Design & Analysis of off-Grid 2kW PV Array System

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Abstract:- **Photovoltaic (PV) systems propose the different source of production because these can be placed near the load centres when compare to other renewable sources of production. The PV system in general is off grid-connected and supports the off-grid load with battery backup. The designed system must ensure total evacuation of generated power and with high efficiency of conversion, and utilizes the resource sufficiently to maximize the utilization of energy. This paper presents modelling and simulation of a PV array of household connected loads. Here we use a PV system with an MPPT algorithm to track the max voltage and power output from the system. Off-Grid is a part of the power distribution system which uses renewable energy-based power generation connected to the grid system. Power generation of multi-energy is composed of renewable energy systems including photovoltaic, wind turbine, energy storage and local loads.**

Keywords: Solar PV array, MPPT, Solar inverter, Off-Grid, PID Controller

I. INTRODUCTION

In recent years, due to environmental pollution, fossil fuel exhaustion and an increase in global energy demand, the development of substitute energy sources has to turn into a worldwide right of way. Among all available renewable energy sources (such as solar, hydro, wind, and biomass), solar energy has the highest importance as it is a freely available, noise-free and most promising renewable source of energy. Therefore, shortly PV systems are expected to play an important role as an energy source in gathering electricity demand. PV systems may be operating in grid, standalone or hybrid mode. Photovoltaic systems have broad application in remote isolated areas and islands, where the utility grid is not accessible to meet the vital electric load. These PV systems should contain a battery storage system to store the charge in them and supply it at night when it is needed. In some areas where the sun is brighter in the daytime, excess energy we stored in a battery. To boost the functioning effectiveness of solar cells a maximum power point tracking (MPPT) algorithm is used this algorithm extracts the maximum power obtainable at some specified voltage and current irrespective of functioning conditions. There are various MPPT control techniques reported. Among all the available storage devices, batteries are above all used for renewable energy sources like PV due to their high energy mass and high performance. Battery storage devices composed of lead-acid, lithium-ion, nickel-cadmium, and sodium sulphur are available. This study offerings an optimization technique to enterprise solar off-grid PV systems for a suburban unit to discover the effective mode to use solar energy at the lowermost cost imaginable [1]. At present, Photovoltaic cells are planned to generate a max power to the grid. Though, the intricacy is that the PV array is unequal, depending upon weather circumstance. Thus, the MPPT makes the PV system providing its maximum power and that energy storage space element is needed to help get constant and reliable power from the PV system for both loads and effectiveness grid, and thus improve both steady and active behaviours of the whole generation system. Because of its little charge and soaring effectiveness, the battery can be put together into a PV production system that can more be established and consistent. In this paper, Off-Grid tested using a renewable energy-based power generation system which is self-possessed of PV array, power electronic converters, filter, controllers, local loads and off-grid. The paper discusses the detailed modelling of the grid-connected PV generation system. The PV array is associated with the off-grid by a solar inverter to optimize the PV output and DC to AC inverter to convert the DC output voltage of the solar output into the AC voltage. The planned model of the entire mechanism and control system are all imitation under MATLAB software. All simulation marks have established the strength of the models and the usefulness of the control method.

II. PV ARRAY

It consists of several PV cells within series and parallel relations. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array, huge the total exterior area of the region of the array, extra solar electricity it will manufacture. A PV cell is capable of represented through a corresponding circuit, as shown in Fig. 1. The type of this PV cell can be obtained using standard equations. To simulate a whole PV array, the replica of a PV module is developed first. Each PV module measured in this paper comprises 36 PV cells connected in series providing an open-circuit voltage (V_{oc}) = 44.86 V and a short-circuit current (I_{sc}) = 5.5A.The main machineries of the system are specifically PV array, MPPT controller, inverter and load. The solar PV system is simulated such that the PV module charge the battery through the controller and battery also delivers the power to the load when the solar radiation is insufficient. DC/AC inverter delivers AC electricity to the required residential AC loads [2-3].

