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Design of Grid Connected Solar Photo Voltaic System of a Polytechnic College Building

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Abstract: This paper is about estimation of the prospective of grid quality solar photovoltaic power of a building therebyto concludeschemecentered on the potential guesstimates for anexpanse of 1080 m^2. Stipulationsof equipments are deliveredconsidering the quantifiable availability in the country. Although, solar energy is evidently unsoiled and boundless means amid other renewable energy possibilities, constraints prove out to be among a standalone solar photovoltaic system and a wind power based energy system, both fail to deliver continuous supply of energy due to naturally occurring cyclic and sporadicdeviations. Thus, in an anticipation of scope to overcomethe stated problem and fulfill the load demand, grid connected systems are into practice these days that combines solar and orthodoxtransfiguration units. In this paper, annual energy generation by proposed Grid connected SPV power plant has been calculated. Finally, cost estimation of grid connected SPV power plant has been made to show the economic viability.

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I. INTRODUCTION

Till date fossil fuel like oil, coal, natural gas has been the main sources of global energy consumption, as 32.9% of global energy are covered by oil making it the world's leading fuel, 30% of global energy are covered by coal and 24% of global energy consumption are taken care of by natural gas. Today's world stands in a juncture due to increasingly energy demand each day ensuing running down of fossil fuel.

Solar energy reaching on the earth can be utilized in two ways, one is solar thermal and the other is solar photovoltaic system. In case of solar thermal power systems, thermal energy from solar radiation is used in water heating to produce steam to drive the steam turbine coupled with generator. Whereas, PV cell converts light energy directly into electrical energy when electrical potential developed in between two different materials of PV cell and their common junction is illuminated with radiation of photons. Solar PV cell application are of two types, one is grid connected (with/without battery) system and another is standalone (off grid) system. The advantages of using standalone system are it is totally energy independent and self-sufficient, so it is free from power outages. An off grid system can be installed anywhere, as long as there is sun, another advantage of off grid system is low loss due to the absence of transmission and distribution system in broad sense. Though it is a general thought that cost of a conventional energy is lower than solar energy but in case of long term investment solar energy is profitable than conventional energy. Recently it is seen that in latest auction on solar power plant tariff rate per kWh energy is lower than coal power plant.

Fig. 1: Roof top view of Technique Polytechnic Institute

II. GRID CONNECTED PHOTOVOLTAIC SYSTEMS

The PV system is linked to the service grid using a quality inverter, to convert DC power from the solar array into AC power that will accomplish the grid's electrical requirements. Diurnally, the electricity generated by the photo cells in the system may possiblybe used either immediately or vended off to electricity supply firms. Nocturnally, when the system is laid-backand supply of power barge in, electricity can be credited back.

As demandof electricity is continuously uprising conventional power plants are failing to meet up the required claim.Thecapacity of firm power will be better as a hybrid concept along with conventional ones throughout the year. Grid tied PV system is obviously more unswerving than other available PV system. The purging of storage cells (battery)shrinks its principalbudgetwhich led us to opt for the grid connected topology. Whenspawned solar energy is assimilated to the conventional network, diurnal demand can be pleased (total 6 hours in broad-spectrum).That is the preciseperiod range when the grid is fed. Nonappearance of backup assures responsibility of the utility tosustainresourcefor the left over extent. Grid-connected systems undoubtedlyvalidatedits prominence in natural catastrophes by continuingsubstitute power capabilities when service power was interjected.

