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DESIGN OF PORTABLE 1KWp SOLAR PV POWER PACK FOR MULTIPLE USES IN RURAL/URBAN AREAS

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ABSTRACT

The purpose of this work is to develop an energy conversion device which can directly convert the abundant Solar energy available in every part of India into electricity. We would like to serve the people of India who do not have access to electricity (especially in rural areas) by giving them a source of clean energy which is easy to operate and reliable.

The Portable Energy Generator will be a boon for rural India as it can easily generate the energy required per day by a rural house hold. It is noise and pollution free. It is portable and can be easily folded, hence no danger of being stolen.

KEYWORDS

Design, Portable, Rural, Urban, Solar PV, Photo Voltaic, Crystalline, Poly Crystalline, Battery Bank

INTRODUCTION

India has tremendous energy needs and is finding it difficult to meet those needs through traditional means of power generation. Electricity consumption in India has been increasing at one of the fastest rates in the world due to population growth and economic development. India's economic growth has been somewhat stalled because the amount of energy generated is inapt to keep the growth motor of India running at the desired speed and there are energy shortages almost everywhere in the country.

Now, the question arises, what can India do to meet the future energy demands and help eliminate wide –ranging power outages in the future? To this the answer is, "India is the Saudi Arabia of renewable energy sources and if properly utilized, India can realize it's place in the world as a great power which can not only take care of its own energy needs but also of other nations.

Installation of solar power plants require nearly 2.4 hectares (6 acres) land per MW capacity which is similar to coal fired power plants when life cycle coal mining, consumptive water storage & ash disposal areas are also accounted and hydro power plants when submergence area of water reservoir is also accounted. 1.33 million MW capacity solar plants can be installed in India on its 1% land (32,000 square km). There are vast tracts of land suitable for solar power in all parts of India exceeding 8% of its total area which are unproductive barren and devoid of vegetation. Part of waste lands (32,000 square km) when installed with solar power plants can produce 2000 billion Kwh of electricity (two times the total generation in the year 2013-14) with land productivity/yield of 1.5 million Rs per acre (6 Rs/kwh price) which is at par with many industrial areas and many times more than the best productive irrigated agriculture lands. Moreover these solar power units are not dependant on supply of any raw material and are self productive. There is unlimited scope for solar electricity to replace all fossil fuel energy requirements (natural gas, coal, lignite and

crude oil) if all the marginally productive lands are occupied by solar power plants in future. The solar power potential of India can meet perennially to cater per capita energy consumption at par with USA/Japan for the peak population in its demographic transition. [1]
Renewable energy also has the advantage of allowing decentralized distribution of energy — particularly for meeting rural energy needs, and thereby empowering people at the grass roots level. Solar electricity could also shift about 90 percent of daily trip mileage from petroleum to electricity by encouraging increased use of plug-in hybrid cars. For drivers in India this means that the cost per km could be reduced by a quarter in today's prices.

RURAL SCENARIO IN INDIA: Majority of India's population lives in villages. The population in these communities has grown substantially in past fifty years. This growth has put tremendous pressure on resources needed to support this sector. In addition, it has resulted in enormous pollution of air, water and land. There is also substantial growth of population in India's cities resulting in similar problems that are encountered by village and rural folks. Clearly, sustainable developments innovations and clean energy technologies are needed to accommodate the growing population in India for healthier environment. The presence of solar energy at any location in a village makes its uses attractive for such an environment. Most prominent of these are the drying of foods, vegetables and fruits for preservation and assured availability during off season periods of the year.

3.1 Some hard facts of energy scenario in rural India

- About 668 million or around 70% of the Indians (in 6.4 lakh villages) live in rural areas and continue to use animal dung, agricultural waste and fuel wood as fuel for cooking,
- The thermal (energy) efficiency of these traditional sources is very low (15%),
- Particulate matter in the Indian households burning biomass is 2000 µg/cubic m which is much higher than the permissible 150 µg/cubic m [9]
- Use of traditional fuel is estimated to cause around 400,000 premature annual deaths due to various respiratory problems.
- 75% of rural households depend on firewood for cooking (and 9% each on, dung-cake and LPG) as against 22% of urban households using firewood for cooking, another 10% on kerosene and about 57% on LPG.
- For domestic lighting 55% of rural households depend on electricity and another 44% on kerosene, while in urban areas dependency is 89% on electricity and 10% on Kerosene.

