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Analysis and Cost Optimization of On-Grid and Off-Grid Solar System

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Abstract: The alarming rate of fossil fuel deficit, increasing oil prices, global warming, harm to ecosystem and environment, the encouraging incentives to develop alternative energy resources with high efficiency and low emission are important Suitable power source at the remote area where conventional power is not obtained Setting of the module on the rooftop or in the solar tree such that the max energy capture by the panel & max hours solar energy obtained Calculation of the wind load on the panel & development of structure which gives the sufficient strength against wind load Study and analysis of the off-grid & on-grid hybrid inverter. The aim of these models is to minimize the cost of energy delivered to the resident if real-time the primary in place. In this optimization seeks to determine how many solar collector and batteries are needed to provide the lowest-cost energy to the customer.
Keywords: Solar, Cost Optimization, Grid, Feasibility, MPP

I. INTRODUCTION

Solar energy is the energy obtained by capturing heat and light from the Sun. Energy from the Sun is referred to as solar energy. Strength of various forms is of great importance in world civilization from the start of it to the modern era. It will play a deterministic role in shaping future human culture. There are different types of energy sources available, and the efficient conversion of different kinds of energy resources to electrical energy is an essential aspect of research work to be carried out extensively. Electrical power is the most crucial form amongst various types of energy, and the use of electrical energy is noticed in everywhere, such as home, industry, and agriculture, transported. The alarming rate of fossil fuel deficit, increasing oil prices, global warming, harm to ecosystem and environment, the encouraging incentives to develop alternative energy resources with high efficiency and low emission are imperative [4]. Insufficient of fossil fuel like coal, and gas has further highlighted the importance of power from these sources [2]. These sources provide an attractive solution for meeting requirement of power at remote locations, in case of which is not feasible to extend the grid. The P-V and V-I curves have been obtained at changing solar irradiation levels and temperatures [7]. These solar energy sources are generally renewable and non- polluting in nature. Performance optimization, operative efficiency, and system dependable for a smart grid system are a crucial criterion.

Here we consider the incremental conductance method for tracking Maximum Power in PV module. This method is proposed because it is precise, vigorous and simple to model the PV array. The Boost DC is used into AC by utilizing three-phase Inverter, and then the AC power is transmitted to the Smart Grid. The MPPT Controller is appropriate for studying Power and voltage as well the current and voltage curve for PV system [1]. The proposed method is designed on MATLAB software. The below-described model, as well as its control strategy, gives us a perfect tool for performance optimization of smart grid [8]. Technology has provided several ways to utilize this abundant resource [9]. It is considered a green technology because it does not emit greenhouse gases. Solar energy is abundantly available and has been utilized since long both as electricity and as a source of heat [5]. A computer program has been developed to size systems components to match the load of the site in the most cost-effective way. In this purpose, the study was executed using a GUI (Graphical User Interferences) programmed in MATLAB. The methodology which we have proposed in this project is a heuristic perspective which uses a stochastic gradient search for global optimization. Here the objective function (the function that it is desired to maximize or minimize) is the minimization of the hybrid system total cost. In India, solar power is a rapidly progressing industry [3]. The solar installed capacity of the country has reached 30.071 Giga Watt on 31 July 2019. India also has the lowest capital cost per Mega Watt worldwide to install solar power plants.

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Table-1

SECTOR	COAL	GAS	DIESEL	TOTAL	NUCLEAR	HYDRO	RES	GRAND TOTAL(MW)
CENTRAL	48130	7519.73	0	55649.73	5780	11091.43	0	72521.16
STATE	58100	6974.42	602.61	65677.53	0	27482	3803.67	96963
PRIVATE	58405	8568	597.14	67570.52	0	2694	31973	102237.81
ALL INDIA	164635	23062.15	1199.75	188897.78	5780	41267.43	35776.96	271722.17

Table 1 Sector wise energy consumption

Table-2

Region	ENERGY			PEAK POWER		
	Requirement (MW)	Availability (MW)	Surplus(+)/Deficit(-)	Demand (MW)	Supply (MW)	Surplus(+)/Deficit(-)
Northern	355794	354540	-0.4%	54329	54137	-0.4%
Western	353068	364826	+3.3%	48479	50254	+3.7%
Southern	313248	277979	-11.3%	43630	35011	-19.8%
Eastern	124610	127066	+2.0%	18507	19358	+4.6%
North-eastern	15703	13934	-11.3%	2650	2544	-4.0%
TOTAL	1162423	1138346	-2.1%	156862	152754	-4.0%