PV module specification

Maximum power (P_{max})	190.15W
Voltage at Pmax (V_{amp})	37.73V
Current at Pmax (Imp)	5.04A
Open-circuit voltage (V_{oc})	44.86
Short-circuit current (I_{SC})	5.5
Maximum system voltage($V_{max)}$	493.5
Temperature (assume)	25 deg.C

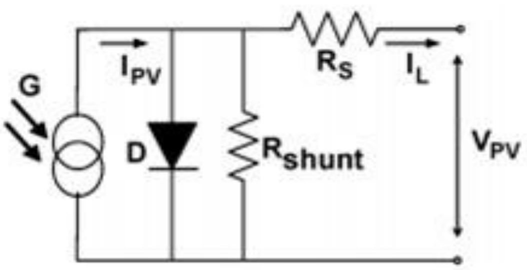


Fig. 1

III. PHOTOVOLTAIC EFFECT

To understand how a solar cell can convert solar energy into electrical energy, we need to get familiar with the phenomenon which is known as the photovoltaic effect. The photovoltaic effect can be defined as the physical phenomenon responsible for the creation of an electrical potential difference (voltage) in a material when exposed to light having a certain frequency. The photovoltaic consequence was exposed by the French physicist, Aleixandre Edmond Becquerel in 1839. When he was experimenting with metal electrodes and electrolyte, he revealed with the intention of conductance increases with incident lighting. He submerged Silver Chloride in an acidic solution and it was connected with platinum electrodes. When illumination was incident, he saw that a potential difference has developed across the electrodes.

Let us assume that a silicon block is doped using donor impurities and the lower portion is doped using acceptor impurities. Hence the concentration of electrons will be higher in the n-type region as compared to the p-type region. Similarly, the concentration of holes will be higher in the p-type region as compared to the n-type region. As a result of this, there will be a steady transfer of charges across the junction line of the block. Free electrons from the n-type region will try to diffuse to the n-type region in the block. This is simply based on the natural phenomenon that charge carriers always tend to move from regions of higher concentration to regions of lower concentration. This is because each of the free electrons in the n-type region is contributed by one neutral donor atom. Similarly, when a hole is diffused from the p-type region to the n-type region, it leaves a negative acceptance or ion behind it in the p-type region.

IV. MPPT CONTROLLER

MPPT Controller stands for Maximum Power Point Tracking and it used in the solar electric charged controller. MPPT is an electronic DC to DC converter that optimizes the match between the solar array and the battery bank. It used to convert a higher voltage DC output from solar panels down to the lower voltage needed to charge batteries. It used to convert a higher voltage DC output from solar panels down to the lower voltage needed to charge batteries. [2]Tracking of maximum power for different environmental conditions is confirmed by the low ripple content in the PV power output around MPP as shown in, when there is a step change in insulation from 0.9 to 0.1 Suns, the operating voltage shifts to the current source region [3]. Classical Maximum Power Point Tracking (MPPT) approaches are not operative due to their incapability to distinguish between local and global maxima.

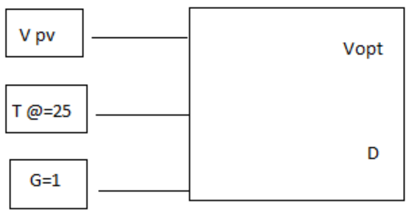


Fig. 2

A. WORKING PRINCIPLE OF MPPT CONTROLLER

The major principles of MPPT are to extract the maximum available power from PV module by making them operate at the most efficient voltage. MPPT checks the output of the PV module. It compares to battery voltage then fixes the best power that PV module can produce to charge the battery and converts to the best voltage to get maximum current into battery. It can also supply power to a DC load that is directly connected to the battery.The MPPT controller is modelled in based on the DC-DC converter which is controlled by the MPPT algorithm in order to operate the PV array at its maximum power point

B. EFFECTIVENESS OF MPPT CONTROLLER

MPPT is more effective under several conditions. Normally, the PV module works better at cold temperatures and MPPT is utilized to extract minimum power from them. On the other hand, when a battery is deeply discharged MPPT can extract more current and charge the battery **[4].** The Voltage V_s Current characteristics of a PV module vary with solar insulation and temperature.

V. PID CONTROLLER'S APPLICATION IN SOLAR PANEL TRACKING SYSTEM

This is a Solar panel tracking structure that operates when used as a power-building process from noon. This requires increasing daylight to create energy. This work helps the energy created by setting up Hardware to get the most natural daylight. This tracking system follows high light intensity. Most of the device output is taken from the PID control unit. Here in this function, you use the PID controller to track and produce solar energy as shown in Figure

The PID controllers are normally utilized to manage the time conduct of a wide range of sorts of dynamic plants and engineering problem solve. PID is a control procedure that objectives to diminish the blunders of a framework by experiencing three diverse numerical tasks and doleful outcomes up delivering a controlled output. Moreover, the PID formula described the PID controllers are normally utilized to manage the time conduct of a wide range of sorts of dynamic plants and engineering problem-solving. PID is a control procedure that objectives to diminish the blunders of a framework by experiencing three diverse numerical tasks and doleful outcomes up delivering a controlled output. Moreover, the PID formula described in Equation (1):

P+I * 1/S + D * N/1+N * 1/S … (1)

