Design and Cost Analysis of PV System Using Nano Solar Cell and Cost Comparison with Grid

Preeti Bhatt, ArunimaVerma

Abstract: Nanotechnology is worldwide regarded as a key technology for innovations and technological progress in almost all branches of economy. In the present day scenario of electricity generation, photovoltaic system using nano solar cells is fast becoming an important area of research to make it a commercial product. Presently the PV market is dominated by wafer based crystalline Si cells, but is hampered by high cost. The paper presents the designing of PV system for a commercial organization to meet its load demand with nano solar cell. Moreover, the cost comparison of grid system and nano PV system carried out in this paper shows the economical superiority of nano solar cells over grid system.

Keyword: Nano solar cell, grid, nano PV system.

I. INTRODUCTION

The generation of electricity with the ever depleting conventional sources has led to the development of photovoltaic (PV) systems. On an average India receives 6-7 KW/m^2 of solar radiant energy for about 300 days in a year [1].This energy can be harnessed to obtain electrical energy to meet the commercial and domestic load demands.These PV systems utilize solar energy for producing electricity. The efficiency and cost of the conventional PV cells, made from wafer based crystalline Si cells, are low and high respectively. Nevertheless to meet the domestic load demands a comparison between grid system and solar PV (SPV) system have shown the latter to less costly and economically viable [2]. Thedrawbacks of conventional PV solar cells to some extent have been curbed by nano solar cells [3].Si solar cell conversion efficiency closer to its theoretical limit to 30.7%. Solar Cells from other materials such as compound semiconductors is now reached to close to 50%[5]. In recent years, solar power generationusing photovoltaics (PVs) has become popular since it is inexpensiveand has low installation costs[7]. The paper presents the design and cost analysis of nano solar PV system for a commercial building. The comparison of the proposed nano SPV system with the existing systems viz. conventional SPV plant and grid on the basis of cost have also been carried out. The analysis indicates that nano SPV system for a commercial building is an economically viable alternative to conventional SPV system and grid electricity.

II. NANO SOLAR PHOTOVOLTAIC SYSTEMS

A SPV system generates electrical energy and providespower for different types of devices after storing the energy in a battery bank. [4].

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The SPV panel is the fundamental component irrespective of any system configuration. Solar cellsare the building blocks of the panel [2]. A complete system includes different components which are selected taking into consideration individual needs, site location, climate and expectations.

2.1 Major System Components

The functional and operational requirements determine the components to be included in the PV system [3]. The major components incorporated in PV system as shown in Figure 1 are DC-AC power inverter, battery bank, system and battery controller, auxiliary energy sources and sometimes the specified electrical loads (appliances) [3].

PV Module –

It is made up of different combination of solar cells in series and parallel connections depending on voltage and current ratings of module. It traps solar energy andconverts solar energy instantly into DC electric power.

- **Inverter** –It converts DC power into standard AC power for use in the home, office etc synchronizing with utility power whenever the electrical grid is distributing electricity.
- **Battery**–Battery stores energy when there is an excess coming in and distribute it back out when there is a demand. Solar PV panels continue to re-charge batteries each day to maintain battery charge.

Utility Meter - utility power is automatically provided at night and during the day when the demand exceeds your solar electric power production. The utility meter actually spins backwards when solar power production exceeds house demand, allowing you to credit any excess electricity against future utility bills.

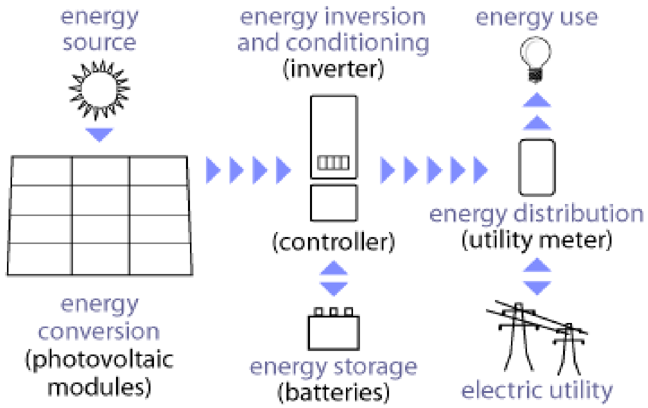

Fig. 1 Different components of PV system [3]

- **Charge Controller**–It prevents battery overcharging and prolongs the battery life of your PV system. In addition,

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an assortment of balance of system hardware; wiring, over-current surge protection and disconnect devices, and other power processing equipment.

