ISSN: 2278-0181
ISNCESR-2015 Conference Proceedings

Study on Installation and Operation of Solar Photovoltaic Power Plant as Non Conventional Energy Resource

Dr. Vinay K. Pandey
Dean, BRSM College of Agricultural Engineering and Technology & Research Station
IGKV, Mungeli - 495334 (CG)

***Abstract*— The paper deals with a case study of installation, operation, data logging and maintenance of 100 KWp Solar Photovoltaic Power Plant in the campus of BRSM College of Agricultural Engineering and Technology & Research Station, Mungeli (Chhattisgarh) located about away from the town in the rural area. This becomes the first Agricultural Engineering College in India which is currently meeting its 100% energy demand through solar power only. The technical and operational details of various components of the systems i.e. PV array systems, grid connected system, grid tied with battery backup PV, solar cell technology system, maximum power point tracking, batteries charge controllers, DCDB, ACDB, factors affecting output, DC to AC conversional losses, sun angle and plant orientation, protection and controls, electricity production, OPS Coms 1.47 software, photovoltaic module performance, system sizing and specification, installation procedure, how solar panels or PV modules work, and general maintenance are described precisely.**

I. INTRODUCTION

India has a renewable energy potential of more than 300 GW. Only 15 GW is currently installed. This is also a 4th largest CO_2 emitter and emission is expected to triple by 2030. NAPCC target to generate 15% power from RE source by 2020. At current rate of consumption, natural gas and oil in the country will last for only 30-50 years. Approx 40% of households have no electricity. There are tremendous problems in conventional grid to reach remote & rural areas. Decentralized generation from renewable energy can facilitate rural upliftment. It can be mentioned that renewable energy can help Chhattisgarh State to achieve energy security in various ways i.e. solar pumps for irrigation, drinking water in remote areas and forest centuries, solar electrification of tribal hostels, tourist spots and guest houses of remote places, police stations and camps of paramilitary forces in Naxal pretentious area, district hospitals and primary health centres, colleges and public schools, banks and rural bank's branches, housing complexes, guest houses, and governments buildings, district collectorates & state assembly etc.. Some of societal & economic benefits of renewable energy projects are National security, reduces importation of fossil fueles, environmental performance substantially better, reduces or avoids CO_2 emissions, ash production, water consumption compared to fossil energy, economic development in rural areas, contribute to the tax base of rural communities, barriers facing renewable etc.

India, due to its geo-physical location, receives solar energy equivalent to nearly 5,000 trillion kWh/year which is equivalent to 600 GW. This is far more than the total energy consumption of the country today. Solar PV solution has the potential to transform the lives of 450 million people, who rely on highly subsidized kerosene oil and other fuels, primarily to light up their homes. But India produces a very negligible amount of solar energy - a mere 0.2 percent compared to other energy resources. A Solar PV Power plant is a concept of generating electricity from the sun and converting it to the AC energy that we use in our daily lives. PV modules are installed on fixed metallic support structures arranged in long rows, adequately spaced themselves, facing south (in the Northern Hemisphere) with an appropriate tilt. PV modules are electrically connected together in series and parallel and then connected by DC cabling to the centralized inverters which convert DC power into AC power and then the produced energy is delivered to grid or load by means of one or more step-up transformers. The energy is free and supply is unlimited. All we need is to find a way to use it.

TABLE 1 : NATIONAL STATUS OF ENERGY CONSUMPTION

Fuel	MW	%
Total Thermal	108362.98	64.6
Coal	89778.38	53.3
Gas	17384.85	10.5
Oil	1199.75	0.9
Hydro (Renewable)	37367.40	24.7
Nuclear	4560.00	2.9
RES (MNRE)	16786.98	7.7
Total	167077.36	100

Sources : CREDA, CG State

Solar Electricity: There are mainly two types of technologies by which solar energy can be converted to electricity. One is direct method i.e. by Photovoltaic (PV) which coverts the solar light to electricity by photoelectric effect. And another is indirect by CSP Concentrated solar power. Unlike solar panels, which convert sunlight directly into electricity, CSP utilizes mirrors to focus light on water pipes or boilers, generating superheated steam to operate the turbines of generators.