Here, P proportional, I integral, D derivative, and N filter constant. The corresponding impact affects controller output as mistakes increase with a particular pick up esteem. The relative impact builds the precision of the dynamic and static reaction of a framework. That is, it affects a system in the method for quick response time and ruination of errors. In this examination, a programmed tuning code is implanted in the PID because of criticism acquired from the framework. The fundamental impact affects controller outputs relative to the total of the mistakes from the powerful activity of the framework. This investigation centres on vital impact and the indispensable coefficient is dictated by a programmed tuning framework and by the experimentation strategy. "Ziegler– Nichols "strategy is a standout amongst the best techniques that expand the utilization of "PID controllers". The initial phase in this technique is to array the "I and D" gain up to zero, expanding the P avail up until managed and static swaying is acquired on the output. At that point, the basic gain up KC and the wavering period P0 is a record and the "P, I, and D" esteems are balanced likewise in Equation (2)

K_p=0.6 K_c, K_1 = 2K_p/P_0, K_d= K_p*P_0/8 … (2)

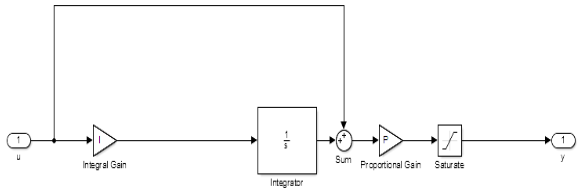


Fig. 3

VI. SOLAR INVERTER

In any solar system, the inverter has a very essential role. It allows monitoring the system so these system operators can look at how this system is working. The main function of an inverter is to convert direct current (DC) energy which is generated from the solar panels into usable alternating current (AC) energy. After the panels themselves, in a solar power system, inverters are the most important equipment. The inverter gives analytical information that can assist the operators in identifying operations & maintenance to fix any issues occurred in the system.

In this project, we are using a 2kW inverter manufactured by Generic (model no: CPS SCE2KTL) which has a Pnom ratio of 1.00. This is an indicator for sizing the inverter. It is often determined for getting a negligible overload loss. The value for "No loss" conditions is evaluated during the sizing in PVSyst, and usually lies between 1.25 and 1.30.

VII. PV ARRAY SIZING AND DATA ANALYSIS USING PV SYST SOFTWARE

PV Syst is software for the study, sizing, simulation and data analysis of complete PV systems. It is suitable for grid-connected, stand-alone and DC-grid (public transport) systems, and offers an extensive meteorological and PV-components database. We create a PV array

Simulation in Kalyani using PV Syst which consists of 2 kWp solar power. We used 10 solar modules manufactured by Generic (model no: FG-4BTM-200) to perform this operation. The solar panels are placed in a total of 19.2 m^2 area. The panels are tilted at 23^0 for better efficiency. A 2kW inverter is used to convert the DC to AC which is manufactured also by Generic (model no: CPS SCE2KTL). The further details are as follows

General parameters

Grid-Connected System	**No 3D scene defined, no shadings**	
PV Field Orientation		
Orientation	**Sheds configuration**	**Models used**
Fixed plane	No 3D scene defined	Transposition: Perez
Tilt/Azimuth: 23 / 0 °		Diffuse: Perez, Meteonorm
		Circumsolar: separate
Horizon	**Near Shadings**	**User's needs**
Free Horizon	No Shadings	Unlimited load (grid)

PV Array Characteristics

PV module		Inverter	
Manufacturer	Generic	Manufacturer	Generic
Model	FG-4BTM-200	Model	CPS SCE2KTL
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	200 Wp	Unit Nom. Power	2.00 kWac
Number of PV modules	10 units	Number of inverters	1 Unit
Nominal (STC)	2000 Wp	Total power	2.0 kWac
Modules	1 String x 10 In series	Operating voltage	200-500 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	1.00
Pmpp	1798 Wp		
U mpp	319 V		
I mpp	5.6 A		

Total PV power		Total inverter power	
Nominal (STC)	2 kWp	Total power	2 kWac
Total	10 modules	Nb. of inverters	1 Unit
Module area	19.2 m²	Pnom ratio	1.00
Cell area	15.1 m²		

A. ARRAY LOSSES

Array Losses

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 20.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 911 mΩ
Loss Fraction 1.5 % at STC