Table 2 Region wise energy and peak power

II. BASICS OF SOLAR PV SYSTEM

A PV cell is an electronic device that converts sunlight into direct current electricity through the PV effect. For this energy conversion to be possible, silicon-based semiconductors are widely-used to form a p-n junction in the PV cell. This junction is created by connecting n-type and p-type semiconductors, which are usually produced through ‘doping’: doping is a technique used to vary the number of electrons and holes in semiconductors to modify their electrical properties through the addition of impurities. Through the connection, excess particles diffuse to the p-type semiconductor from the n-type semiconductor, and conversely excess holes diffuse to the n-type semiconductor from the p-type semiconductor, such a movement creating a positively charged area at the n-type side and a negatively charged area at the p-type side, hence forming an electric field at the junction. When the photovoltaic cell is illuminated, electrons in the semiconductor material will be knocked loose from their atoms when light photons hit the cell, assuming that the energy of these photons is higher than the energy band gap of the material, multiple electron-hole pairs will be formed, and electrons will start to flow through the material and the external circuit in the direction dictated by the electric field at the junction. After completing all the travelling, the electrons will then return and recombine with the holes back in the semiconductor to close the circuit. Therefore direct current electricity is generated as a result. On the other hand, an inverter can be used to convert direct current into alternating current if required. Solar cells are the building blocks of a PV array. These are made up of semiconductor materials like silicon etc. A thin semiconductor layer is specially treated to form an electric field, positive on a side and negative on the other. Electrons are knocked loose from the atoms of the semiconductor material when light strikes upon them. If an electrical circuit is made attaching a conductor to both sides of the semiconductor, electrons flow will start causing an electric current. It can be circular or square in construction.

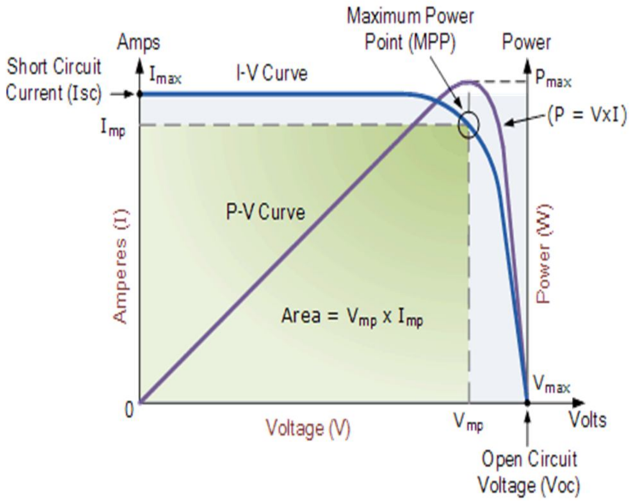

Fig 3: Solar Cell I-V Characteristic Curve

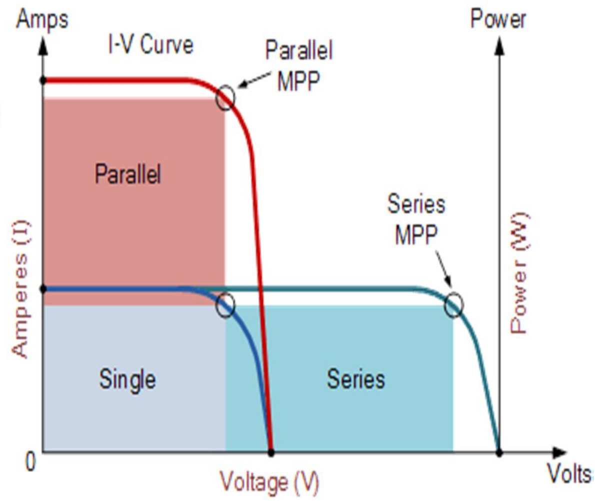

Fig 4: Solar panel I-V Characteristic Curve

III. PHOTOVOLTAIC ARRAY

To fulfil the requirement of the power, the power produced by a single module is not enough. PV arrays can use inverters to convert the dc output into ac and use it for motors, lighting and other loads. By connecting in series, the modules get more voltage rating, and by joining in parallel, the modules reach the current specifications.

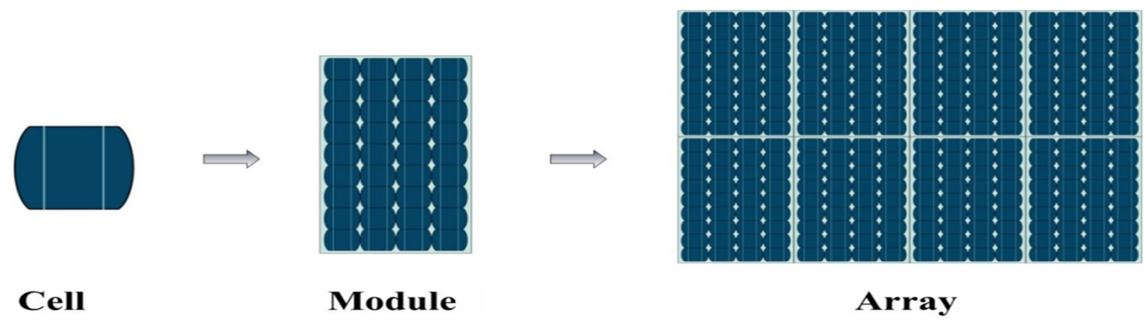

Table-3

Solar Cell Technology	Max lab Efficiency	Typical Cell Thickness	Si Use	Cost
Mono-Crystalline Silicon	27.6	~200μm	High	High
Poly Crystalline Silicon	20.4	~200μm	Moderate	Moderate
Amorphous Silicon Thin-Film	12.5	<1μm	Low	Low