I. MATERIALS AND METHODS

The BRSM College of Agricultural Engineering and Technology & Research Station, Mungeli in Chhattisgarh State is situated on the outskirts of the village namely Chatarkhar. The solar power plant of 100 KWp capacity was installed to fulfill its energy requirements in various fields.

A). Solar Cell

The heart of a photovoltaic system is a solid-state device called a solar cell. A solar cell directly converts solar energy into electrical energy. Groups of solar cells can be packaged into modules, panels and arrays to provide useful output voltages and currents to provide a specific power output. Fig.2.

B). Photovoltaic effect and how solar cells work

The term photovoltaic refers the direct conversion of light into electrical energy using solar cells. Semiconductor materials such as silicon, gallium arsenide, cadmium telluride or copper indium dieseline are used in these solar cells. When the module is connected to a closed external circuit (e.g., to charge a battery or directly feed a DC load), electrical current is generated. The moving electrons provide power to the circuit and load, then return to the other side of the solar cell to start the process over again.

C). Inverter

A solar inverter, or PV inverter, converts the variable direct current (DC) output of a photovoltaic(PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical component in a photovoltaic system, allowing the use of ordinary commercial appliances. Solar inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection. Solar inverters use maximum power point tracking (MPPT) to get the maximum possible power from the PV array. Two invertors (50 KWp each) are installed in this power plant.

D). Batteries

These are simple element of storage of electrical energy. The primary purpose is to store the electricity not for immediately used, which could be used at some later time. With net metering, the value of batteries is less because the utility grid basically acts as a storage facility. For a reliable generation system that can function independent of the utility grid, however, batteries may be available component to the total system. Total 300 Nos. of batteries (600 pp VRCA: 240, & 2VF 300 pp VRCA: 60) are installed with the system.

E). Charge Controller

A charge controller fitted is charging the batteries. Its purpose is to keep your batteries properly fed and safe for the long term. The controller charge the battery bank within specified range, block reverse current and prevent battery overcharge. It also prevent battery over discharge, protect from electrical overload, and display battery status and the flow of power.

F). Direct Current Distribution Box (DCDB)

The DCDB installed is used to provide flexibility for the operator of the solar power plant to disconnect and connect both the inward solar supply and battery terminals. Here an MCB and a fuse of proper rating are used. DCDB is provided with a digital ampere hour meter to observe the charging/discharging currents of the battery i.e. Ah of the battery. This meter is intended to work only on the AC external supply from the ACDB feeder.

G). Alternate Current Distribution Box (ACDB)

The ACDB installed is made of epoxy powder coated metal casting. Three feeders are provided in ACDB with MCB of required capacity. One Electronic Energy Meter, ISI make, is provided in ACDB to measure the consumption of power from SPV power plant. A separate dedicated feeder from conventional line to PCU as well as ACDB is also provided. A separate change over switch is provided in the ACDB to isolate the existing connected load from the solar system & switch it over to the existing convention power (mains), in case of emergency.

H). DC to AC conversional Losses

The DC power generated by the solar module must pass through an inverter to be converted into common household AC power. Actual field conditions usually result in overall DC to AC conversion efficiencies of about 82-89%, using 86% or 0.86 as a compromise.

I). Installation procedure

Firstly, ground survey was done for site selection. Focused points considered were availability of proper sunlight on the area, orientation of structure (North South direction), shaded area by trees and buildings etc. was avoided; availability of construction materials on spot was assured. Holes of 1.5 m depth were dugout with the help of auger for foundation, of size 34×34×57 cm^3, GI rod were inserted inside the foundation, Supporting frames was laid on GI rods, whole structures were then mounted on supporting frame, there were total 340 panels on 11 rows, In each row panels were arranged in series,

A control room was located 2 m apart from whole structure. The panels were installed on the ground covering an area of 2965 sq m. Inside the control room battery bank (240V, 300Ah), ACDB and DCDB, two PCUs and a computer were installed. Exhaust fans and cooling systems were also provided for suitable cooling of the control room, to protect the panel from lightning hazard lightning arrester was installed. The output electricity is divided in three sections, two of which is fed to laod1 and load2 and third section is for feeding to the grid. Fig.3.