Module Quality Loss
Loss Fraction 2.8 %

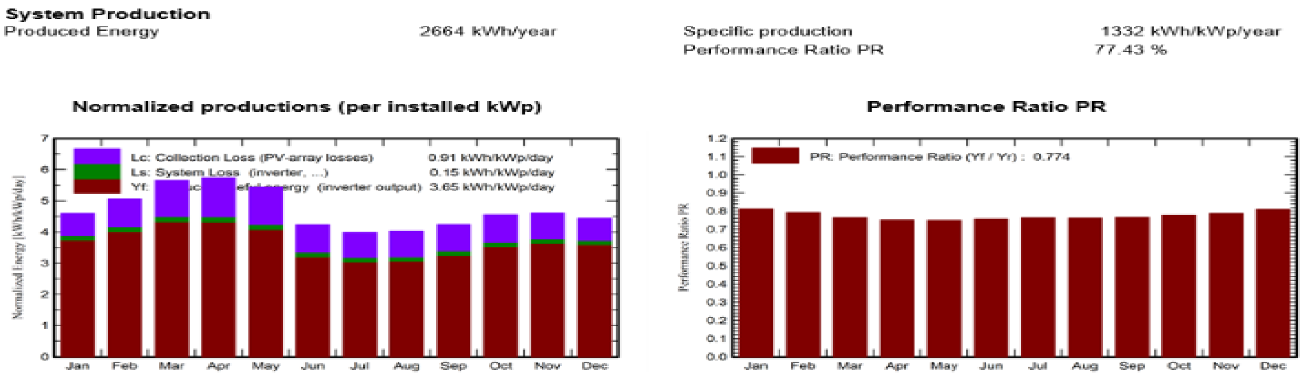
Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): Fresnel AR coating, n(glass)=1.526, n(AR)=1.290