Table-3 Characteristics of various types of solar panel

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IV. EQUIVALENT CIRCUIT MODEL

Equivalent circuit models define the entire I-V curve of a cell, module, or array as a continuous function for a given set of operating conditions. One basic equivalent circuit model in everyday use is the single diode model, which is derived from physical principles and represented by the following circuit for a single solar cell:

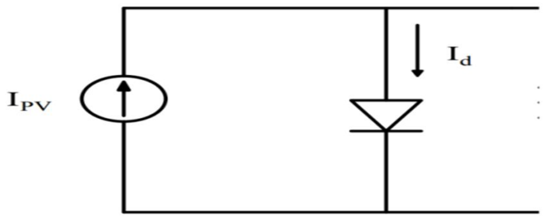

Figure 5: Equivalent circuit models

By using Kirchhoff's current law, we can formulate the governing equation for this equivalent circuit for current I:

$$\boldsymbol{I = I_L - I_d - I_{sh}} \text{ .... } \mathbf{(1)}$$

Here,

$\boldsymbol{I_L}$ = The light-generated current in the cell, $\boldsymbol{I_d}$ = the voltage-dependent current lost to recombination, $\boldsymbol{I_{sh}}$ = the current lost due to shunt resistances

In this single diode model, Id is modelled using the Shockley equation for an ideal diode:

$$\boldsymbol{I_D = \left[exp(\frac{V+IR_S}{nV_T})\right] - 1} \text{ .... } \mathbf{(2)}$$

Where, is the diode ideality factor, is the saturation current, and is the thermal voltage given by:

$$\boldsymbol{V_T = \frac{kT_C}{q}} \text{ .... } \mathbf{(3)}$$

Where, **k** is Boltzmann's constant (1.381×10^{-23} J/K), and **q** is the elementary charge (1.602×10^{-19} C)

V. MAXIMUM POWER POINT TRACKING

In a P-V characteristic curve of PV cells or modules, there exists only operating point where the power is maximum. This point is known as the MPP

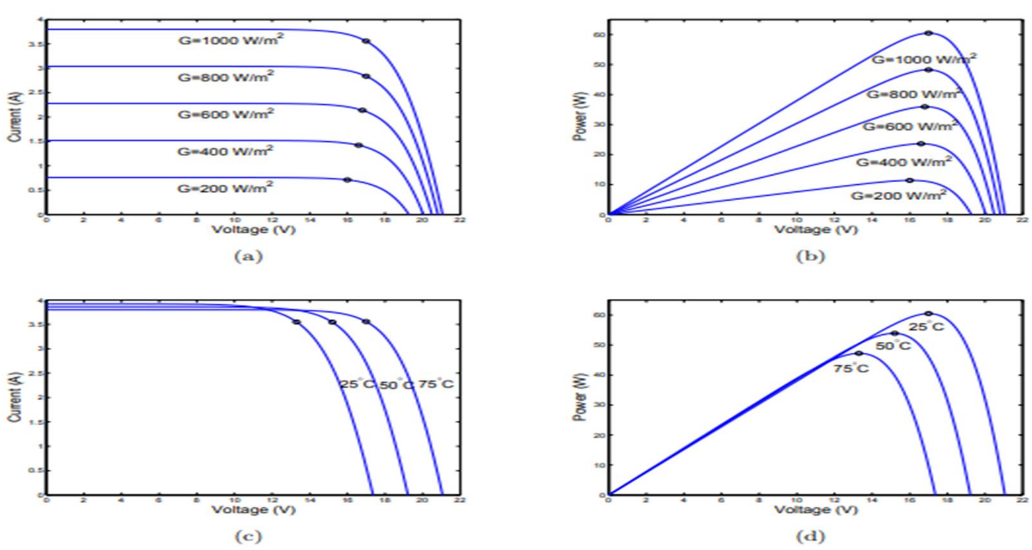

Fig 6 Electrical characteristic curves of a MSX60 PV module under different atmospheric conditions: (a) I-V curves under various irradiance levels; (b) P-V curves under various irradiance levels; (c) I-V curves under various temperatures; (d) P-V curves under various temperatures

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VI. PARTIAL SHADING TECHNIQUE

The output power delivered by a single solar cell is typically small to drive the load connected across the output terminals. Therefore, many such cells are connected in different configurations to boost the output voltage and current ratings. PV modules are made of PV cells connected in series and parallel configurations to generate higher voltages and currents. The manufacturing, material and architectural constraints limit the number of cells that can be combined in these configurations. Therefore, PV modules are interconnected to form PV arrays.