J). System Design

Desired power, voltage and current are obtained by connecting individual PV modules in series and parallel. When circuits are wired in series (positive to negative), the voltage of each panel is added together but the amperage remains the same. When circuits are wired in parallel (positive to positive, negative to negative), the voltage of each panel remains the same and the amperage of each panel is added. This wiring principle is used to build photovoltaic (PV) modules. In the existing structure total number of module is 340. Each module consists 72 PV cells . To form a string 10 modules are connected in series through 4 mm^2 1 core cu cable . Thus, there are total 34 strings. These strings or arrays are connected in parallel to an array junction box (AJB). In the present structure there are total 8 AJBs. Out of 8 AJBs , 6 AJBs connect 4 strings while 2 AJBs connect 5 strings in parallel. From an array junction box a single output 2 core x 25 mm^2 Cu armored flexible cable is joined to DCDB (Direct Current Distribution Board) . There are 2 DCDB units which are connected to PCU (Power Conditioning Unit) through 2 core x 95 mm^2 Cu unarmored flexible cable. For the battery back up, connection is provided between PCU and battery bank through a 2 core x 95 mm^2 Cu unarmored flexible cable.PCU is connected to ACDB (Alternating Current Distribution Board) through an input and an output 3.5 core x 50 mm^2 Al armored flexible cable each. Finally, from ACDB 3.5 core x 50 mm^2 Al armored flexible cable goes to load and a 3.5 core x 120 mm ^{2} armored flexible Al cable goes to grid connection Fig. 5.

II. RESULTS AND DISCUSSION

A). Electricity production

Since, each module contains 72 PV cells and each cell is rated with 0.5 volt. So total 72 PV cells connected in series produces 72 x 0.5 = 36 volts. 10 modules are connected in series to form a string. So, total output from a string is 10 x 36 =360 volts. The rated power of single module is 295 Wp . So, predicted that the current from single module is as 295/36 =8.19 amp. Since, there are 34 parallel connections exists, the total expected maximum output without losses from solar PV structure is as given –

Total voltage is 10 x36 =360 Volts. and Total current is 8.19 x 34 =278.5 Amp.

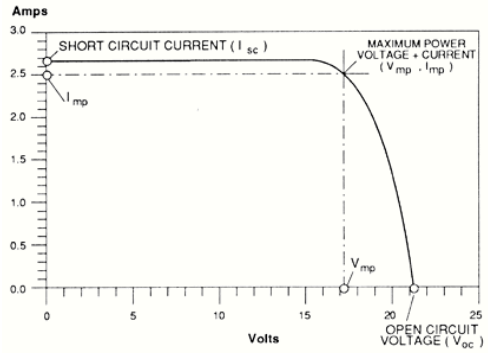
The output from solar photovoltaic structure is fluctuated, because it depends on radiance of solar energy on the structure and weather conditions. The fluctuation is noted and found within the specified range.

OPS Coms 1.47

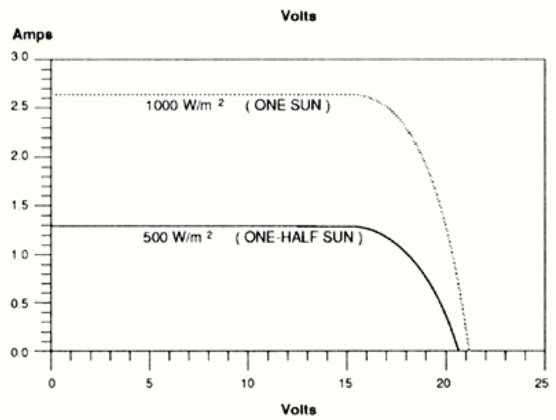
The whole system is controlled by Power Conditioning Unit (PCU). The PCUs are connected with a computer. Computer records all the data regarding the entire plant. OPS Coms 1.47 (Fig. 6&7) is a software used to link the computer with PCUs and record all data like voltage, current, power, temperature, air speed etc. A data log shows all these information about battery, load and solar inputs.

