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Design of Standalone and Grid Connected Solar Power System

Vinutha N R
M.Tech Student, Department of EEE, Dr.AIT, Bengaluru, Karnataka, India

ABSTRACT

This paper displays the outline and advancement of sun oriented power plant using photovoltaic technology. Entire segments required and cost estimation for design of solar power plant is done with high productivity counts. Plan of standalone (independent framework) system and Grid connected (Network associated framework) system are made by considering some as the parameters which influences the maximum or greatest power generation from solar modules. Design calculation of individual parts is clarified in well ordered. Ecological impact of solar power plant and payback period for sun oriented power plant establishment are additionally clarified in this paper.

Keywords: Photovoltaic Technology, Standalone System, Grid connected System, solar module structures

I. INTRODUCTION

In the present scenario, due to ecological issues and vitality emergency as a result of constrained fossil assets, an alternative sustainable power source demand is increasing. To take care of the vitality demand, photovoltaic, wind turbine frameworks are assuming vital part. The utilization of different wellsprings of vitality advances keep on being produced to diminish the ozone depleting substance discharge and to achieve the future vitality request.

The issue is the manner by which to utilize solar PV panels to get optimal power yield and to choose singular parts as for climate and atmosphere insights [1]. The outline of solar power plant must be made with the end goal that maximum sun oriented radiation should got by each PV panel [2]. New advancements that assistance to oversee Non-conventional vitality so it can deliver day and night while reinforcing the power matrix. These advances incorporate battery storage, supply forecast and smart grid innovations. There are numerous kinds of solar PV modules [3]. Contrasted with all kind of crystalline module polycrystalline is the more affordable with more efficiency of 13 to 15%. Along these lines in this paper polycrystalline sun oriented modules are utilized for outlining the standalone [4] and grid connected [5] solar power plant. At first to design the solar power plant, calculation of energy for specific region is assessed by National Renewable Energy Laboratory Software [6].

Solar power system incorporates distinctive segments relying upon system type, size, and area [2]. The fundamental parts for solar power plant are,

1. Mounting structures
2. Solar PV panel
3. Array junction box
4. Charge controller
5. Inverter
6. Battery bank
7. Transformer
8. Auxiliary vitality sources and loads

II. METHODOLOGY

A. Factors Affecting Generation of Power:

Solar Radiation, which solar radiation incident on the solar modules varies depending on the area of the module, location and time interim per day. Along these lines solar radiation directly affects the panel power. Subsequently, a reduction in solar radiation decreases the output power. Expression for output power from solar panel in terms of radiation

$$Power\ output = R \times A \times \eta$$

Where, R = Solar radiation

A = Area of a panel

η = Panel efficiency

Above condition demonstrate that solar radiation is directly relative to power output. As solar radiation incident on panel increases power output additionally increments. 100- 200 W/m^2 least power required to produce minimum rated output from the PV Panel. Optimization of power and voltage control can also be done using newer technology [7]

Tilt Angle, which is the point between the flat plane and the solar panel. The tilt angle of the panel is the way to obtain maximum energy. Solar panels are most proficient, when they are perpendicular to the solar radiation. Tilt angle for particular area can be ascertained by adding 15 degrees to the latitude in winter or by subtracting 15 degrees from the scope in summer.

Temperature, which plays important role in solar power output from solar PV panels. Increment in temperature makes voltage diminish however current to increment [1]. The general impact of such temperature is that it causes the power yield of the solar module to diminish. Solar panel power loss can be calculated by the expression,

$$\begin{matrix}\text{Power output} \\ \text{loss in \%}\end{matrix} = \begin{matrix}\text{Temperature} \\ \text{difference}\end{matrix} \times \begin{matrix}\text{Temperature} \\ \text{coefficient}\end{matrix}$$

Temperature difference = difference between temperature at particular time and nominal temperature of the day

Temperature coefficient = -0.5% (Normally all Panels are designed with -0.5%)

$$\begin{matrix}\text{Solar module} \\ \text{power loss}\end{matrix} = \begin{matrix}\text{Power output} \\ \text{loss in \%}\end{matrix} \times \begin{matrix}\text{Rated power} \\ \text{of panel}\end{matrix}$$

Wind Speed, this is an additional vital factor which influencing the generation of power. Solar panels may get removed from mounting structure due to strong breezes. And furthermore higher the height of the under structure, more are the breeze loads on such tilted boards. High wind speed effect expands the cost of under structure and it again expands the overall system cost. Wind has monetary part on the framework execution. Tilt of board by wind has critical part in the electrical qualities of board.

