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Pragmatic Shift from Conventional to Solar Off-Grid Access to Electricity in Isolated Places

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Facing ever-increasing worldwide energy demand, the reliable and eco-friendly use of green power drive as sources is one of the biggest challenges in 21st century. About 200 million people of India are deprived of grid power supply, prominently in unreachable hilly and rural locations of the country. Solar energy is a free, green and a leading source of sustainable energy to produce electricity and can overcome the gap between energy demand and generation in the developing countries. Solar energy technologies can be harnessed either through photovoltaic for electrical energy or thermal power for heat generation respectively. Present novel research is an effort to design, connect and suitably apply solar off grid system in an isolated place like at the premises of Centurion University, Odisha. The approach is to develop low cost, ecofriendly, and less energy ingesting solar off-grid systems such as emergency light, street light, and water pumps for suitable

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locations in-side and out-side of the University. The efficient design of off-grid system plays a vital role in the larger development of solar power generation in the country. The opportunity will helps to upcoming researchers and industry experts to implement environmental friendly solar off-grid system, and welcome to a better tomorrow.

Keywords: Solar energy; photovoltaic (PV); off-grid system; electricity; ecofriendly.

1. INTRODUCTION

The enormous energy source of the earth can be harnessed by two ways from sun through thermal route for heat and photovoltaic route for light respectively. World is speedily moving towards generating electricity from solar photovoltaic (PV) system to bridge the gaps between energy demand, supply, and production of the country [1-2]. Use of Solar power system can be one among the two technologies:

- Photovoltaic (PV) systems use solar panels, either on rooftops or in ground-mounted solar farms, converting sunlight directly into electric power.
- Concentrated solar power or thermal (CSP) plants use solar thermal energy to make steam, and later converted into electricity by a turbine [3].

A solar photovoltaic (SPV) system alters the solar light energy into electrical energy. The SPV system comprises of solar panel, charge controller (CCR) or inverter, battery and electrical assosories. One of the prominent models of such a technology is solar off-grid system [4-6]. The off-grid system is not connected to the normal supply grid. The power generated can be stored in batteries for further applications. The PV uses solar cells (mostly Si type) bundled in solar panels to produce direct current (DC) [7,8].

With about 310 clear and sunny days in a year, the considered solar energy incidence on India's land area is about 5000 trillion kilowatt-hours (kWh) per year. Till March 2021, the solar power system installed capacity was 40 GW in India against the target of 100 GW (including 40 GW rooftop) by 2022 [9-11]. The government is also promoting more sustainable development in agriculture through solar PV installation. The power network of renewable energy in Odisha is managed by Odisha Renewable Energy Development Agency (OREDA). According to OREDA, the solar PV power installed capacity is around 480 MW by 2020 [12-14]. The designer of the system is responsible for selecting the value of the different parameters like number and type of PV modules, controller or inverter type, distribution of components in the installation field. India is facing a severe energy scarcity which is hindering its industrial growth and economic progress [15-17]. Setting up of modern solar power systems is certainly independent of fossil fuels. Thus, it is essential to tackle the energy crisis through judicious utilization of abundant the solar energy, especially solar photovoltaic system [18-21].

2. METHODS AND METHODOLOGY

The Indian state, Odisha receives an average solar irediance of 5.5 kWh per square meter area with around 310 clear sunny days per year [1-4], illustrated in Fig.1.

The solar photovoltaic (SPV) system is a power system intended to supply serviceable solar power by means of photovoltaics. This converts light energy from the sun to generate electricity. The basic block diagram of a solar Off-grid system is llustrated in Fig. 2.

On-Grid systems are solar PV systems that only generate power when the utility power grid is available. They must connect to the grid to function. Off-Grid systems allow you to store your solar power in batteries for use when the power grid goes down or if you are not on the grid [5,6].

The above SPV system consists of following components;

1. Solar panel or module
2. Solar charge controller (CCR)
3. Solar inverter (optional)
4. Solar battery
5. Electrical load

2.1 Solar PV Cell and Module

The majority solar cell is made up by silicon material to produce electricity, illustrated in Fig. 3. To achieve a required voltage and current [7, 8], a group of PV modules or panels are wired into large array that called PV array.

