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Design PV Power System: A Case Between Two Different Types of Solar Modules

Abstract. *A photovoltaic (PV) is a technical terminology that is used to generate electricity from sunlight. Solar energy is one of the solutions for solving the electricity needs in any area. Designing a grid-tie PV system based on real data is very important to utilize a great system. The case study was taken on a national thermal power corporation (NTPC) that lies at Gomti Nager in India. In this work, Newzealand mathematical calculation method is used to design a PV system and a comparison between conventional PV systems and nano PV systems is made. It has been concluded that the nano-PV system cost was lesser than the conventional PV system.*

Streszczenie*. Fotowoltaika (PV) to terminologia techniczna używana do wytwarzania energii elektrycznej ze światła słonecznego. Energia słoneczna jest jednym z rozwiązań pozwalających na zaspokojenie zapotrzebowania na energię elektryczną w dowolnym obszarze. Projektowanie sieciowego systemu fotowoltaicznego opartego na rzeczywistych danych jest bardzo ważne, aby wykorzystać świetny system. Studium przypadku dotyczyło krajowej korporacji energetycznej (NTPC), która znajduje się w Gomti Nager w Indiach. W tej pracy do zaprojektowania systemu fotowoltaicznego zastosowano matematyczną metodę obliczeń Newzealand i dokonano porównania między konwencjonalnymi systemami fotowoltaicznymi a nano systemami fotowoltaicznymi. Stwierdzono, że koszt systemu nano-PV był niższy niż w przypadku konwencjonalnego systemu PV. (****Projekt systemu zasilania fotowoltaicznego: przypadek między dwoma różnymi typami modułów słonecznych****)*

Keywords: photovoltaic system, PV system design, conventional PV system, nano PV system, grid-tie.
Słowa kluczowe: system fotowoltaiczny, nano PV system

Introduction

Generating electricity with consuming classical infinitives is steered to the evolution of (PV) systems [1]. These PV systems depended on sunlight for generating electricity. The efficiency of the traditional PV modules is lower than that of nano modules [2], [3]. In order to design a solar energy plant, some real conditions must be available: solar radiation, load profile, solar energy potential, and installation areas are needed; energy consumption amount in these areas represents the main factor in the design, also the load growth discretion is requested in order to enable the installed system works with good manner. These researcher projections are used for designing a solar system. The number of batteries and capacities used in the remote areas must have a little wasted energy. The fixture for declining cost of electric power and reliability in isolated regions in the world is the essential force driving the worldwide PV industry during the present time. Exemplary applications of PV that use today involve grid-tie PV systems for remote and cottages residences [4].

System Components

The functional and working needs designate components, which are included within the PV system [5]. The main components of the PV system as illustrated in Fig.1 are PV modules, MPPT-controller inverter, battery bank, and loads.

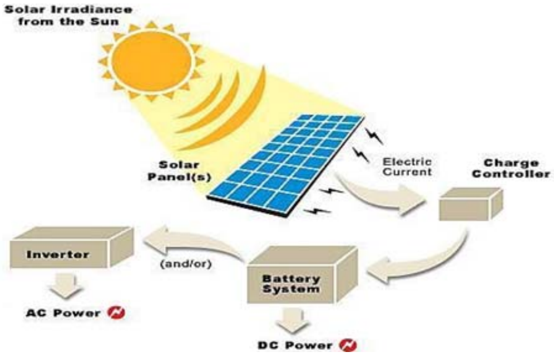

Fig.1 PV system components

PV modules:

Fig.2. represents the picture of the SunPower 220W PV module.

Fig.2 SunPower 220W PV module

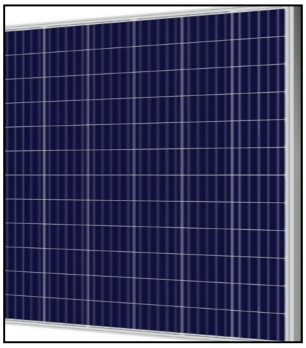

Fig.3 Renesola 220W PV module

The specifications of SunPower 220W PV module are given in table1.