III. GRID CONNECTED PV SYSTEM DESIGN

The schemes of Grid connected PV system offers likelihoods as such, with/without battery, with/without transformer, gross metering system or net metering system. Here a system deprived of storage type grid interconnected system has been discussed, taking into accountdiminutivelifespan, hefty replacement budget and augmentedputting incharge. A transformer is employed for heightening the ac output voltage to the rated feeder voltage. In gross metering system total generated solar power directly fed to the grid and household fulfil their demand from grid through import meter. Whereas in net metering system generated solar power first utilised in household after that excess power fed to the grid. Customer pays the difference amount thus save the energy bill.Use ofthese meters can straightforwardlyconcludeto theexpanse of energy fed to the grid to meeting the load requirement of Polytechnic Institute. Such a design can be performed through following plans. The shadow-free area required for installation of a rooftop solar PV system is about 12 m^2 per kW (kilowatt). This number includes provision for clearances between solar PV array rows.Results reveal that a 90kWp solar photovoltaic power plant can be developed on 1080 m^2 chosen area. Corresponding system sizing and specifications are provided along with the system design.

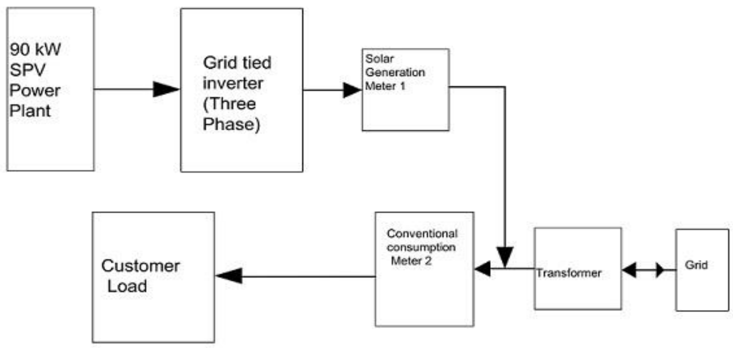

Fig.2: Block diagram gross metering system

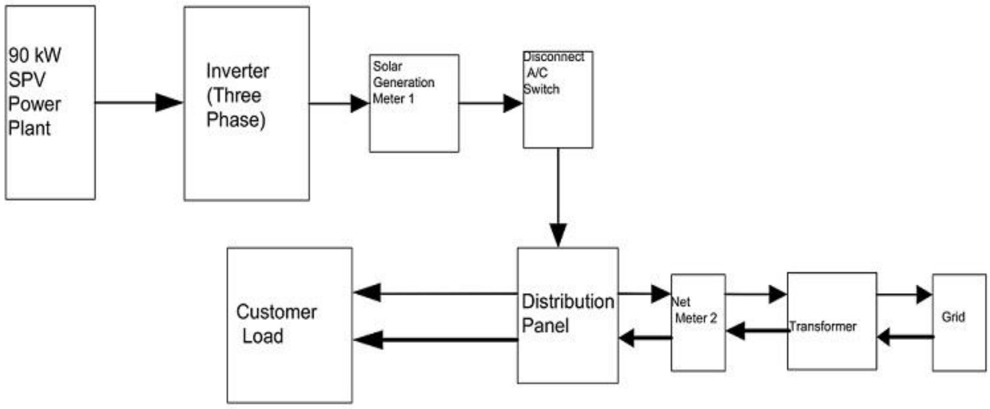

Fig.3: Block diagram net metering system

IV. CASE STUDY OF A POLYTECHNIC COLLEGE, WEST BENGAL, INDIA

Polytechnic college located in the district Hooghly, state of West Bengal in India at latitude of 22.9146°N and longitude of 88.3609° E. The average solar radiation of this place is 4.13 Kwh/m2/day and average mean temperature is 26.8°C although monthly mean temperature range is 16°C to 33°C. Maximum temperatures in Hooghly often exceed 38°C and minimum temperature range lying between 11°C to 17°C. Average radiation data per month of the site,

Table 1: Monthly average irradiance data of the site

Month	**Irradiance (Kwh/m2/day)**
January	4.13
February	4.89
March	5.59
April	5.99
May	5.79
June	4.49
July	4.09
August	3.90
September	3.88
October	4.32
November	4.21
December	4.02