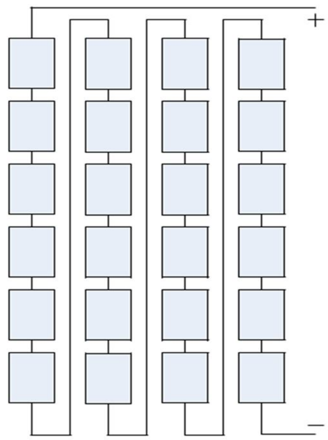

Figure 6.1: Series connected PV module.

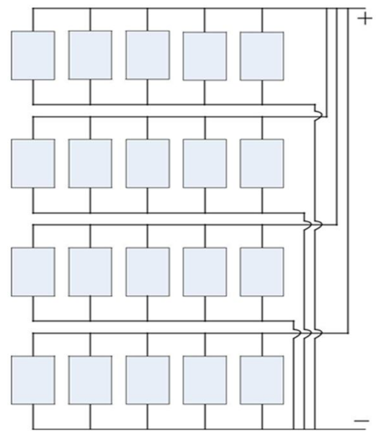

Figure 6.2: Parallel connected PV module.

Shading can occur due to several factors such as passing clouds, dust deposition, a shade of the trees or adjacent buildings, bird droppings, etc. and can be broadly classified into two types;

Uniform Shading and Non- uniform/ Partial Shading

To better understand the effect of shading, let us consider a PV module with identical cells connected in series, as shown in Figure 3-3. In a series module, the voltage drop across each cell adds up to give the module voltage with the current flow through all the cells remaining the same irrespective of shaded cells producing reduced photonic current. Thus the overall module parameters are given as;

$$Im = Ic \qquad \text{.............} \quad \textbf{(4)}$$

$$V_m = \sum_{C=1}^{N_S} V_C \qquad \text{..............} \quad \textbf{(5)}$$

Im =total model current, Ic= individual cell current, Vm = total voltage across the module, Vc = voltage across individual cells

Ns = number of cells connected in series. Scientifically the model simulated PS conditions to compare the performance difference between different connecting methodologies, a series of PS patterns