Table1. SunPower 220W PV module parameters.

Rated voltage (Vmp)	41.0 V
Peak power (+/- 3%) (Pmax)	220 W
Open circuit voltage (Voc)	48.6 V
Rated current (Imp)	5.37 A
Maximum system voltage (IEC)	1000 V
Short circuit current (Isc)	5.75 A
PV Voltage degression per temperature	-132.5 mV / °C
Power	-0.38% / °C
Short circuit Current degression per temperature	3.5 mA / °C
Peak power per unit area	177 W/m^2
Series fuse rating	20 A

Electrical Data Measured under Standard Test Conditions (STC): Irradiance of 1000/m^2, cell mass, and air temperature 25^o C.

Fig.3. represents the picture of Renesola 220W PV module 156 series polycrystalline solar module.
The specifications of Renesola 220W PV module are given in table2.

Table 2. Renesola 220W PV module parameters.

Electrical data at STC	JC220M-24/Bb
Maximum power (Pmax)	220W
Power tolerance	±3%
Efficiency of module	13.52%
Optimum operation current (Imp)	7.64A
Optimum operation voltage (Vmp)	28.8V
Short circuit current (Isc)	8.01A
Open circuit voltage (Voc)	37.1V

Values under standard test conditions STC (Irradiance 1000W/m^2, Cell temperature 25^o C, Air mass 1.5).

Battery type

The battery type that used in this storage system is a 12V, 200Ah gel VRLA deep cycle. Fig. 4 represents the battery shape and its specifications are illustrated in table 3 [7]. Gel battery shows some discriminatory advantages, such as good recovery from deep discharge, high deep discharge capability, and super thermal stability even if this type of batteries are left discharged for 3 days, they will recover to 100% of capacity.

Table3. Battery specifications

Code	YGE12-200
Design number	27002042E
Nominal capacity (Ah)	200
Box type / number of Cells	C / 6
Voltage (V)	12
Electrolite type	Gel
Weight (kg) (+ - %3)	73.6
Dimensions (mm) L/W/H(H1-H2)	518/273/213-236
Terminal type	Round Type (D N72311-4) + M8 Optional
Float voltage	13.6 – 13.8 VDC @25^{o}C
Cycle voltage	14.25 – 14.6 VDC @ 25^{o}C
Recommended charging current limit (Ah)	20
Discharge cut-off voltage %100 Depth of discharge (D.O.D)	1.75 VDC @ (A) <= 0.2 C
Capacity C20 (Ah)	200.0
Capacity C10 (Ah)	185.8
Capacity C5 (Ah)	169.3
Capacity C3 (Ah)	155.2
Storage time	6 months @ 25^{o}C Charge Recommended Before Using
Self-discharge	Less than %2 per month @ 25^{o}C
Cycle life DoD %80	650
Cycle life DoD %50	1500
Cycle life DoD %20	3200
Internal resistance (milliohm)	5.1 @ 25^{o}C
Short circuit current (Ampere)	3483

Inverter type

The inverter type that used is in this PV system is a 30kW model, in order to control DC to AC and connected with the grid (grid-tie).

The specifications of 30kW grid-tie three-phase inverter is given in table4.