B). The Standard V-I Characteristic Curve of Photovoltaic Module

A photovoltaic module produces its maximum current when there is essentially no resistance in the circuit. This is a short circuit between its positive and negative terminals. This maximum current is short circuit current I(sc). When the module is shorted, the voltage in the circuit is zero. Conversely, the maximum voltage is produced when there is a break in the circuit. This is open circuit voltage V(oc). Under this condition the resistance is infinitely high and there is no current, since the circuit is incomplete



There is a point on the "knee" of the curve where the maximum power output is located. This point on example curve is where the voltage is 17 volts, and the current is 2.5 amps. Therefore, the maximum power in watts is 17 volts times 2.5 amps, equaling 42.5 watts. The power, expressed in watts, at the maximum power point is described as peak, maximum, or ideal, among other terms. Maximum power is generally denoted as "I (mp)."



C). Impact of Temperature on V-I Characteristic Curve of Photovoltaic Module

Module temperature affects the output voltage inversely. Higher module temperatures reduces the voltage by 0.04 to 0.1 volts for every one degree celsius rise in temperature (0.04V/0C to 0.1V/0C). A Typical Current-Voltage Curve for a Module at 25°C (77°F) and 85°C (185°F) is shown above. An air space of 4-6 inches is given to provide proper ventilation.

D). Impact of shading effect on V-I Characteristic Curve of Photovoltaic Module

Because photovoltaic cells are electrical semiconductors, partial shading of the module will cause the shaded cells to heat up. They started acting as inefficient conductors instead of electrical generators. Partial shading may ruin shaded cells. Partial module shading has a serious effect on module power output. For a typical module, completely shading of only one cell can reduce the module output by as much as 80%. One or more damaged cells in a module can have the same effect as shading.

TABLE II : LIST OF MATERIAL FOR 100 KWP SPVPP

Sl. No.	Item	Quantity
1	Solar PV Modules	340
2	Structure	1
3	Inverters with Data Logger	2 Nos.
4	Cables	m
4.1	1 C × 4 Sq mm Cu. Cable	1 Set
4.2	2 C × 25 Sq mm Al. Cable	1 Set
4.3	2C × 95 Sq mm Al Cable	1 Set
4.4	3.5 C × 120 Sq mm Al. Cable	1 Set
4.5	1C × 6 Sq mm Cable	1 Set
5	Distribution Box	2 Nos.
5.1	AJB	8 Set
5.2	DCCB	2 Set
5.2	ACDB	2 Set
5.3	UPS-DB	2 Set
6	Earthing kit along with accessories	11 Set
7	Lightning arrestor	1 Set

TABLE III : BATTERY BANK

Attribute	Specification
Normal rating	300 Ah
Voltage	240 V DC
Cell Voltage	2 V
Nos. of cells in series	120
Battery bank	2
Battery type	Hybrid VRLA
Battery rating	240 V – 300 Ah at 27^{0}C
Charge regime	Constant potential mode
Float charging voltage	270.00 to 272.40 V
Boost charging voltage	276-282 V
Current limit	75 Amp