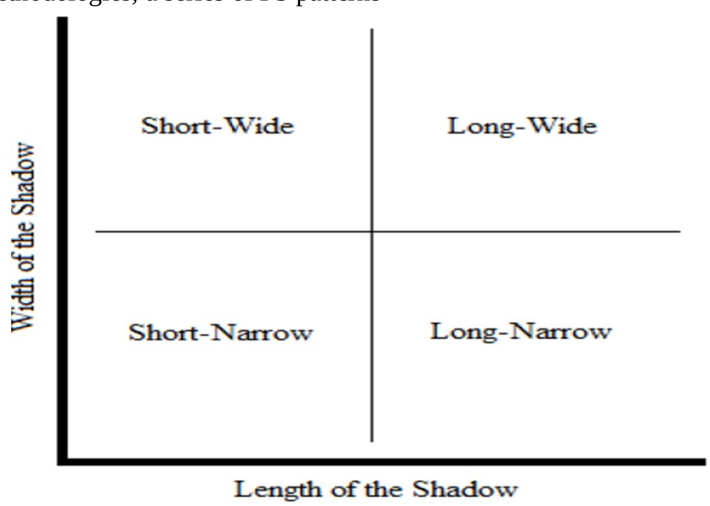

Figure 7 Four different PS conditions

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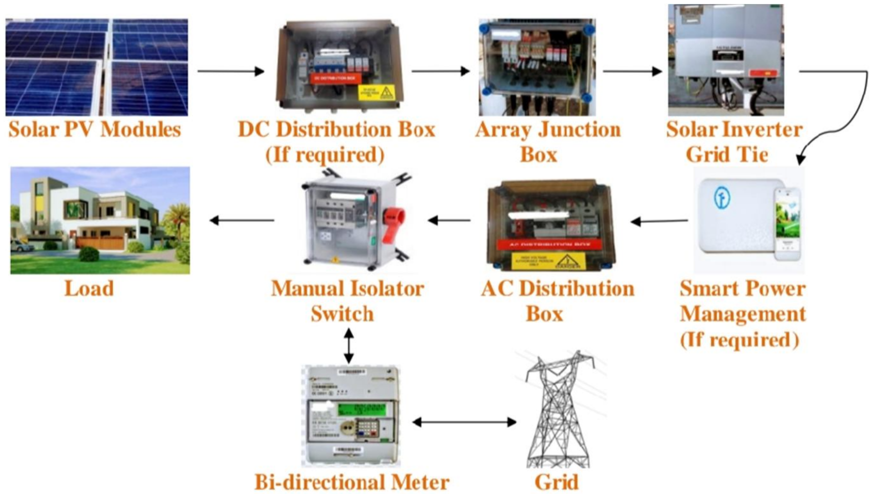
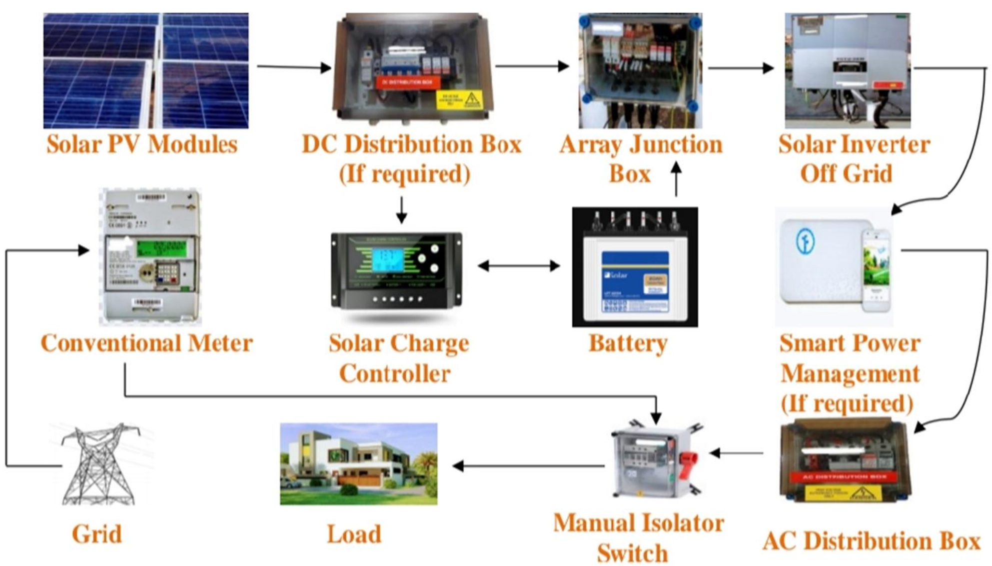
VII. GRID BASED SOLAR PANEL

A. On-Grid Solar Panel



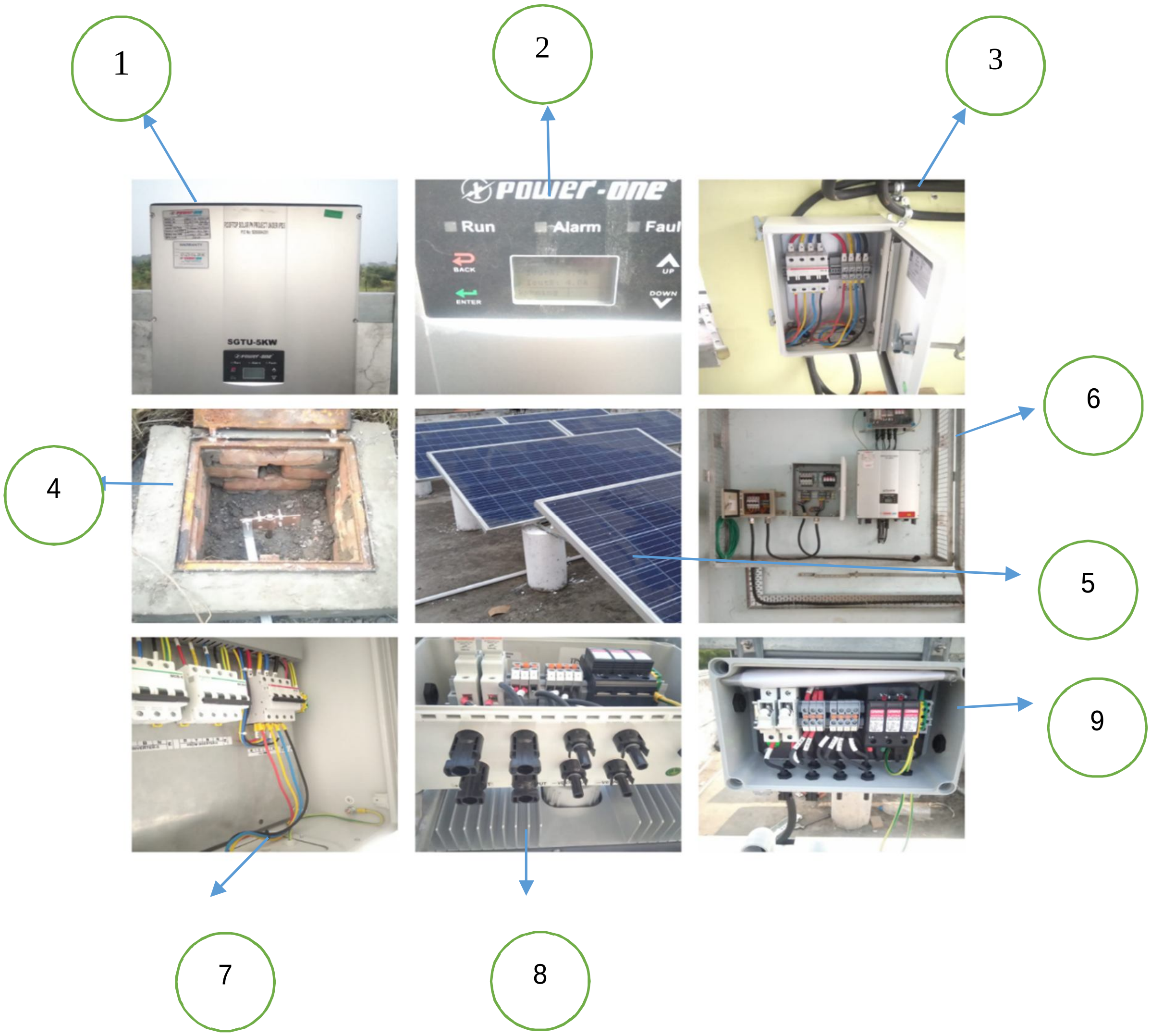
On-grid means your solar system is tied to your local utility's GRID. A grid-connection will allow you to save more money with solar panels through better efficiency rates, net metering, plus lower equipment and installation costs. The electric power grid is in many ways also a battery, without the need for maintenance or replacements, and with much better efficiency rates. In those solar project have no storage unit, production power is directly connected to the grid (LT Panel) with bi-directional meter-substation and commercial unit. At day time the sizeable solar panel is developed by panel, and it is sent to the grid through the inverter. At night load take the power from the grid to calculate the power we use the bi-directional meter, which counts the produce solar power and consume power.

