs 2.44. A 100KW ROOF TOP Grid connected PV installed at GNDEC, Bidar in 2015. It has 400 Modules each rated 250 W capacity with 6 string inverters with a roof area of 1256m^2. PV module type Poly Crystalline. Inverter type grid tied IGBT Based SMA inverter, capacity 17 kVA.

The average monthly generation from the 100kWp roof top solar plant from April 2016 to March 2018 is 10865 kWh. This typically accounts for 35 % of gndec monthly electricity consumption. This has resulted a monthly saving of Rs 70000 to 90000 in the electricity bill of gndec. The plant exported a monthly average of 460 kWh. However the gndec has net import from the grid as its consumption is more than the solar generation.

GNDEC has a contract demand of 200 kVA, approximate billing demand is 150 kVA. It has 500kVA Transformer and 2x 125 kVA DG sets in the campus and is maintaining a unity power factor.

Table 1. Solar array Support Roof Structure

Type: Elevated roof mount	Material: Galvanized Iron
AC Distribution board: Type: 6 in and 1 out	Make: Greensol Renewable power pvt ltd.
Table configuration: Total no of modules : 400	16 no's of 2 x 11 =352 modules 2 no's of 2 x 12 = 48 modules
Major components:	4P, 32 A MCB for each inverter on input side Surge protecting device for each phase Disconnect switch on output side.
Synchronization panel:	LV panel: existing GNDEC panel board Disconnect: 4pole 200A Isolator with enclosure
Voltage	320-480 V
Frequency	48-52 Hz.
Average daily generation	390 kWh.

II. INSTALLATION OF ROOF TOP SOLAR PLANT AT GNDEC

A 100KWP ROOFTOP GRID TIED solar pv plant installed at gndec in may 2015. It is located in the roof of electrical science block of GNDEC. The output from the PV system connected to the grid through local AC Distribution Boards (ACDB). The college DG set is being used to create the local grid during load shedding.

Major components of the plant are 250Wp polycrystalline PV modules 400 in numbers, 17 kVA string inverters 6 in numbers and Aluminium mounting structure. The rated output is generated at standard test condition (STC), which is defined as 1000W/m^2 irradiance, 25^{o}C cell temperature, Air mass 1.5g and the NOCT is 46^{o}C.

Table 2. Solar Module Specifications

Solar cell	Poly crystalline
Module dimensions	1639x982x35
NOCT	46^{o}C
Open circuit voltage	37.20
Short circuit current	8.75
Maximum power voltage	29.95
Maximum current	8.35
Peak power	250
Fill factor	74
Maximum system voltage	1000
efficiency	15.54%

Solar irradiance	1000 W/m^2
Ambient temperature	25^{o}C
CUF	16.07%

The plant uses string Inverters manufactured by SMA Solar Technology. Model name is FLX Pro 17. Nominal active power is 17kW maximum efficiency is 98% frequency 50Hz. All inverters have built in monitoring system. One inverter chosen as Master inverter and remaining inverters are connected to the Master via Ethernet, RS485. This makes the system communication and monitoring simpler.

The mounting structure is designed to withstand wind speed of 160kmph as per IS875-1987 (part3). The structure is made of MS frames in both directions and the structure is checked as per IS 800 stipulations.

Balance of material: The balance of material is required for connecting the major components of the system. The material used in GNDEC PV Plant consists of

DC Side: 1 core 4sq mm annealed tinned flexible copper conductor, electron Beam Cross Linked XLPO 120 oC insulated and sheathed 1.8kV DC rated solar cable.
AC Side: 4 core 16sqmm Armored Aluminum Conductor with XLPE insulated 1.1kVrated, 3.5 core 120 sq mm Armored Aluminum Conductor with XLPE insulated 1.1kV rated.
Lighting arrestors, earthing system and safety equipment.
A Bidirectional meter (Net Meter) L&T make is installed in the GNDEC Campus.

III. RECORDED MAXIMUM VALUES ON BOTH DC AND AC SIDE

A. AC power Generation:

The maximum values recorded on both DC and AC side. The recorded maximum power on AC side is 65 kW. There are six inverters in the GNDEC; average generation on output (AC) side is 64 kW. The recorded maximum active power generation is 65kW; its overall average generation is 357 kWh per day. Average active power generation for different seasons shown in fig 2.

The maximum values of voltage, current and power recorded on both DC and AC side are shown in Table 3. Maximum PV values and Maximum AC values measured since installation date - note: values must be treated independently.