V. POLYTECHNIC COLLEGE LOAD ESTIMATION

Table 2: Sample of Load Consumption

SL No	Appliance	Amount	Power rating(Watt)	Total Power (Watt)	Consumptions hours per day	Energy (Wh)
1	Fluorescent Tube	488	52	25376	6	152256
2	CFL	9	18	162	6	972
3	Fan	446	65	28990	6	173940
4	Computer	232	150	34800	1	34800
5	Printer	8	60	480	1	480
6	Exhaust	20	50	1000	1.5	1500
7	Xeroxmachine	1	600	600	2	1200
8	Water purifier	6	50	300	2	600
			Total Load Power	91708	Total Energy Consumed/day	365748

VI. PV ARRAY SIZING

At time of PV array sizing, first to estimate the daily energy demand and average sun shine hours. To determine the array size and the cost of an array the steps are followed,
Individual module voltage (V_{IM}) = 30.2V, Individual module current (I_{IM}) = 8.30A,
Short circuit current (I_{SC})=8.71A, System voltage (V_{DC}) = 400V, Average sun hours at Hooghly (T_{SH}) =5.77 Hr, Daily average demand (E_D) = 365748 watt–hour or 365.748 Kwh, Inverter efficiency = 95%, Transformer efficiency = 95%

$$E_{RD} = \frac{E_D}{\eta_I \times \eta_T} = 405.26\,Kwh$$

$$P_{avgpeak} = \frac{E_{RD}}{T_{SH}} = 70235.86\,watt$$

$$I_{DC} = \frac{P_{avgpeak}}{V_{DC}} = 175.58A$$

$$N_{SM} = \frac{V_{DC}}{V_{IM}} = 13.24 \approx 13$$

$$N_{PM} = \frac{I_{DC}}{I_{IM}} = 21.15 \approx 21$$

Total numbers of module are $(N_{TM}) = N_{SM} \times N_{PM} = 273$

VII.CAPACITY OF INVERTER

The recommended solar grid inverter capacity in kW shall be in a range of 95% - 110% of the solar PV array capacity. In the above example, the solar array
Capacity was calculated to be 90 kW. The solar grid inverter required for this array would be in a range of 85.5 – 99 kW.

Table 3: Transformer Specification

KVA rating	100 KVA
No of phases	3-phase
Frequency rating	50 Hz
Primary voltage rating	433 - 250 V
Secondary voltage rating	11 KV
Primary current rating	133.0 A5
Secondary current rating	5.25 A
Connections HV	Delta
Connections LV	Star(Neutral brought out)
Efficiency	Almost 95 %

VIII. CABLE SIZE CALCULATION

The dimensions of the cables among array interconnections, array to junction boxes, junction boxes to PCU etc.are to be so designatedkeeping into consideration the voltage drop and losses.The bright annealed copper conductors (99.97% pure)can serve the purpose owing to its low conductor resistance, ensuingminor heating. The insulationmay be of special grade PVC compound.

Cables are bendable& of toughened electrolytic grade conductor and shall conform to IS 1554/694-1990 and are extremely robust and resist high mechanical load and scuff.Cable is of high temperature resistance and excellent weatherproofing characteristics which provides a long service life to the cables used in large scale projects. The connectors/lugs of copper material with high current capacity and easy mode of assembly are proposed.

$$I_{INV} = \frac{Power}{\eta_{INV} \times V_{DC}}$$
$$= 241.33A$$

So, 3×150 mm^2 PVC insulated armoured aluminum cable required.
Inverter to bus bar section of control panel,

$$I_L = \frac{Power}{V_{AC} \times PF}$$
$$= 276.22A$$

So, 3.5×225 mm^2 PVC insulated armoured aluminum cable required.