2.2 ALGORITHM OF PV SYSTEM FOR A COMMERCIAL APPLICATION:

To design a PV system for offices the following steps have been considered. The designing depends on the types of load connected, built in area available for the installation of the system, the amount of sunlight available and the availability of fund[15].

Step1 Determination of load

To determine the total load demand, individualac and dc loads and usage hours of particular equipments or appliances are considered. The total load is calculated using equation (1).

$$Total\ load = (ac\ load \times\ hrs\ of\ operation/\ day) + (dc\ load \times hrs\ of\ operation/\ day) \quad (1)$$

Step2 Select the battery size

To calculate number of batteries required for battery bank, equations (2-4) is used.The days without sunshine (as monsoon)i.e the days of autonomy are decided. During this periodthe load is met through the batteries for which the depth of discharge (DoD) of the battery is required to be considered. The battery capacity in Ah in equation (2) is

$$Required\ battery\ bank\ capacity = \frac{avg\ Wh/\ day \times days\ of\ autonomy}{Battery\ voltage \times DoD} \quad (2)$$

Now,total number of batteries comprises of number of batteries in series and in parallel. To calculate number of batteries in series, the knowledge of nominal voltage of the battery is necessary as shown in equation (3).

$$Number\ of\ batteries\ in\ series = \frac{voltage\ of\ the\ system}{nominal\ voltage\ of\ \ battery} \quad (3)$$

Similarly by knowing the value of Ah of battery, number of batteries in parallel is calculated from equation (4)

$$Number\ of\ batteries\ in\ parallel = \frac{Ah\ rating\ of\ battery\ bank}{Ah\ of\ Battery} \quad (4)$$

Step3 Select the size of solar array

Equations (5-8) provide the size of the PV solar array. The array sizing should be such that it meets the average Ah demand per day needed with the nominal operating voltage. The average Ah per day that has to be supplied by the array to the battery is obtained from equation 5.

$$avg\ Ah/\ day\ to\ be\ supplied\ by\ the\ array = \frac{daily\ avg\ taken\ from\ the\ battery}{efficiency\ of\ the\ battery} \quad (5)$$

$$Array\ peak\ amps = \frac{avg\ Ah\ /day\ to\ be\ supplied\ by\ the\ array}{peak\ Sunshine\ hours\ per\ day} \quad (6)$$

Module in parallel can be calculated as

$$connected\ in\ parallel = \frac{array\ peak\ amps}{peak\ amps\ per\ module} \quad (7)$$

Module in series can be calculated as

$$Module\ connected\ in\ series = \frac{battery\ bank\ volt}{nominal\ \ module\ volt} \quad (8)$$

Step4 Select the array inclination

The PV arrays are horizontal, the panel rating outputwill only be possible during the summer months as thesun travels directly overhead at 12 p.m. During the wintermonths, since the sun is located more in the southern direction, the horizontal arrays will not capture as much irradiance, so the output will be less than the total panel rating[14].It is a usual practice to position a PV module facing the south in northern hemisphere and north in the southern hemisphere. Thus, solar module is fixed so that it always faces the sun at noon. A steeper angle tilting increases the output in winter while a shallower angle gives more output in summer. In practice, it is preferred that the panel is fixed at an angle corresponding to the latitude of the place, for which it becomes necessary to either add or subtract another 10^{o} depending on the season. Table 1 gives the optimum tilt angle at different latitude [6].

Table 1: PV module tilt angle

Latitude (degree)	Optimum Tilt angle (degree)
9	15
10-20	Latitude +5
21-45	Latitude +10
46-65	Latitude +15
66-75	80

Step5 Finally estimate the system design

After carrying outthe above calculations including size of battery bank, size of array and array inclination, final estimation of the system design is taken up to connect all the components as shown in figure 1.

III. DESIGNING AND CALCULATIONS OF PV SYSTEM (CASE STUDY)

The commercial building [14],National Thermal Power Corporation (NTPC), Lucknow,considered as a case study, is a very well known organization of the country housed in the northern region. The building is a newly constructed Northern Region Head Quarter (NRHQ) of NTPC organization located at Gomti Nagar in Lucknow, Uttar Pradesh, India.The total load of the commercial building of 269.3318 KWh [14] has been calculated using equation (1). Table 2 gives the total load of the NTPC building including the internal and external load.