Humidity, it portrays the amount of water vapor in air. The humidity reduces the measure of visible solar radiation incident on solar modules. In this manner humidity influence the current, voltage, power output. As the level of humidity expands, level of power generation likewise diminishes.

B. Standalone System:

The rooftop PV framework is a photovoltaic framework where solar panels are mounted on the rooftop of a private or business building or structure. The different segments of such a framework incorporate photovoltaic modules, array junction box, mounting structures, charge controller, cables, solar inverters, battery bank, and other electrical frill.

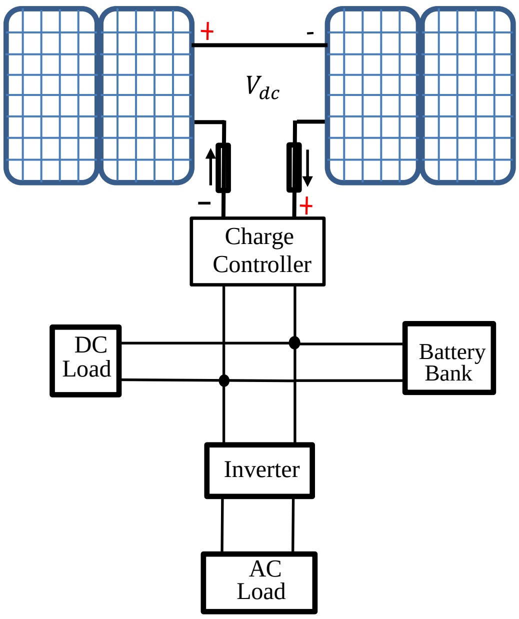

Figure 1. Simplified Standalone System

C. Grid Connected System:

A grid-connected PV system consists of solar panels, one or several inverters, a power conditioning unit and grid connection equipment. The low voltage generated by the plant is stepped up using a transformer and that is connected to grid.

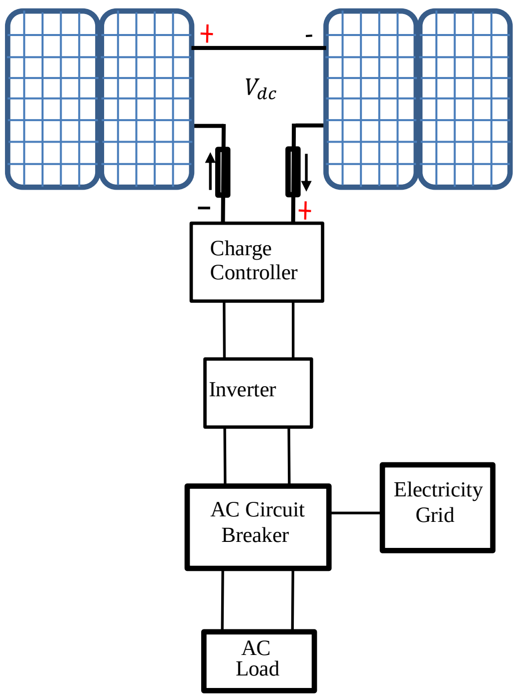

Figure 2. Simplified Grid connected System

III. DESIGN AND CALCULATION

A. Design ofStandalone Solar Power Plant

The Table 1 shows the energy consumption per day of a single house which is located at Bengaluru

Table 1: Energy consumed per day					
Sl.	Items	Pow	Numbe	No. of	Wh
1	Incandes	40	2	1	80
2	CFL	85	1	1	85
3	LED	7	3	6	126
4	Refrigera	11	1	6	690
5	Table	50	1	1	50
6	Mixer	50	1	0.25	125
7	Televisio	12	1	5	625
	Total	99	Total Wh per		1781

No. of units consumed per day =1781Wh or 1.781kWh =1.781units

No. of units consumed in the month of August

= 1.781×30 = 53.43units

Bill Amount = Rs. 239.39

Design of solar panel system

Sanction load = 0.00HP + 0.48 kW = 0.48 kW

The solar panel system is designed for 1.0 kW

Expected area required = 10 ×10 = 100 sqft

Expected generation per day: 5-6 Unit/kW

The details of energy consumption per hour in a house are given below based on the connected load.

Table 2. Energy consumed per hour				
Sl. No	Items	Power (watts)	Num ber	Wh per hour
1	Incandescent bulb	40	2	80
2	CFL Bulb	85	1	85
3	LED Bulb	7	3	21
4	Refrigerato	115	1	115
5	Fan	50	1	50
6	Mixer	500	1	500
7	Television	125	1	125
	Total watts	992	Total Wh	976

No. Of units consumed per hour = 0.476

Daily Energy Consumption = 1.781 kWh

Hourly Energy Consumption = 0.976 kWh

1. Selection of inverter:

Inverter is selected for 1.25 times the hourly load.