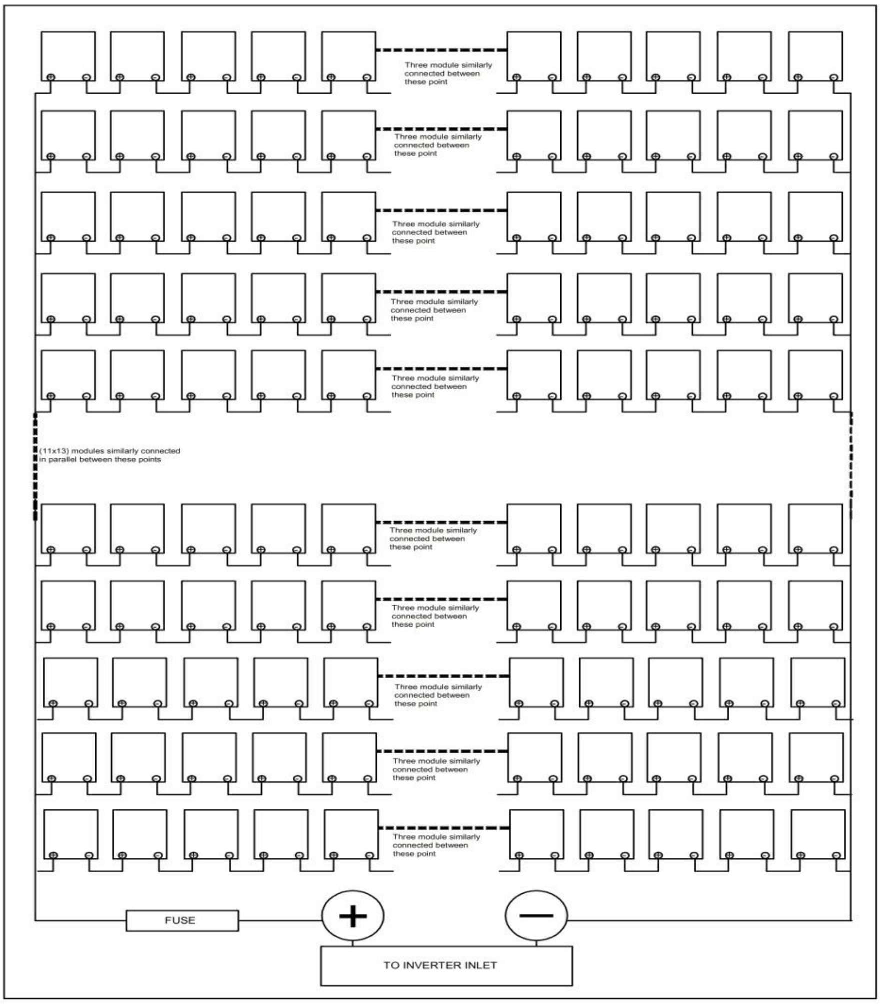

Fig.4: Wiring diagram of PV array

IX.COST ANALYSIS FOR 90KW GRID CONNECTED SOLAR POWER PLANT

Table 4: Cost analysis for 90kw grid connected solar power plant

Sl. No.	Component's Name	Amount	Price per amount (Rs.)	Total price (Rs.)
1	Solar panel (TITAN) Model No TITAN S6-60	273	10000	2730000
2	ABB On-Grid / Grid-Tie / Grid-Connected Solar Inverters 30 kW-3P	3	199000X3	597000
3	ACDB	9	5000X9	45000
4	DCDB	18	7500X18	135000
5	100kVA transformer	125000	125000X1	125000
6	Solar panel structure	35/Kg		200000(Approx.)
7	4 core 95 sq.mm armoured aluminium cable	448/m	100X448	44800(Approx.)
8	Cable required for SPV			70000(Approx.)
	Total cost of above materials			3946800.00
9	Installation cost 10% of PV cost			273000
	Total Grid connected PV system cost			4219800.00

Considering inflation (i) rate 3% and a discount (d) or interest rate 10%, cost of maintenance and operation per year 2% of PV system cost, so the cost throughout the life cycle (N=25Yrs) of the system and can be calculated as,

$$C_{MPW} = (M/Yr)\times\left(\frac{1+i}{1+d}\right)\times\left[\frac{1-\left(\frac{1+i}{1+d}\right)^N}{1-\left(\frac{1+i}{1+d}\right)}\right] = \text{Rs. } 643930.00$$