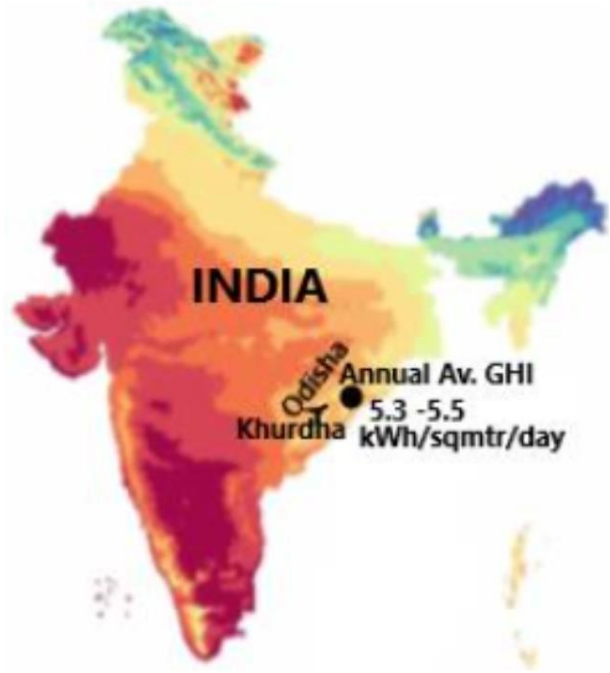

Fig. 1. Global Horizontal Irediance in Odisha [4]

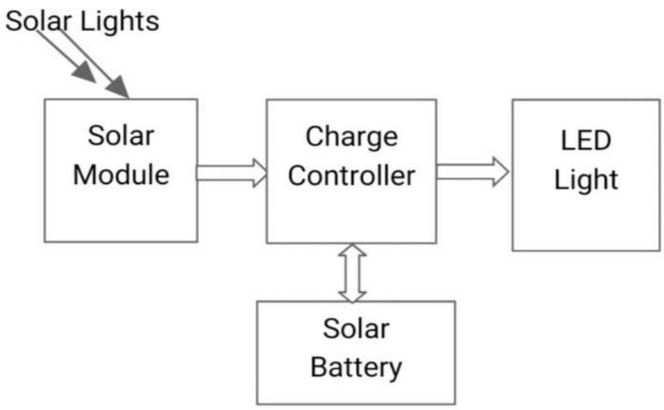

Fig. 2. Basic Block Diagram of Solar Off-Grid System

Mathematically, $I=I_L-I_D$

$$I = I_L - I_0 \left[exp\left(\frac{eV}{KT}\right) - 1\right] \quad (1)$$

Where,

I= electric current
I_L= solar light generated current
I_D= diode current
I_0= saturation current
e= electron charge
V= voltage across the junction
K= Boltzmann's constant and
T= absolute temperature.

In India, Poly-crystalline panel is more used as compare to other type [9,10]. Different types of solar modules or panels are illustrated in Fig. 4. Rating of solar panels is in Watts with specified voltage for an off-grid system.

2.2 Solar Charge Controller

- A solar charge controller limits the rate at which electric current is added to or drawn from electric batteries, illustrated in Fig. 5.
- It is a DC device (DC to DC converter).

- There are different types of solar charge controllers, such as PWM and MPPT solar charge controllers [11].
- Rating: Volt Ampere Hour (V Ah)

2.3 Solar Inverter

- A solar inverter is a power electronic device that converts direct current (DC) to alternating current (AC), illustrated in Fig. 6.
- Rating: Volt-Ampere (VA) or Kilo-Volta-Ampere (kVA).

2.4 Solar Battery

- A solar battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices [12-14], illustrated in Fig. 7.
- Rating: Volt Ampere-hour (V Ah)