Table4. Three phase gird-tie 30kW inverter specifcations

Output Specifications	
Continuous Output Power	30kW
Acceptable Unbalanced Load	100%
Output Phase Voltage	240V (ac)
Power Factor	0.9-1
Connection Mode	3-phase 4-wire system + Ground
Output Voltage Rating	3AC/N 400V or 208V
Output Frequency	50/60 Hz +/- 0.3Hz
THD	<3% (Linear Load)
Input Specifications	
Nominal Input Voltage	48V (DC)
Minimum Start Voltage	42VDC / 44V (DC)
Low Battery Trip	40V / 42V
Low Battery Voltage Recover	52V (DC)
Idle Consumption Search Mode	<100 Watts (when Power Saver on)
Charger Specifications	
Output voltage	48V (DC) same as input
Charger Breaker Rating (240VAC)	50 A
Max Charge Rate	300 A
Power Factor	0.97 MAX

Array inclination

The position of PV modules usually facing the north in the southern hemisphere and the south in the northern hemisphere. Therefore, PV modules are fixed semper faces the sun at noon. In winter, an acuter angle tilting will increase the output while in summer the smaller angle will give more output.

Table 5. Illustrates the optimum tilt angle at different latitude.

Table5. Tilt angle of PV module

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

Designing and calculation of PV system (case study)

(NTPC) is a famous organization in the northern region of the country (India). The building called (NRHQ) of NTPC organization lie at Gomti Nagar. The total load of this building is given in table 6.

Table 6. Load of building

Internal load	222931.8 Wh
External load	46400 Wh
Total load	269331.8 Wh

Flowchart and Methodology

The mathematical procedures that used to design the solar PV system based Newzealand method is shown in Fig. 4.

Mathematical concept of solar PV system

In order to evaluate solar PV system, Newzealand design method has been used, a quick guide is used to calculate the total energy of any building, number of PV modules, number of batteries and inverter capacity. Solar PV systems come in a diversity of factors and a range of electricity generating capacities. At the first stage, the amount of total power that typically use and the number of hours of sunlight per day according to the location must be determined [9-17].

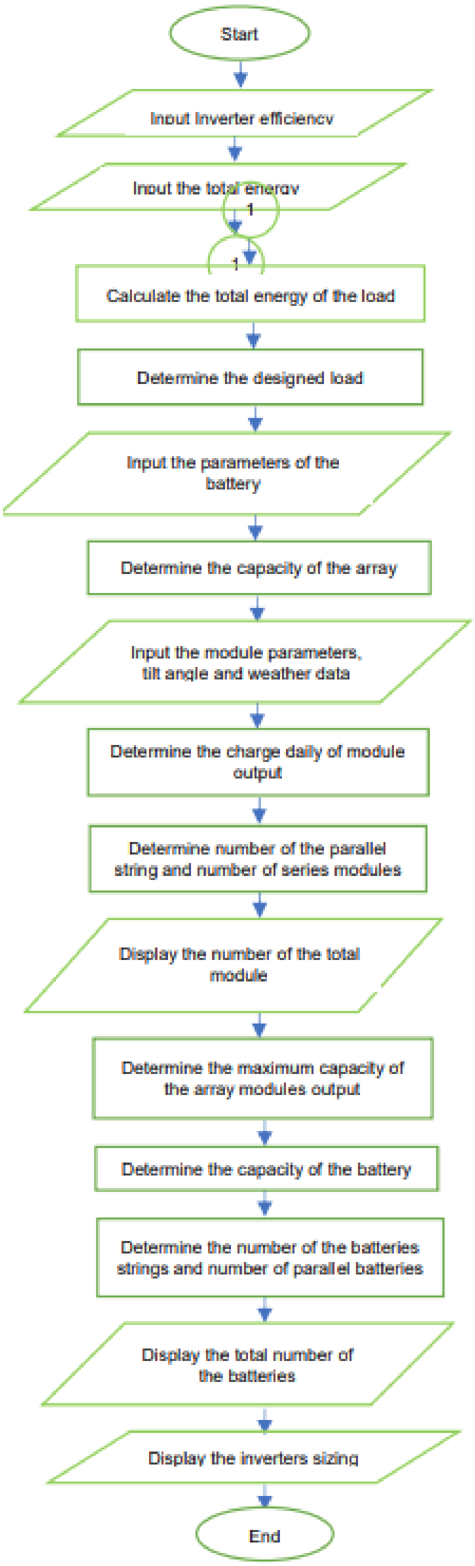

Fig.4 Flowchart of solar PV system design based on Newzealand method

A- Conventional SunPower 200W PV module

PV sizing

Design load energy (E_{total})