So the LCC is = Initial cost of standalone PV system + CMPW = Rs. 4863730.00

X.ANNUAL ENERGY GENERATION

The almanac energy reachable from the SPV power plant has been driven out established on the data of mean global solar radiant exposure over West Bengal at district Hooghly. The mean global solar radiant exposure varies from 3.88 kWh/nr /day in the month of September to 5.99 kWh/m^2 day in the month of April. So annual energy feed to the grid,

E= A×r×H×PR

Where, E = Energy (KWh)
A= Total solar panel area (m^2)
r= Solar panel efficiency (%)
H= Annual average solar radiation
PR= Performance ratio (default value 0.75)
E= 1100.49×15.6×1507.45×0.75
= 193977 KWh/annum

Monthly Average energy export to Grid is 16.16MWh. The annual energy generation feed into the grid is estimated as 193.977MWh.

Therefore total generated unit (kWh) in life cycle (ELC) = $193977\times 25 =$ 4849425kWh

So, per unit (kWh) generation cost = $\frac{LCC}{E_{LC}} = \frac{4863730}{4849425}$ = Rs. 1.00/kWh

Rate of energy varies for different state in India. In West Bengal 7.17 per kWh (average). Another fixed or demand charge is applicable for bulk consumer that is Rs.255 per kVA demand. So the payback calculation as follows,

Therefore average savings per year = Rs. 1390815.09
So, payback period = Initial investment of standalone PV system/Average savings per year
= 4219800/1390815.09
= 3 years

XI.CONCLUSION

The design described is based on the potential measured. System sizing and specifications are provided based on the design made.From the diurnal variation analysis of 12 month we conclude that solar potential is maximum at noon. The April month gives the maximum monthly energy output out of twelve months. It is found that the month of September produces the lowest solar radiation. Monthly and yearly outputs were calculated on the basis of 1100.49 m^2 area. Finally, cost analysis is carried out for the proposed design. Total estimated LCC of grid connected PV system is Rs.4863730.00. Annual energy generation is also calculated. The annual energy generation feed into the grid is approximately estimated as 193.977MWh. It is also very fascinating that the per unit generation cost is only Rs.1.00, it is immenselylesser compared to the present tariff of conventional energy sources. Calculated payback period is also very less, that is 3 years only. It is anticipated that the Grid Connected SPV system can afford quiterespite towards impendingoomph.