TABLE IV : SOLAR MODULE PARTICULARS

Attribute	Specification
Type of pv module	Polycrystalline
Normal rating	295 Wp
Tolerance (%)	-0 to 2.5
Open circuit voltage (voc)	45.22 v
Short circuit current (ics)	8.52 a
Max power point voltage (vmp)	36.70 v
Max power point current (imp)	8.04 a
System voltage	1000 v
Series fuse rating(a)	15
Junction box	Ip 66
Glass	High transmittance 3.2 mm textured & tempered glass
Temperature range c	-40̊c to +85̊c
Module efficiency %	14.79%
Module dimensions (mm)	2100mm×1200mm
Module mounting dimensions (mm)	21 ̊
Life	25 Years

TABLE V : LIGHTENING ARRESTER

Attribute	Specification
External lightening	Level II
Lightening air terminal radius protection	62 m
Quality	1
Height	5 m
Lightening	15 kA
Earthing	Chemical

BRSM College of Agricultural Engineering and Technology & Research Station at Mungeli in Chhattisgarh State is located at 100 km away from capital city Raipur and about 06 km way from the town in a rural\village location. Currently the college is fulfilling it's all the energy requirements through the Solar Power only. At present college do not even have Electric Transformer of State Electricity Board in the college campus. Various college buildings, laboratories, hostels, Campus Street lights are being energizes through solar generated electricity. Drip irrigation system, Sprinkler irrigation System, Micro sprinkler irrigation system, Domestic water supply pumps, Farm irrigation pumps, Workshop machines, Field lab equipments, office ACs, Coolers etc. are also operated using solar power only. With this the college is well equipped with uninterrupted and environmental friendly power supply. The students of the college are also being benefitted through practical demonstration and training about planning , operation and maintenance of this system. Other visitors of various organizations/ Institutes/ departments and farmers also having good experience of this affords. An understanding about layout design, erection procedure, electricity generation and it's distribution, operation and maintenance has been developed for the college. Various factors affecting the output of electricity such as temperature, sun angle and orientation of structure, sunshine hour, and intensity of solar radiation, AC to DC conversion losses, dirt and dust, shading have been studied. During two National level formal presentations cum meetings, it has been appreciated by all and expressed as "It is commendable that this is the first and only Agricultural Engineering College in India which is 100% running on Solar Energy.

ACKNOWLEDGEMENT

The cooperation extended by CREDA, Govt. of Chhattisgarh, Lanco Solar Energy Pvt. Ltd., IGKV authorities, Research Scholars of the college in planning and execution of Solar Power Plant in the college campus is duly acknowledge.

REFERENCES

[1] Anonymous (2008). Akshay Urja : Special Issue on Solar Energy for Urban and Industrial Applications. Vol.1. No. 5. March-April 2008. Ministry of New and Renewable Energy, Government of India.

[2] D. M. Bagnall, , & M. Boreland (2008). Photovoltaic technologies, Energy Policy, 36(12), 4390-4396.

[3] H.P. Hertlein, H. Klaiss, and J. Nitsch (1991). Cost Analysis of Solar power Plants. In Solar Power Plants: Fundamentals, Technology, Systems Economics. Berlin, New York, London: Springer-Verlag.

ISSN: 2278-0181
ISNCESR-2015 Conference Proceedings

[4] J. G. Dorn (2007). Solar Cell Production Jumps 50 Percent in 2007. Retrieved September 12, 2008, from http://www.earth-policy.org/Indicators/Solar/2007.htm

[5] R. Banerjee (2005). Renewable Energy. Background Paper Submitted to the Integrated Energy Policy Committee, Government of India. Retrieved September 22, 2008, from http:// www.whrc.org/ policy/COP/India/REMay05%20 (sent%20by%20 Rangan%20Baneriee).pdf

[6] R. P. Charls, K. W. Davis. and J. L. Smith, (2005). Assessment of Concentrating Solar Power technology Cost and Performance Forecasts. http:// www. trecuk. org.uk/ reports /sargent_Iundy_2005.pdf

[7] W. Ahiataku-Togobo, (2003). Challengers of Solar PV for Remote Electrification in Ghana. Accra, Ghana: Renewable Energy Unit, Ministry of Energy,2003. Retrieved August 20, 2008.