Table 2: Load of NTPC, NRHQ Building, Lucknow

Internal load (Wh)	222931.8
external load (Wh)	46400
Total	**269331.8**

Internal load (W)	24770.2
External load (W)	4640
Total	**29410.2**

Table 3providesdifferent ratings of Battery, PV conventional modules and Nano PV module .These equipments are used for designing the conventional solar PV andnano solar PV systems.

Table 3: Ratings of Different Equipments Used

Battery		Module (Nano) [6]	
Voltage	12 V	Peak power	170 W
		Peak power voltage	27 .8V
ampere hours	200Ah	Peak power current	4.3A
		Open circuit voltage	41.1 V
Depth of discharge	0.8	Short circuit current	5.7 A
		Max. system voltage	1500 V
Efficiency	0.9	Series fuse rating	25

3.1 Calculation for designing of PV system using nano solar PV module

The step wise calculation for battery bank and array size for nano solar based PV systemusing equations (2-8) is provided in table 5[appendix]****. The rating values provided in table 3 for battery and PV module (nano) and assumed data in appendix are utilized for designing.

IV. COST ANALYSISOF NANO SPV AND GRIDSYSTEMS

4.1 Data used for cost analysis of SPV Systems

For determining the cost viability of a SPV system, the power requirements of NRHQ, NTPC for internal and external lightings are being considered. The cost analysis is further based on the following configuration.

a) The life expectancy of different of PV system are given in table 6[8]

Table 6: Life expectancy of components

PV module	25 years
Regulator	15 year
Inverter	10-15 years
Solar Battery	5 years
Wiring	10 years

b) Financial incentive to investor of SPV plants
- Subsidy provided by MNRE is 30% of capital cost of PV system.[8]
- Soft loan upto 80% of project cost is provided by IREDA[9]

c) The average number of sunshine days in a year in Indiais 300 days.

d) The average insulation during the least sunny days is 5.3 kWh/m^2/day in India.

e) The maximum power of each PV panel is 150 Wp.[10]

f) Market price of different equipment components of PV system are:
- PV panels @ Rs 150/ Wp {Cost of panel=150×No of cells in panel(72)}[10]
- Nano PV panels @ Rs 50/Wp {Cost of panel=50*No of cells in panel(84)}[11-12]
- Solar Battery @ Rs 11000/- each
- 30 KW inverter @ Rs 246000/- each

g) Cost of conventional (grid) power including fix tariff for commercial building is Rs. 9 per unit [14].

h) Depreciation on battery is 20% and on the remaining components of the PV system is 4% considering battery life and balance equipment life as 5 years and 25years respectively.

i) Annual operation and maintenance (O&M) cost of the system is 0.5% of the capital cost and interest charge [8].

j) Depreciated value is calculated on the basis of sinking fund method and is given by equation (9) [8]
$[(Initial\ value - \ salvage\ value) \times r] \div [(1+r)^n$-$1]$(9)

Where;
r = rate of compound interest per annum =8%
n= number of years over which the total amount of depreciation is to be saved= 25 years

4.2 Cost Analysis of SPV system using nano module.

The data in section3.1 have been utilized in calculating cost of SPV system consideringnano solar cells. The cost of module and required data has been collected from a company based in California,USA [11-12].Stepwise cost calculation is shown in table 8[.Appendix]

4.3 Cost calculation considering utility /grid (For 10 years)

The cost analysis of the load of NTPC, Lucknow,considering grid supply has been carried out in this section. The total cost will be borne by NTPC. For the calculation the tariff of electricitycharged by the grid from commercial organization i.e. NTPC is Rs. 6.0 per unit. Considering an annual increment in cost/unit by 12%, calculation has been done for 10 year shown in table 9.

Total units = 269.3318
Cost/unit (Rs) = 6

Table 9Cost analysis considering utility /grid

Year	Average per unit cost	Total Units	Cost/Year
1st	6	269.3318	589836.64
2nd	6.72	269.3318	660617.04
3rd	7.5264	269.3318	739891.08
4th	8.429568	269.3318	828678.01

5th	9.4411162	269.3318	928119.38
6th	10.57405	269.3318	1039493.7
7th	11.842936	269.3318	1164232.9
8th	13.264088	269.3318	1303940.9
9th	14.855779	269.3318	1460413.8
10th	16.638473	269.3318	1635663.5
	Total cost (Rs)		**10350887**

V. RESULTS AND DISCUSSIONS

The results obtained from the analysis of the cost of conventional SPV, nano SPV and grid system for a commercial building. Table 10 shows comparison of cost calculation of all three systems.