B. Off-Grid Solar Panel



An off-grid solar system is the obvious alternative to one that is grid-tied. To ensure access to electricity at all times, off-grid solar systems require battery storage and a backup generator (if you live off-the-grid). On top of this, a battery bank typically needs to be replaced after ten years. Batteries are complicated, expensive and decrease overall system efficiency. In those solar project store in the battery and few parts send to the load. At day time the power is produced by the solar panel and in the night when solar radiation is not available from the battery the power supply to the load through an inverter.

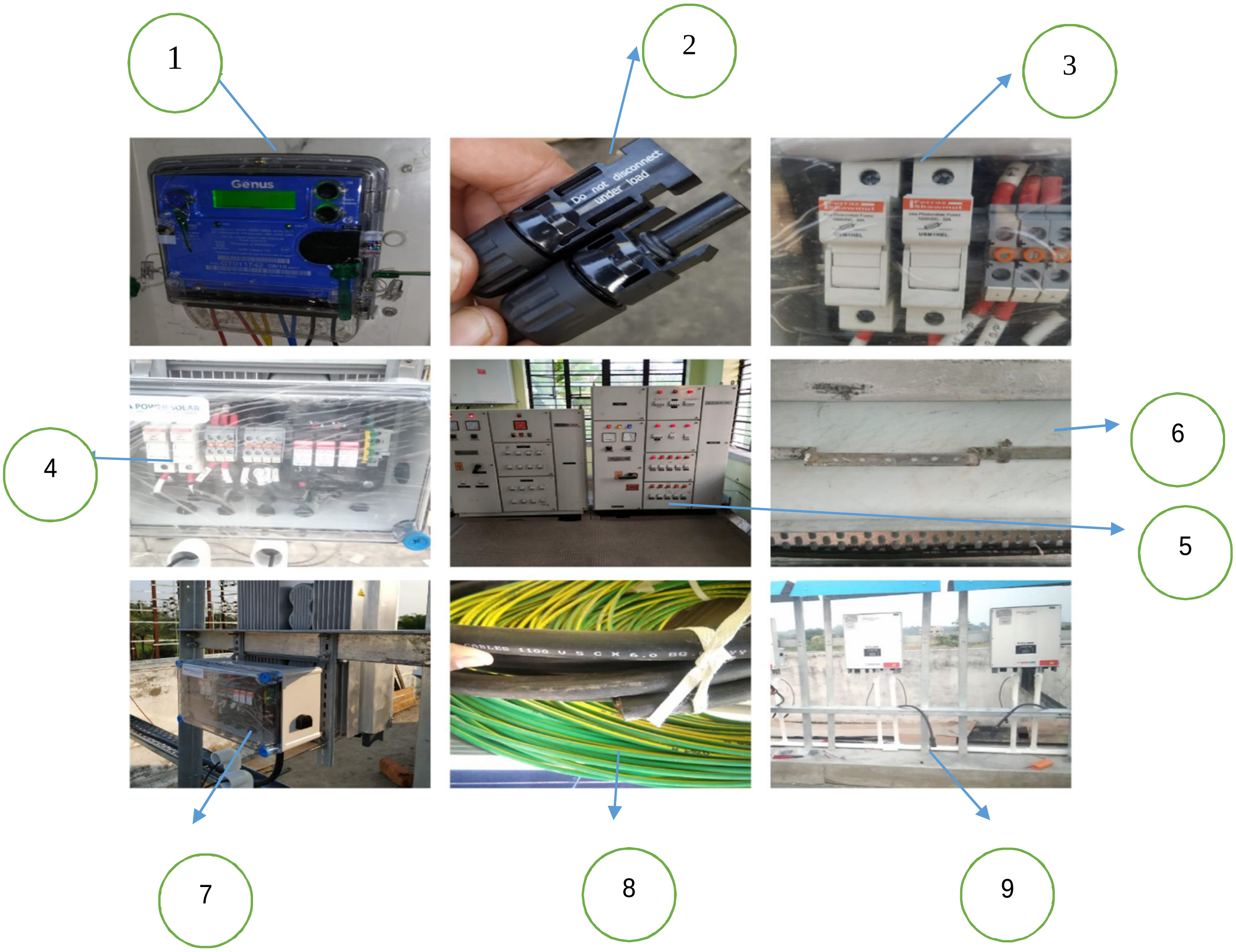
VIII. HARDWARE MODULE & SITE VISIT-1



Now describing the above figure:

1) Inverter (35 KW MPPT inverter DC I/P, 3-phase, 415 volt, AC O/P)
2) Inverter Display
3) Isolation switch box (using MCB)
4) Earth Pit (Using Gi earth electrode)
5) Solar panel (350 Wp (Peak Power) per panel polycrystalline; Vmpp-37V; Impp-8.53; Voc-44.9V; Isc-8.97A; Maximum series use-20A; Power tolerance-0 to+5 W) (The size of the panel is approx. 1984mm x 1150mm. The wafer is set on the PVC module and the border is binding with GI frame)
6) Whole system set-up
7) ACDB- AC distribution box (single phase with MCB & SPD)
8) DC & AC Terminal
9) DCDB- DC distribution box (2 in, 2 out with 2 MCB, 2 SPD & 2 FUSE)

IX. HARDWARE MODULE & SITE VISIT-2



Now describing the above figure:

1) Fully static watt hour meter for solar rooftop [bidirectional, single phase, 2 wire, 5-30 amp. LCD display]
2) Male and Female Cord (Negative terminal of the 1st panel directly run to the negative terminal of the AJB Box and the positive terminal of the 1st panel connect with a negative terminal of the next panel)
3) DC fuse (use photovoltaic fuses, 1000V DC and 32 A)
4) Array Junction Box (AJB use to 5kw power with 16panrls in series and ampere is 8.53A and voltage is 37 x 16 =592v)
5) Low Tension panel
6) For Earth we use Strip only and carry the cable tray
7) DC Distribution box setup
8) DC/AC cable
9) Inverter setup (Solar power inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection)

X. PRICE CALCULATION

1) *Off-Grid:* Non Commercial meter (Rs 1.15 Lakh/KW) [collected price/data from Jana Consultancy Firm]
2) *On-Grid:* Commercial Meter (Rs 75000/KW) [collected price/data from Jana Consultancy Firm]

A. *Now the capacity calculation of ON-GRID*

Total bill amount: Rs 10000
Bill reduces: Rs 9000 (90%)
Unit develop: (9000/7) = 1285.7 KWH
Unit develop/day: (1285.7/30) = 42.8 KWH/day
Solar hours = 6 hours
Solar Plant Capacity = (42.8/6) = 7KW
Now, expenditure = 7 x 75000 = Rs 525000
Monthly save = Rs 9000
Save in a year = 12 x 9000 = Rs 108000

XI. COST OPTIMIZATION

In our technical study, cost optimization is also necessary. It is a business focus technique. In this scenario, we are giving minimum resources and will get maximum output. It is mainly the Life cycle cost. We also say that maintained cost and Capital cost both are included in it. The novelty of this paper is to put the solar panel into the grid. For ease of calculation, the optimization problem is divided into two steps. The most crucial step in the process is to minimize the electricity bill the next level, considering the achieved result, to maximize the investment return. It is an onetime investment, and the payback is within 7 to 8 years max. So for the next 18 years, you will produce your power at free of cost.