$$(1)\quad \text{Etotal} = 0 + \frac{\mathit{Total\ load}}{\mu\text{inv}}$$

$$\text{Etotal} = 0 + \frac{269331.8}{0.95} = 283507.15\ \text{Wh}$$

$$(2)\quad \text{Design load (Ah)} = \frac{E_{total}}{V_{d.c}}$$

$$\text{Design load (Ah)} = \frac{283507.15}{48\ \text{V}} = 5906.39\ \text{Ah}$$

$$(3)\quad \text{Output array} = \frac{\text{Design load Ah}}{\mu\text{batt}}$$

$$\text{Output array} = \frac{5906.39\ \text{Ah}}{0.9} = 6562.66\ \text{Ah}$$

$$(4)\ \text{Daily charge output per module} = \text{Pabric tolerance} * \text{Imp} * \text{fdirt} * \text{Htilt}$$

$$\mathit{Daily\ charge\ output\ per\ module} = (1 - 0.05) * 5.37 * 0.95 * 5.99 = 29.03\ \mathit{Ah}$$

No. of series modules per strings (N_s)

$$(5)\qquad \text{Ns} = \frac{V_{dc}}{V_{oc}}$$

$$\text{Ns} = \frac{48\ \text{v}}{48.6} = 0.98 \simeq 1\ \text{pcs}$$

No. of parallel modules per strings

$$(6)\ \ \text{Np} = \frac{\text{required array output} * f_o}{\text{daily charge output per module}}$$

$$\text{Np} = \frac{6562.66\ \text{Ah} * 1.3}{29.03\ \text{Ah}} = 293.8 \simeq 294\ \text{pcs}$$

No. of modules (N)

$$(7)\quad N = N_s * N_p \qquad)$$

$$N = 1 * 294 = 294\ \text{pcs}$$

f_o = over supply co-efficient

Total capacity of PV array capacity (P_{pv})

$$P_{pv}\ \text{array} = \text{total PV modules} * \text{power per PV} \quad (8)\ \text{module}$$

$$P_{pv}\ \text{array} = 294 * 220 = 64680\ \text{W}$$

Battery sizing

$$(9)\ \text{Battery capacity} = \frac{\text{design and Ah} * \text{autonomy days}}{\text{DoD} * \text{TCF}}$$

$$\text{Battery capacity} = \frac{5906.39\ \text{Ah} * 1}{0.8 * 0.95} = 7771.56\ \text{Ah}$$

No. of battery strings (N_{sbatt})

$$(10)\quad \text{Ns batt} = \frac{V_{dc}\text{bus}}{V_{dc}\ \text{batt}}$$

$$\text{Ns batt} = \frac{48}{12} = 4\ \text{pcs}$$

No. of parallel battery per strings (N_p batt)

$$(11)\ \ \text{Np batt} = \frac{\text{battery capacity}}{\text{capacity of one battery}}$$

$$\text{Np batt} = \frac{7771.56\ \text{Ah}}{200\ \text{Ah}} = 38.85 \simeq 39\ \text{pcs}$$

No. of battery

$$(12)\ \ \text{No. of battery} = N_s * N_p$$

$$\text{No. of battery} = 4 * 39 = 156\ \text{pcs}$$

Inverter sizing

$$(13)\ \ P_{inv} = \text{Peak}_{load} * f_o$$

$$P_{inv} = 47251.19\ \text{w} * 1.3 = 61426.549\ \text{W}$$

The average sun arc in NRHQ is between (5-6) h

Then,

$$(14)\ \ \text{Peakload (w)} = \frac{E_{total}}{6}$$

$$\text{Peakload (w)} = \frac{283507.15}{6} = 47251.19\ \text{W}$$

The elements of conventional PV system can be summarized as given in table 7.