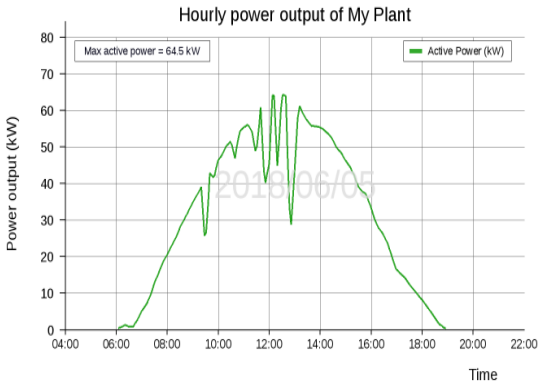

Fig1. Solar Power Generation on A Typical Summer Day May 6th 2018

Table 3 Recorded Maximum Values on Both DC And AC Side

		Voltage (V)		Current (A)		Max.Power(W)	
		DC	AC	DC	AC	DC	AC
Inverter1	PV1/L1	806	297	11.5	31.3	6777	6087
	PV2/L2	804	321	11	31.2	6277	6017
	PV3/L3	804	361	11.2	32	6394	5974
Inverter2	PV1/L1	801	298	11.8	32.6	6857	6052
	PV2/L2	800	307	11	29.9	6274	6042
	PV3/L3	801	361	11.1	30.9	6403	5988
Inverter3	PV1/L1	805	297	11.8	3	6786	5997
	PV2/L2	803	303	11	30.4	6199	6083
	PV3/L3	804	348	11.1	32.8	6456	5988
Inverter4	PV1/L1	799	297	11.9	30.6	6839	6064
	PV2/L2	801	321	11.2	29.6	6449	6123
	PV3/L3	802	361	11.6	31.1	6161	5948
Inverter5	PV1/L1	800	298	12.5	31	6603	6241
	PV2/L2	803	323	12.4	32.4	6207	6205
	PV3/L3	872	358	11.4	31.9	7195	6165
Inverter6	PV1/L1	803	297	12.5	36.9	6728	6198
	PV2/L2	805	322	12.4	33.2	6454	6115
	PV3/L3	878	363	11.5	32.3	6936	6166

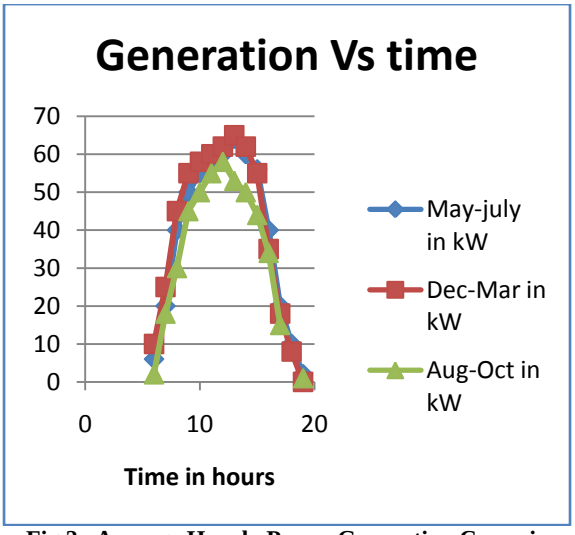

Fig 2. Average Hourly Power Generation Curve in dDifferent Seasons

B. Capacity Utilization Factor (CUF):

Capacity utilization factor is the ratio of energy generated by a plant in a certain period to the maximum amount of energy that could produce in that period.

CUF= Monthly Solar generation / (Rating of the plant * No of Hours * No of days in a month)

Monthly CUF = Monthly Solar generation / (100KW x 24 x 30)

Yearly CUF= Total solar generation in a year / (Rated capacity of the plant x 24 x 365)

The monthly capacity utilization factors are calculated for two financial years 2016-2017 and 2017-2018. The values are tabulated as follows

From the above values it is observed that the total average Capacity Utilization Factor CUF for a period of 2 years is 14.89% but it is 1.18% short by the manufacture's value. The total production for two years is 260758 kWh, the average daily generation is 357kWh as per the manufacturer's data it is short by 33 kWh.

The average efficiency of the plant = total monthly solar generation / rated monthly generation
The average efficiency of the plant = 10865 / 11855 = 91.65 it is approximately 92%.
The simple payback period = Initial Investment / Annual Savings = 6000000 / 953623 ≈ 6.5 years.

The total solar generation is estimated for 25 years, from the total generation 95% of energy consumed at GNDEC and the remaining 5% of total energy Exported to the Grid at rate of Rs.9.56 per kWh for 25 years. Grid consumption purchase charges are raised every year by 30 paisa or Rs 0.30 starting from Rs.7. and the tax paid is Rs 0.06 every year on savings in electricity, the average O&M charges is Rs 30000 per year for 25 years. Consider Degradation in generation is 1% every year. (Bank interest rates are not included)

Table 4. Monthly Capacity Utilization Factor (CUF) values

Month	Solar Generation (kWh)	CUF (%)	Month	Solar Generation (kWh)	CUF (%)
April16	11080	15.39	April_17	8130	11.29
May_16	11990	16.12	May_17	12000	16.13
June_16	6500	9.03	Jun_17	8291	11.52
July_16	8000	10.75	Jul_17	9843	13.23
Aug_16	8050	10.82	Aug_17	9223	12.40
Sep_16	8750	12.15	Sep_17	10385	14.42
Oct_16	12300	16.53	Oct_17	11421	15.35
Nov_16	12200	16.94	Nov_17	12249	17.01
Dec_16	12300	16.53	Dec_17	12100	16.26
Jan_17	12710	17.08	Jan_18	11214	15.07
Feb_17	13260	19.73	Feb_18	11175	16.63
Mar_17	14750	19.83	Mar_18	12837	17.25
	Average Capacity Utilization Factor CUF				**14.89 %**

Total generation for the year 2017-18 is 128868 kWh; the total savings is Rs.**953, 623** per annum.