REFERENCES

[1]. Japs, E., Peters, S., Sonnenrein, G., Krauter, S., 2014. Energy-economic comparison ofphotovoltaic modules equipped with a layer of conventional and improved phasechangematerial. In: Proceedings of the 40th IEEE Photovoltaic Specialist Conference, Denver CO (USA), pp. 1348–1352.
[2]. Roy, K; Mandal, K,K; Mandal, C,K; 2016; Modeling and managing of micro grid connected system using Improved Artificial Bee Colony algorithm; Electrical Power and Energy Systems 75 (2016) 50–58.
[3]. Attari, K; Elyaakoubi, A; Asselman, A; 2016; Performance analysis and investigation of a grid-connected photovoltaic installation in Morocco; Energy Reports 2 (2016) 261–266.
[4]. Talavera, D.L; Munoz-Cerón, E; Casa la de, J; Ortega, j, M; Almonacid, G; 2011; Energy and economic analysis for large-scale integration of small photovoltaic systems in buildings: The case of a public location in Southern Spain; Renewable and Sustainable Energy Reviews 15 (2011) 4310– 4319
[5]. Shukla, N, K; Sudhakar, K; Rangnekar, S; 2015; Estimation and Validation of Solar Radiation Incident onHorizontal and Tilted Surface at Bhopal, Madhya Pradesh, India; American-Eurasian J. Agric. & Environ. Sci., 15 (1): 129-139, 2015
[6]. Oko, C,O,C; Diemuodeke, O,E; Omunakwe,F,N; Nnamdi, E; 2012; Design and Economic Analysis of a Photovoltaic System: A Case Study; Int. Journal of Renewable Energy Development 1 (3) 2012: 65-73
[7]. Perraki, V., Megas, L., 2014. Single axis tracker versus fixed tilt PV: experimental and simulated results. In: Proceedings of the 29th European Photovoltaic Solar EnergyConference, Amsterdam (The Netherlands), pp. 2711–2714.
[8]. Molin, A., Schneider, S., Rohdin, P., Moshfegh, B., 2016. Assessing a regional building applied PV potential – spatial and dynamic analysis of supply and load matching; Renewable Energy 91, 261–274.
[9]. Arikan, O. , Isen, E. , Durusu, A. , Kekezoglu, B. , Bozkurt, A. , and Erduman, A. , 2013, " Introduction to Hybrid Systems—Yildiz Technical University," Eurocon, Zagreb, Croatia, July 1–4, pp. 1145–1149
[10]. Kekezoglu, B. ,Arikan, O. , Erduman, A. , Isen, E. , Durusu, A. , and Bozkurt, A. , 2013, " Reliability Analysis of Hybrid Energy Systems: Case Study of Davutpasa Campus," Eurocon, Zagreb, Croatia, July 1–4, pp. 1141–1144.
[11]. Demain, C. ,Journée, M. , and Bertrand, C. , 2013, " Evaluation of Different Models to Estimate the Global Solar Radiation on Inclined Surfaces," Renewable Energy, 50, pp. 710–721.
[12]. Kornelakis, A. , and Koutroulis, E. , 2009, " Methodology for the Design Optimisation and the Economic Analysis of Grid-Connected Photovoltaic System," IET Renewable Power Gener., 3(4), pp. 476–492.
[13]. REN21, 2017, "Renewables 2017 Global Status Report," Renewable Energy Policy Network for the 21st Century, Paris, France, accessed Dec. 4, 2017.
[14]. Kerekes, T. ,Koutroulis, E. , Eyigun, S. , Teodorescu, M. , Katsanevakis, M. , and Sera, D. , 2011, " A Practical Optimization Method for Designing Large PV Plants," IEEE International Symposium on Industrial Electronics (ISIE), Gdansk, Poland, June 27–30, pp. 2051–2056.
[15]. Senol, M. ,Abbasoglu, S. , Kukrer, O. , and Babatunde, A. , 2016, " A Guide in Installing Large-Scale PV Power Plant for Self-Consumption Mechanism," Sol. Energy, 132, pp. 518–537.
[16]. Mahela, O. P. , and Shaik, A. G. , 2017, " Comprehensive Overview of Grid Interfaced Solar Photovoltaic Systems," Renewable Sustainable Energy Rev., 68(Pt. 1), pp. 316–332.
[17]. Obi, M. , and Bass, R. , 2016, " Trends and Challenges of Grid-Connected Photovoltaic Systems–A Review," Renewable Sustainable Energy Rev., 58, pp. 1082–1094.

[18]. Yang, Y. , Wang, H. , and Blaabjerg, F. , 2014, " Reactive Power Injection Strategies for Single-Phase Photovoltaic Systems Considering Grid Requirements," IEEE Trans. Ind. Appl., 50(6), pp. 4065–4076.
[19]. Bae, Y. , Vu, T.-K. , and Kim, R.-Y. , 2013, " Implemental Control Strategy for Grid Stabilization of Grid-Connected PV System Based on German Grid Code in Symmetrical Low-to-Medium Voltage Network," IEEE Trans. Energy Convers., 28(3), pp. 619–631.
[20]. Petrović, I. , Šimić, Z. , and Vražić, M. , 2014, " Advanced PV Plant Planning Based on Measured Energy Production Results-Approach and Measured Data Processing," Adv. Electr. Comput. Eng., 14(1), pp. 49–54.

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