Nevertheless, around 412 million Indians have no access to electricity although records tell that around 82% of the villages (4.89 lakh) were electrified as on 31.12.2008 [10], only about 44% of the rural households have access to electricity compared to around 87% in urban India.
As reflected in the Economic Census 2005, "there are 42.12 million enterprises in the country engaged in different economic activities other than crop production and plantation. Out of which, 25.81 million enterprises (61.3%) are in the rural areas and 16.31 million enterprises (38.7%) in the urban areas."

And more precisely, in the Micro Small and Medium Enterprises (MSME) segment, around 44.52% of the registered units and around 54.68% unregistered units are in the rural areas.
Besides, there are thousands of rural artisans like weavers who operate as Own Account Enterprises (OAEs) mainly in the rural areas with erratic power supply. The livelihood earning

potential of these people could be enhanced by increasing their productivity through supply of clean energy on a regular basis.
Therefore, there needs to be a paradigm shift especially:

- in the perception of rural energy needs,
- defining the goals as well as strategies of India's energy security,
- shifting from centralized mega-thermal/hydro/nuclear plants etc, and,
- more importantly concentrating in renewable and sustainable sources of energy.

Pattern of Energy Consumption in Rural areas
In rural areas, power is consumed in three main ways:

Domestic consumption
- For cooking
- For lightening

Industrial consumption
- For Micro Small and Medium Enterprises
- For Big Industry

On-farm energy consumption
- Energy consumption for farming

THE SOLUTION: PORTABLE PV POWER PACK

What seems to be an appropriate solution to all the rural needs is development of Energy Generator which has the following qualities:-

1) Reliable
2) De-centralized
3) Caters to individual household needs
4) Noise and pollution free
5) Not bulky
6) Easy to understand, operate and maintain

All these qualities are incorporated in **PORTABLE SOLAR PV POWER PACK**
MAJOR COMPONENTS
1. BATTERY
2. INVERTER
3. PV MODULE

DESIGN OF PORTABLE 1KW PV ENERGY GENERATOR

Wattage requirement of sample rural household

S.NO	LOAD	NUMBER	Wattage(W)
1.	CFL	3	11
2.	TV(Colour)	1	18

3.	Fan	2	20

Table 2: Power Consumption of sample household equipments

Usage hours of sample rural household

S.NO	LOAD	NUMBER	Wattage(W)	Hours/day
1.	CFL	3	11	5
2.	TV(Colour)	1	18	5
3.	Fan	2	20	8

Table 3: Energy Consumption of sample household equipments

TOTAL LOAD DETERMINATION

The total load is expressed in terms of watt hour/ day (Wh/day). This is determined by multiplying the number of devices with their respective wattage and the numbers of hours used per day.

For ex, for sample household a DC fan operational during summer (4 months) and not in winter is taken into account. The system design is for maximum electrical load requirement.

Total load calculated is as shown:

S.NO	LOAD	NUMBER	Wattage(W)	Hours/day	Load (Wh/day)
1.	CFL	3	11	5	165
2.	TV(Colour)	1	18	5	90
3.	Fan	2	20	8	320

Table 4: Load Calculation of sample household equipments

Total Wh = 575 Wh/day.

BATTERY DESIGN

Purpose of Batteries

- Energy Storage Capacity and Autonomy: to store electrical energy when it is produced by the PV array and to supply energy to electrical loads as needed or on demand.

- Voltage and Current Stabilization: to supply power to electrical loads at stable voltages and currents. by suppressing or 'smoothing out' transients that may occur in PV systems.
- Supply Surge Currents: to supply surge or high peak operating currents to electrical.