Table7. Components of conventional PV system

No. of PV modules	294 pcs
NO. batteries	156 pcs
Inverter capacity	61426.549 W

B- Renesola polycrystalline solar module nano PV module (220W)

PV sizing

Design load energy (E_{total})

$$(15)\ \ \text{Etotal} = 0 + \frac{\mathit{Total\ load}}{\mu\text{inv}}$$

$$\text{Etotal} = 0 + \frac{269331.8}{0.95} = 283507.15\text{Wh}$$

(16) $\text{Design load (Ah)} = \frac{E_{total}}{V_{dc}}$

$\text{Design load (Ah)} = \frac{283507.15\ \text{Wh}}{48\ \text{V}} = 5906.39\ \text{Ah}$

(17) $\text{Output array} = \frac{\text{design load Ah}}{\mu \text{batt}}$

$\text{Output array} = \frac{5906.39\ \text{Ah}}{0.9} = 6562.66\ \text{Ah}$

No. of series modules per strings (N_s)

(18) $Ns = \frac{V_{dc}}{V_{oc}}$

$Ns = \frac{48}{37.1} = 1.29 \simeq 2\ \text{pcs}$

No. of parallel module per strings (N_p)

(19) $Np = \frac{\text{required array output} * f_o}{\text{daily charge output per module}}$

$Np = \frac{6562.66\ \text{Ah}}{41.3\ \text{Ah}} = 158.9 \simeq 159\ \text{pcs}$

Daily charge output per module = Pabric tolerance
(20) $*I_{mp} * f_{dirt} * H_{tilt}$)

Daily charge output per module = (1 – 0.05) * 7.64 * 0.95 * 5.99 = 41.3 Ah

No. of modules (N)

(21) $N = N_s * N_p$

N = 2 * 159 = 318 pcs

Total capacity of PV array (P_{pv})

(22) P_{pv} array = total PV module * power per PV module

P_{pv} array = 318 * 220 = 69960W

Battery sizing

(23) $\text{Battery capacity} = \frac{\text{design load Ah} * \text{autonomy days}}{\text{DoD} * \text{TCF}}$

$\text{Battery capacity} = \frac{5906.39\ \text{Ah} * 1}{0.8 * 0.95} = 7771.56\ \text{Ah}$

No. of series batteries per strings (N_s batt)

(24) $\text{Ns batt} = \frac{v_{dc\ bus}}{v_{dc\ batt}}$

$\text{Ns batt} = \frac{48}{12} = 4\ \text{pcs}$

No. parallel batteries per strings ($N_{P\ batt}$)

(*25) $\text{Np batt} = \frac{\text{batteries capacity}}{\text{capacity of one battery}}$

$\text{Np batt} = \frac{7771.56}{200\ \text{Ah}} = 39\ \text{pcs}$

(26) No. of batteries = $N_{s\ batt} * N_{p\ batt}$

No. of batteries = 4 * 39 = 156 pcs

Inverter sizing (P_{inv})

(27) $P_{inv} = \text{Peak}_{load}(W) * f_o$

$P_{inv} = 47251.19 * 1.3 = 61426.549$ W.

The elements of nano PV system can be summarized as given in table 8.

Table8. Components of Nano PV system

No. of PV modules	318 pcs
No. of batteries	156 pcs
Inverter Capacity	61426.549 W

Conclusions:

From the results, the number of nano PV modules are more than that the conventional PV modules, same batteries and inverter capacity for same grid-tie PV systems, Nano technology give mire efficiency working performance and low cost for same PV module power. The total cost for designing grid-tie nano PV system is more economical than that of conventional PV system due to less number of the battery bank, in spite of the increase number in PV modules but the batteries number have significant affect on the total cost. When the dirt factor and H tilt angle increases the number of parallel modules per string decrease. The capacity of the battery increases as the DoD decrease.

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