XII. CONCLUSION

The concept of the solar system is not well-known to everybody, so we required to expand the knowledge of solar energy in the society. Such that community can interest to the solar energy. In India, at a remote area, conventional power is not available .In those are we can install the solar power plant to develop of society. We just elaborate on the whole solar system in two ways, on and off-grid. On-grid systems send excess power generated to the utility grid when you are overproducing. These are the most cost-effective and most uncomplicated systems to install. Off-grid systems allow you to store and save your solar power in batteries when the power grid goes down. It is meant to be entirely self-sustaining. This system is excellent for the environment, and people can live a self-sufficient lifestyle. As the control facilities influence each other, a proper coordination is required to bring all devices to work together, without interfering with each other. It is found that the due to the robustness of the controller, just after the fault system parameters regain Conclusion their original values.

XIII. FUTURE SCOPE

A. We study deeply on the ON-GRID & OFF-GRID Solar System with merit & demerit. We will try to develop higher efficient solar module. When the grid supply is off, the solar system produce the D.C power but the inverter unable to supply the A.C power to the load. I try to solve this problem.
B. In solar system cost is increase due to the high cost of the modules. We will try to develop the module such that the cost of the module is decrease. In INDIA at remote area conventional power is not available in those area. We can install the solar power plant for develop our society.

XIV. ACKNOWLEDGEMENT

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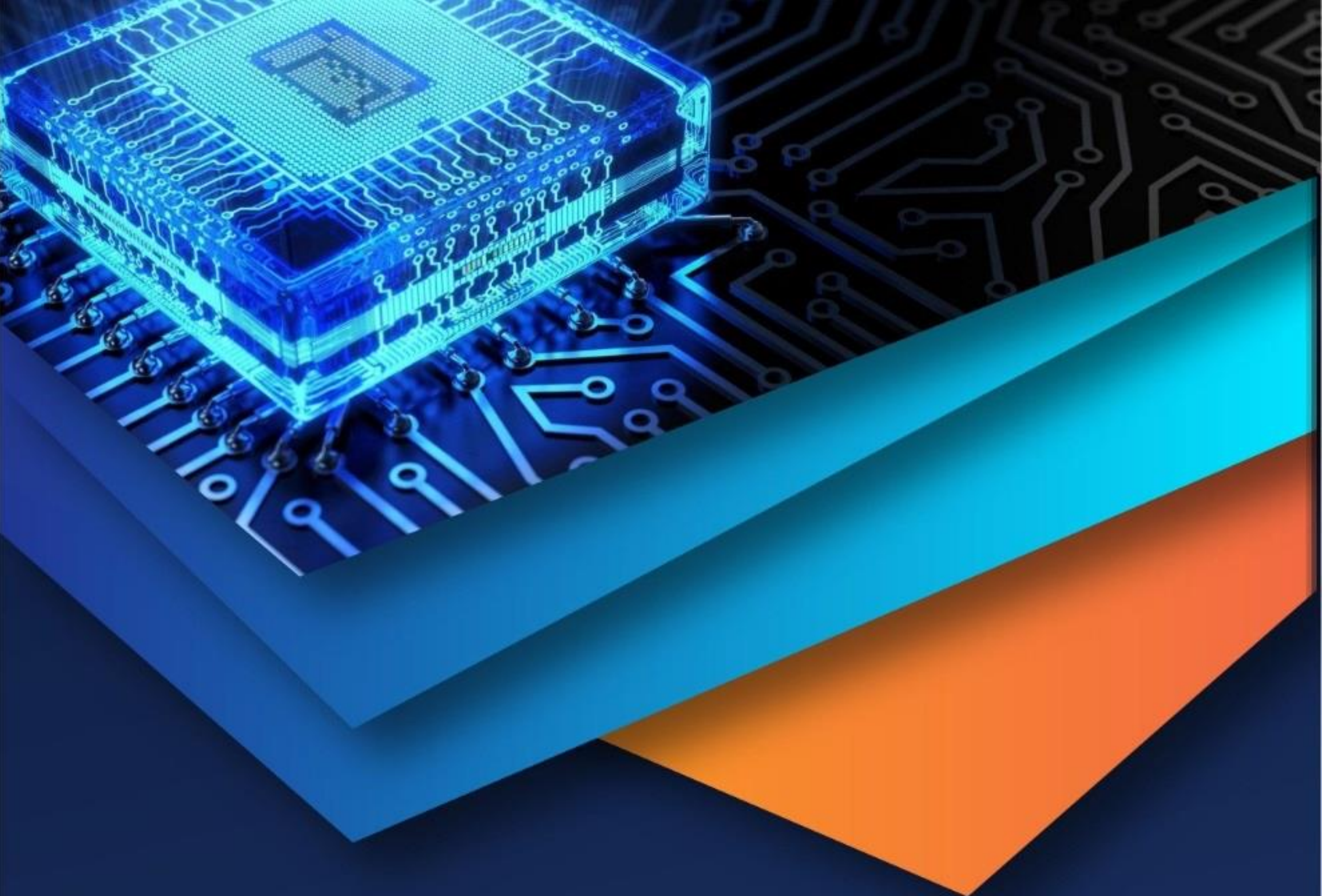

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