Table 10 Comparison of systems

Sr. No.	System	Cost(Rs)	Result
1.	Grid	10350886.96	Nano SPV System is better than Grid
2.	Nano	3677878	

The cost analysis for both systems has been carried out for 10 years including maintenance cost of the system. From the above calculations, it is evident that to have reliable and power conditioned electric energy supply,the proposed nano SPV system is much more cost-effective thangrid to meet the load demand of the commercial building in concern.This is because, the cost of nano SPV system installation to be borne by the commercial consumer to meet the load requirement of 269.18 units is less (i.e. Rs. 3677878) than the cost of conventional grid system to meet the same load demand over a period of 10 years (i.e. Rs. 10350886.96). Thus, nano SPV system is an economically viable alternative togrid supply. Besides the SPV system has an advantage over grid system of providing non pollutant electric energy which in the long run will be beneficial for the government and the society as a whole. This clearly establishes the higher efficacy of SPV system over the conventional grid system of electric supply to meet the load requirement of a residential building [my paper].

VI. CONCLUSION

The results obtained for the case study reveal that nano SPV system designed for single phase load of NTPC NRHQ building, Lucknow is much more economical as compared to that of grid system. This makes the consumer independent of paying the recurrent cost to the grid and in turn, also reduces the burden on the electricity grid. A part of the total connected load especially single phase load of the NRHQ building has been considered for analysis purpose, because nano SPV system cannot be utilized for high power load on account of its low conversion efficiency. Such high power loads are still supplied by grid system. To provide a complete stand alone nano SPV system for the three phase load requirement of the whole building, the conversion efficiency is required to be high. In this light, this work can be helpful for the researches to carry outfurther investigations regarding improvement in conversion efficiency of nano solar cells.

VII. APPENDIX

Assumed data:

Inverter: 30 KW; Day of Autonomy: 1; System Voltage: 220V; Peak Sun Shine: 5

Table 5Design of SPV system using nano module

1	Battery bank amp/Ah	(AvgWh/day × day of autonomy)/battery voltage	26933.8×1 220	1224.23
2	Final battery bank capacity Ah	Battery bank Amph/DOD	1224.23 0.8	1530.28
3	Batteries in series	System voltage /battery voltage	220/12	18
4	Batteries in parallel	Ah of battery bank/Ah of battery	1530.28/200	8
	Total No. of batteries	**3*4**	**18 ×8**	**144**
5	Array peak amp	Battery bank Ah capacity / (battery efficiency× peak sun shine)	1530.28 0.9×5	340.06
6	modules in parallel	Array peak amp/peak amp per module	340.06 4.3	79
7	modules in series	Battery bank voltage/nominal module voltage	220 27	9
	Total no of PV modules	**6*7**	**79×9**	**623**

Table 8 Cost analysis of PV System considering Nano Solarcell

1		Total load of system(Wh)	269331.8
2		Total load of system (W)	29410.2
3		Required number of modules	711
4		Required numbers of batteries	144
5		Cost of different components of required PV system:	
	a)	Cost of each module	4200/-
	b)	Cost of total modules (3×a)	2986200/-
	c)	Cost of each battery	11000
	d)	Cost of total batteries (4×c)	1584000/-
	e)	Cost of inverter	246000/-
		Total (b+d+e)	4816200/-
	f)	Cost of wiring + installation (2% of Total)	96324/-
	g)	Total capital cost (Total + f)	4912524/-
	h)	Calculation of Salvage value for depreciation of PV equipment	
	h1	module at 60% of initial cost (60% of b)	1791720/-
	h2	Inverter at 20% of initial cost (20% of e)	49200/-
		Total salvage value against initial cost (h1 + h2)	1840920/-
	i)	Total cost on PV system installation to be borne by NTPC organization is calculated as follows[10]	
		Depreciation on battery cost (20% of d)(considering life of 5 year)	316800/-
	j)	Depreciated value on balance equipment of cost	3328524/-
	k)	Referring eq. 3 in section 3.1(d-g) and (h1+h2) @8% after 25 years	5605.197/-
	l)	Depreciation on total cost @ 4% (4% of k)	224.2079/-
	m)	Maintenance cost of PV system @ 0.5% (0.5% of g)	24562.62/-
6		Total cost on PV system installation (g+i+l+m)	5254111/-
7		Subsidy on capital cost (30%) =	1576233/-
8		**Cost to be borne by NTPC organization (6-7)**	**3677878/-**

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