Rating of Inverter = 1.25×0.976 = 1.22 kW

If a power factor of 0.7 is assumed then, the required inverter rating is = $\frac{1.22}{0.7}$ = 1.7428 kVA

Let an inverter of 1-3 kVA be selected.

2. Selection of Battery:

Battery capacity is selected based on daily energy consumption.

If 12V, 120Ah battery is selected, then the kWh of battery = 12V x 120Ah = 1.44kWh

If the deep discharge value of the battery is 70 %, then the energy to be stored by the battery is the sum of daily energy consumption and extra energy

(30%) that the battery has to store because of deep discharge = 1.781 + (0.3×1.781) = 2.3153 kWh

Number of batteries required is the ratio of total kWh to be stored by the battery and kWh of battery $= \frac{2.3153}{1.44}$ = 1.608 ≈ 2 Batteries each of 120 Ah

3. Selection of Solar PV panels:

Consider solar PV panel of capacity 250Wp

Average generation is taken as 5 Units per day by a 1kW solar module

To generate 1.781 Units/day, the solar module capacity needed is $= \frac{1.781}{5}$ = 0.3562 kW

25% Extra module capacity = 0.25 × 0.3562
= 0.08905 kW

Total solar PV requirement = 0.3562 + 0.08905
= 0.44525 kW

Number of solar panels required $= \frac{0.44525kW}{250W}$
= 1.781 ~ **2 panels**

For 1.718kWh requirement, 2 panels, 2 batteries and inverter of 1 kVA are required.

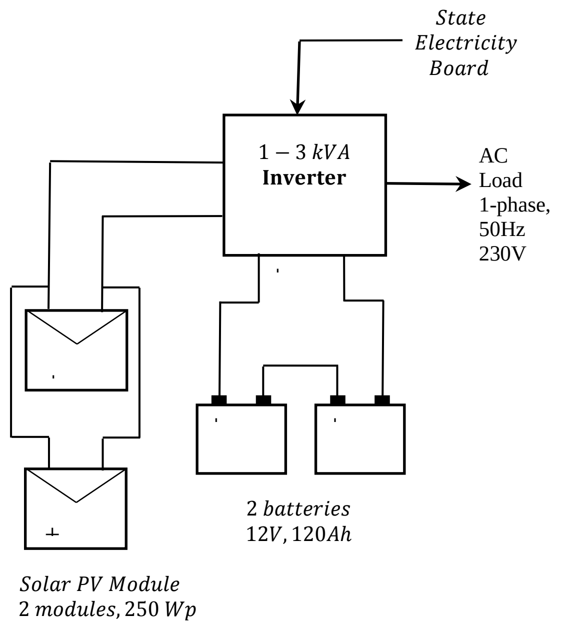

Figure 3. Design of standalone solar PV system

Cost Estimation for Installation 1MW Solar Power Plant:

SOLAR PV MODULE

Cost of 250W panel – Rs. 7000/-

For 1MW Power generation, module cost around Rs. 2.8 Crores

COST OF LAND

Land costs vary from Place to Place and based on the particular location of the projects. However, it must be noted that the land Utilized for Solar projects is to be plane surface. Thus, approximate land cost is Rs. 25 lakhs/MW.

CIVIL AND GENERAL WORK

Civil and general works cost is proposed to be set to Rs. 35 lakhs/MW. The cost of civil works depends on the quality of soil, ground water table, shape of ground, etc.

Civil works include preparation of terrain for digging, levelling and mounting, building control room to house inverter and other components, fencing or boundary wall, cable trenching, arranging water supply, lighting etc.

MOUNTING STRUCTURE

The amount of steel required for 1MW is nearly 50 tons. Cost per ton of steel is about Rs. 60000/- to Rs. 70000/-

The approximate cost for mounting structure is 35 Lakhs/MW

POWER CONDITIONING UNIT

The commission acknowledges the fact that the additional cost of replacement of inverter parts or upgrade of inverter at 12-14 years should be considered. Thus the commission includes additional Rs. 5 lakhs/MW for requisite replacement or upgrade. The PCU cost is thereby set to Rs. 35 lakhs/MW.