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

B. MAIN RESULTS



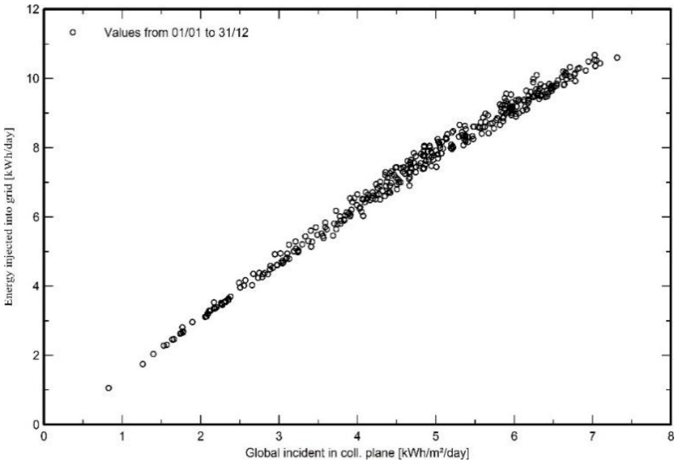


Fig. 4 Daily Input-Output Diagram

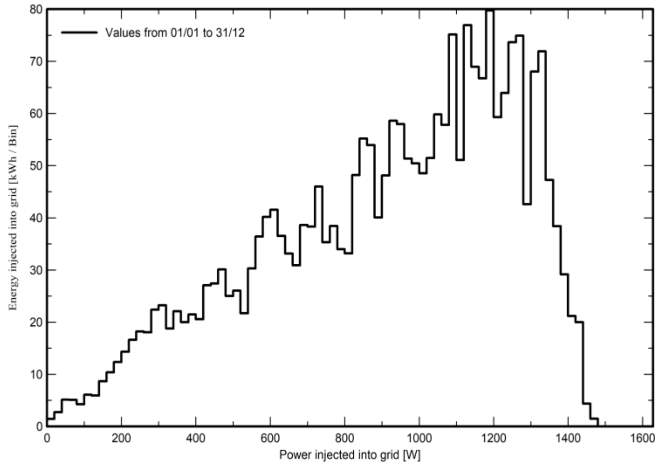


Fig. 5 System Output Power Distribution

C. LOSSES

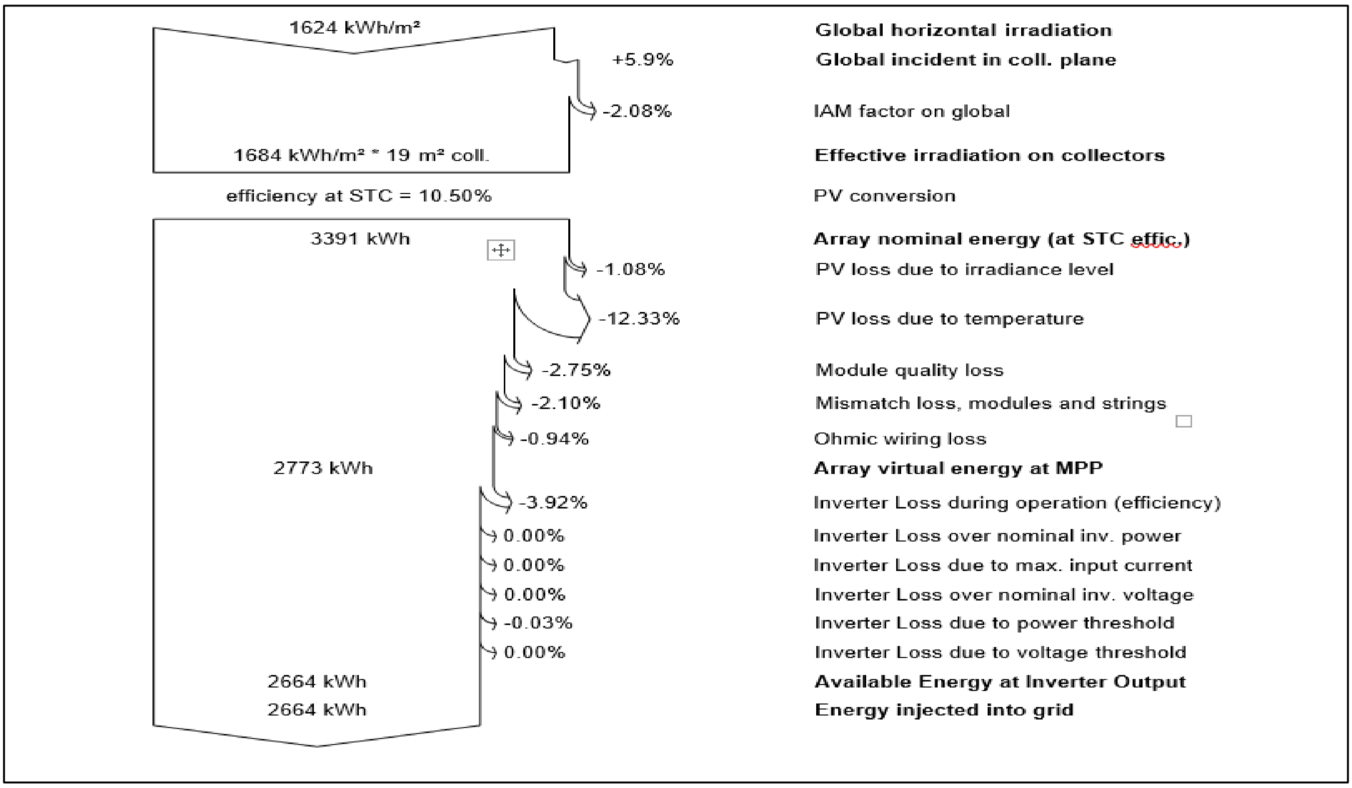


Fig: 6

IX. CONCLUSION

After studying and analysing all the things related to solar PV module we say that its efficiency not as much as thermal power plant which is a very important power generating source nowadays. But if we will look onto future in 2030-50 then we say that its future aspects are very much effective with its efficiency. Off-grid (or stand-alone) claims are typically used where there is no electric grid or when the cost of connecting to the grid is high. Applications are normally smaller than other system types and are habitually used for small-scale developments in rural areas, as a resolution in emerging countries, as well as for suburban households willing to disconnect from the grid (typically not the most economic or efficient option) (IRENA, 2017a). A key feature of off-grid renewable energy keys is that they offer speedily deployable, dependable and, in many cases, the most sparingly supportable option to address the necessity for energy access. They can efficiently growth the flexibility of energy systems, improve energy safekeeping, empower societies, reduce local and regional CO_2 discharges and, depending on which systems are adopted, foster energy price decreases [5-6].

The breakthrough in renewable bulk accompaniments over past few years has largely been achieved due to significant cost discounts driven by enabling government policies, including arrangement policies, research and development (R&D) backing, and other policies that have supported the development of the industry in leading countries. Levelled cost of electricity for solar PV is now modest compared to all cohort sources (including fossil fuels) and is predictable to flagging further in the coming decades, falling within the variety of INR 1.46 and 0.08/kWh by 2030 and INR 1.02 0.05/kWh. Solar PV is emerging as one of the most competitive sources of new power generation capacity. The future marketing growth of the solar module is increasing due to its materials like silicon & in advanced solar architecture we need perk, hybrid cells, thin film & non silicon materials like perovskites, Beyond fields, we use solar PV modules in floating PV panels, building integrated PV models also known as solar shingles , solar trees, solar carports which are installed in ground so that parking lots and home driveways can be laid underneath to form a carport, solar PA thermal systems etc. The solar PV industry labouring 3.6 million people worldwide in 2018 and this number is projected to rise further to 18.7 million people by 2050 in the Remap case.

X. REFERENCES

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