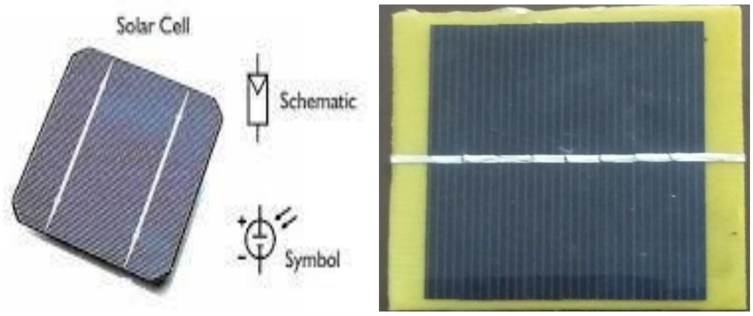

Fig. 3. Solar Cell

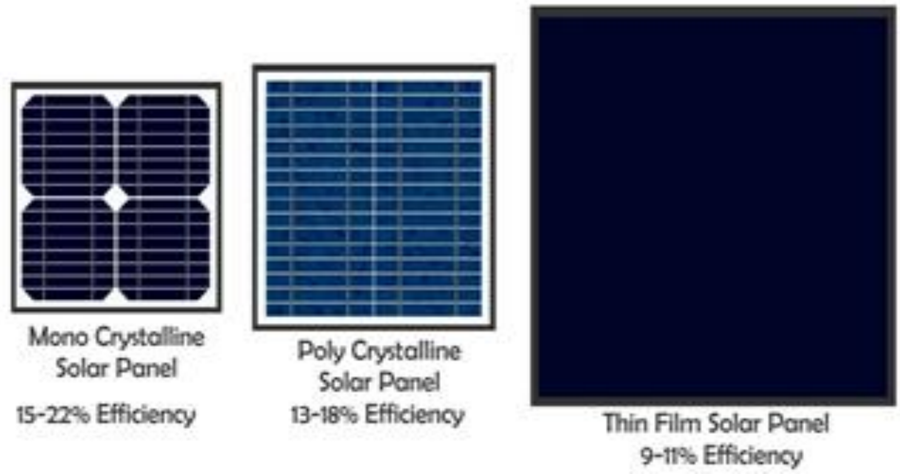

Fig. 4. Solar Modules (Mono, Poly-crystalline and Thin film types)

Fig. 5. Solar charge controller (PWM type)

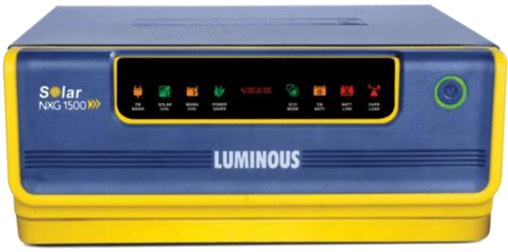

Fig. 6. Solar NXG Hybrid Inverter

Fig. 7. Solar Tubular (Lead-Acid), Maintenance free and Li-ion Battery

2.5 System Connection and Operation

The following steps need to be followed for suitable implementation of a solar off-grid system any geographical area of the world.

Step-1: At first Civil and mounting structure must be completed after proper site survey
Step-2: Solar PV system need to be connected after proper checking [15-17]
Step-3: Positive (red) and negative (black) color wire of each component need to be connected with solar charge controller or inverter of the system [18-20]
Step-4: After connection of all the apparatus, proper checking is needed for its successful operation and applications
Step-5: Operation and Maintenance

2.6 Solar PV Applications

The design, connection practice and applications is carryout in Centurion university of technology and management, Odisha, illustrated in Fig. 8.

Government of Odisha is also promoting the solar PV in irrigation system under two schemes such as Soura Kalanidhi and Kusum Yojana. Soura Jalanidhi project are promoting the uses of solar power in irrigation by farmers. Under the scheme Government distributed 5000 solar pumps to the farmers in the state. The Odisha Renewable Energy Development Agency (OREDA) has invited bids to develop 500 MW of ground-mounted solar pump projects under the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM KUSUM) scheme [21], illustrated in Fig. 9.

Fig. 8. Different solar off-grid applications in Centurion University, Odisha

Fig. 9. Solar water pumps (1 HP and 2 HP Capacities)

The cost of running pumps solely depends upon its materials, and installations. The cost should be wallet friendly. The low cost pumps as per local market price in a advancing state like Odisha, India are 0.5 HP DC Pump cost: ₹42,000 to ₹45,000 including installation without subsidy, 1 HP DC Pump cost: ₹83,000 to ₹85,000, 2 HP DC Pump cost: ₹143000 to ₹146000, 3 HP DC Pump cost: ₹193000 to ₹196000, 5 HP DC Pump cost: ₹283000 to 286000. To encourage PV installations for renewable energy the Government subsidy @30% by the central government and 30% by state government will be provided as solar pump subsidy. So as a total 60% subsidy on the cost of solar water pump is given as subsidy by the government, that encourage for prompt installation to other offices and institutions.

3. CONCLUSION

The year 2020 and till date in 2021 the human livelihood has been dared through the present situation and many solar institutions are drowned and lagged the rapid progress of previous years. The solar PV technology it's designed and applications at Centurion University of technology and management, Odisha is carried out in both theoretical and practical aspects. Based on the empirical study, the main observation, calculation and experimentation values are as follows:

- The annual average global horizontal irradiance of the place is having 5.3 - 5.5 kWh/m2/day.
- The solar portable emergency and street lights are easy to design with average cost is ranging from ₹ 80 to ₹ 2,000.
- The system is very efficient to install, and maintain in suitable locations.
- The solar lead acid battery have charged within 6 hours in sunny day.
- The system is very much energy efficient with running upto 11 hours at night.

The above data will help in efficient design and implementation in different location in Odisha, so also in India and shall welcome to an environmental friendly power generation system for better tomorrow.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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