EVACUATION COST

Evacuation cost includes, cost of transformers and all DC and AC cabling within the solar farm, including DC cabling between solar PV panels and inverters, junction boxes, AC cabling between inverter and pooling station, Earthing; LT & HT switchgear, step-up transformer, breakers, isolators, protection relays, CT, PT, and metering. It also includes cost of SCADA systems. This cost may be fixed as Rs. 4-

5 lakhs/MW. The total cost for evacuation is hereby set to Rs. 44 lakhs/MW.

Therefore overall cost estimation for 1MW Solar Power Plant is Rs. 4.54 Crores

Area Required for 1MW Solar Power Generation:

Total area required for installation of solar power plant is splited into 4 parts.

1. Area for panel installation
2. Area required to minimize the shading effect by any obstacle.
3. Area for control and service rooms for the inverter and monitoring systems.
4. Additional land area required for the Storage rooms and Worker's room.

In designing of solar power plant each panel considered, is assumed with the capacity of 250W and dimension of 1976 x 990 x 42 mm ($2m^2$)

6 panels are required to generate 1kW thereby area required for 6 panels is $12m^2$ and to generate 1MW $12000m^2$ (3 Acres) area is required.

Area required to minimize the shading effect by any obstacle and area required for control and service rooms for the inverter and monitoring systems is nearly equal to 1 Acre.

Total area required for solar power plant installation is approximately 4 Acres.

Technical Specification and Design Calculations:

Table 3. Technical Specification of Solar PV	
Module type	RI 210
Model Capacity	210 Wp
Solar PV Technology	Polycrystallin
Open Circuit voltage	36 V
Short Circuit Current	7.68 A
Maximum voltage (V)	29 V
Maximum current (I_{max})	7.25 A
Technical Specification of Grid-tie Inverter/Power	
Inverter Capacity	1000 kVA
Minimum Input DC	450 V
Maximum Input DC	850 V
Permissible Voltage limit	900 V
Output AC Voltage	440 V, 50 Hz,3
Technical Specification of Unit	
Primary voltage	11/33 kV
Secondary voltage	440 V
Transformer Capacity	1250 kVA

Grid Connected Plant Capacity = 1000kW

Required voltage to GPCU (String voltage) = 650V

To generate required voltage, the total number of modules to be connected in series = 650/29 = 22

Number of modules in each string = 22

Total power generation per string= 4.713A

To generate a required power, total number of string connected in parallel per inverter = (Capacity of GPCU/ Total power generation per string) = 212

Total number of modules used per Inverter = (Number of strings x Number of modules in a string) = 4756

Total Installed Capacity per inverter = (Total number of module× each module capacity) per Inverter = 999kWp

Total energy generation @ 5hours average per day per inverter = (Total installed capacity per inverter x 5hours) = 4994kWh/day

Total energy generation per year (for 300 days) per inverter = (Total installed capacity per inverter x 5 x 300) = 1498MWh/year = 1.5MU

Total AC power generation per Inverter = (Total DC power generation - Total loss) = 1000 – 240 = 760kW

Unit Transformer Capacity = 1250kW

Proposed Unit Transformer Capacity = (Unit transformer capacity x Total installed capacity) = 1250kVA

Total No. of Unit Transformer = (Proposed Unit Transformer Capacity x power factor) = 1

Table 4. Economic Analysis	
Investment Cost	4Crores/MW
Total Investment Cost	Rs.4 Crores
Total O & M Expenditure for the Life of SPVPP @ Rs 25 Lakhs/Year/MW	625Lakhs / 25 Years
Over all Expenditure (Total Investment Cost + Total O&M Expenditure)	Rs.10.25 Crores
Area Required	4 Acres/MW
Total Area Required	4 Acres

Life of the SPV modules	25 Years
Tariff as per KERC	Rs 6.51/unit
Total Revenue (Total Energy Generation x Tariff)	Rs.97.54 Lacks/ year
Payback period excluding Interest and O&M expenditure = (Total Investment Cost/Total Revenue)	4.1011387 years

IV. CONCLUSION

This paper has discussed the design of Standalone solar power plant and grid connected solar power plant with the following features: (a) plant power generation can be maximized by considering the factors affecting the generation of power; (b) data collection and estimation of power generation will lead to minimize cost, losses and makes installation easier. Individual can install solar power plant based on estimation of energy consumption per month. Total power generation of 1498216kWh/year from solar power plant with installed capacity of 1MW. Referring to the above solar power plant, 1498216kWh/year is the total conventional energy savings @1unit saved equal to 2 units generated, 1498216kgs/year is the total coal saved @1kg/unit, 4944114Lts/year is the total water saved @ 3.3Lts/unit, 1498216kgs/year is the total Co2 + GHG saved @ 1kg/unit generation at consumer point.

V. REFERENCES

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