Table 5. Electricity consumption and generation at GNDEC for the year 2017-18

Month	Import from the GRID(kWh)	Export to the GRID (kWh)	Solar Generation (kWh)	Net import from grid (kWh)
April_17	40995	135	8130	40860
May_17	40965	60	12000	40905
Jun_17	35145	60	8291	35085
Jul_17	31590	525	9843	31065
Aug_17	27915	600	9223	27315
Sep_17	30570	420	10385	30150
Oct_17	32235	405	11421	31830
Nov_17	26310	675	12249	25635
Dec_17	26910	150	12100	26760
Jan_18	21855	720	11214	21135
Feb_18	26085	255	11175	25830
Mar_18	36180	270	12837	35910
Total	**376755**	**4275**	**128868**	**372480**

Table 6. Captive Generation of 100kWp Roof Top Grid Connected PV Plant at GNDEC

Year	Generation	Energy consumed	Energy sold	Grid purchase price	Savings in electricity	Energy sold @ 9.56/ kwh	Total revenue from sale and savings	Per Unit O&M cost	Electricty Tax **@Rs 0.06**	Net revenue after Tax and O&M charges
	Lakh kWh	Lakh kWh	Lakh kWh	Rs/kWh	Rs lacs	Rs lacs	Rs lacs	Rs lacs	Rs lacs	Rs lacs
1	1.32	1.254	0.066	7	8.778	0.631	9.409	0.3	0.53	8.58
2	1.307	1.242	0.065	7.3	9.064	0.625	9.689	0.3	0.54	8.84
3	1.294	1.229	0.065	7.6	9.343	0.619	9.961	0.3	0.56	9.10
4	1.281	1.217	0.064	7.9	9.614	0.612	10.226	0.3	0.58	9.35
5	1.268	1.205	0.063	8.2	9.878	0.606	10.484	0.3	0.59	9.59
6	1.255	1.192	0.063	8.5	10.134	0.600	10.734	0.3	0.61	9.83
7	1.242	1.180	0.062	8.8	10.383	0.594	10.977	0.3	0.62	10.05
8	1.229	1.168	0.061	9.1	10.625	0.587	11.212	0.3	0.64	10.27
9	1.216	1.155	0.061	9.4	10.859	0.581	11.440	0.3	0.65	10.49
10	1.203	1.143	0.060	9.7	11.086	0.575	11.661	0.3	0.67	10.70
11	1.19	1.131	0.060	10	11.305	0.569	11.874	0.3	0.68	10.90
12	1.177	1.118	0.059	10.3	11.517	0.563	12.080	0.3	0.69	11.09
13	1.164	1.106	0.058	10.6	11.721	0.556	12.278	0.3	0.70	11.27
14	1.151	1.093	0.058	10.9	11.919	0.550	12.469	0.3	0.72	11.45
15	1.138	1.081	0.057	11.2	12.108	0.544	12.652	0.3	0.73	11.63
16	1.125	1.069	0.056	11.5	12.291	0.538	12.828	0.3	0.74	11.79
17	1.112	1.056	0.056	11.8	12.466	0.532	12.997	0.3	0.75	11.95
18	1.099	1.044	0.055	12.1	12.633	0.525	13.158	0.3	0.76	12.10
19	1.086	1.032	0.054	12.4	12.793	0.519	13.312	0.3	0.77	12.24
20	1.073	1.019	0.054	12.7	12.946	0.513	13.459	0.3	0.78	12.38
21	1.03	0.979	0.052	13	12.721	0.492	13.213	0.3	0.76	12.15
22	1.047	0.995	0.052	13.3	13.229	0.500	13.729	0.3	0.79	12.64
23	1.034	0.982	0.052	13.6	13.359	0.494	13.854	0.3	0.80	12.75
24	1.021	0.970	0.051	13.9	13.482	0.488	13.970	0.3	0.81	12.86
25	1.008	0.958	0.050	14.2	13.598	0.482	14.080	0.3	0.82	12.96

C. Module Cleaning:

The modules must be cleaned regularly to get maximum power. To clean modules soft cloth and soft water only used. The cleaning must be done weekly once or twice based on accumulation of dust particles on panels if it is more cleaning has to be done very frequently. Panels must be cleaned in early hours of the day, so that generation will increase if it done at night time's water droplets remains on panels takes longer time to dry and may cause less efficient

IV. CONCLUSION

The grid connected roof top 100kWp solar plant at GNDEC performance and generation economics are studied in this paper. The total generation, O&M costs and total revenue generated have been estimated for 25 years. And recommendations made on solar module cleaning, improvements in solar power generation. By applying a simple payback method it is observed that the payback period is 7 years.

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