  Types of secondary batteries generally used in PV applications are:

  - Lead Acid Batteries - Flooded Electrolyte & VRLA*
  - Ni-Cd batteries
  - Lithium Ion
  - Vanadium Redox Battery and Zinc-Bromide Batteries

Factors affect capacity of the battery

- Temperature
- Discharge Rate
- Cut off voltage
- Self-discharge rate [13]

Factors that affect battery lifetime

- Vibrations
- Temperature
- Depth of Discharge
- Rate of charge/discharge
- Sulphation [14]

Basic Battery Sizing Calculation

BATTERY SIZE = (D * E)*100/ (N.V * % Discharge)

Where

D = Days of Reserve

E= Energy required /day

N.V= Nominal System Voltage

%Discharge= Amount of Discharge Allowed

Therefore for our system the battery Ah rating should be:-

For a load of 575 Wh/Day battery required for system with 2 days reserve backup will be as calculated below:-

Load = 575 wh/day

Reserve days = 2 days

Maximum allowable discharge = 50%

System Nominal Voltage = 12V

Battery capacity = (575 * 2)/(12 * .5) = 191 Ah

NUMBER OF PV MODULES REQUIRED

The basic unit of a PV module is SOLAR CELL. Hence the number of PV modules required will depend on the parameters of Solar cells.

- **VARIOUS PARAMETERS OF SOLAR CELL**
  1) Short Circuit Current
  2) Open Circuit Voltage
  3) Maximum Power Point
  4) Current at Maximum Power Point
  5) Voltage at maximum Power point
  6) Fill Factor (FF)
  7) Efficiency

- **Typical Solar Cell Parameters of Commercial Solar Cells with Available Cell area** [16]

Solar Cell Type	Efficiency (%)	Cell area (cm^2)	Output Voltage (V)	Output Current (mA/cm^2)	Fill Factor (%)
Mono Crystalline Silicon	14-17	5-156	0.55-0.68	30-38	70-78
Poly Crystalline Silicon	14-16	5-156	0.55-0.65	30-35	70-76
Amorphous	6-9	5-200	0.70-1.1	8-15	60-70
Cadmium Telluride	8-11	5-200	0.80-1.0	15-25	60-70
Copper-indium-gallium-selenide	8-11	5-200	.50-.7	20-30	60-70
Gallium indium phosphide	30-35	1-4	1-2.5	15-35	70-85

Table 6: Solar Cell Parameters
Source: Solar PhotoVoltaic Technology and Systems, C.S. Solanki, 2014.

- **Factors Affecting Electricity Generated by a Solar Cell** [17]
  1) The conversion Efficiency
  2) The amount of light
  3) The solar cell area
  4) The angle at which day light falls
  5) The operating temperature

- **Effect of Conversion Efficiency** : Of the total light energy falling on a solar cell, only some fraction of the light energy gets converted into electrical energy by the solar cells. The ratio of electrical energy generated to the input light energy is referred as conversion efficiency of solar cells. Efficiency of a Solar cell is given in terms of maximum power that solar cell can generate for a given input solar radiation.
- **Change in the Amount of Input Light** : The electric current generated by a Solar cell is directly proportional to the amount of light falling on it.
- **Change in Solar Cell Area** : The current output is directly proportional to the cell area.
- **Change in Angle of Light Falling on Solar Cell** : Solar cell produces maximum power when sunlight falls perpendicular to the surface of solar cells. When light is not perpendicular to solar cells, it always give less output than maximum possible output power.
- **Change in Solar Cell Operating Temperature** : The Solar cells output voltage , power and efficiency ratings are given at standard condition (STC = 1000 W/m^2 and 25°C). With increase in temperature the Solar cell output voltage, efficiency and power reduces.

Parameter of crystalline Silicon Solar Cells	Decrease per ° C rise in cell temperature from standard test condition (STC) value of 25 °C
Voltage	-2.3 mV
Power	-0.45%
Efficiency	-o.45%

Table 7: Solar Cell efficiency
Source: Solar Photovoltaic Technology and Systems, C.S. Solanki, 2014

The number of PV modules can be calculated by either using the wattage of the module and the mean daily solar insolation in the region.

Hence efficiency at 60 ° C can be calculated by below mentioned formula:

η (Actual at 25 ° C) – 0.45 (Temp_Outside – Temp_Standard)

η at 60 ° C = 15 – 0.45* (60-25) = 12.63%

Efficiency of the System:

ηSystem = ηPV-T * ηReg * ηBatt = 12.63 * 95 * 70 = **8.39 %**

$\eta_{PV\text{-}T}$ = Efficiency at 60°C Cell Temperature (around 12.63% as calculated)

η_{Reg} = Efficiency of regulator (MPPT (Inverter) efficiency typically 90-95%)

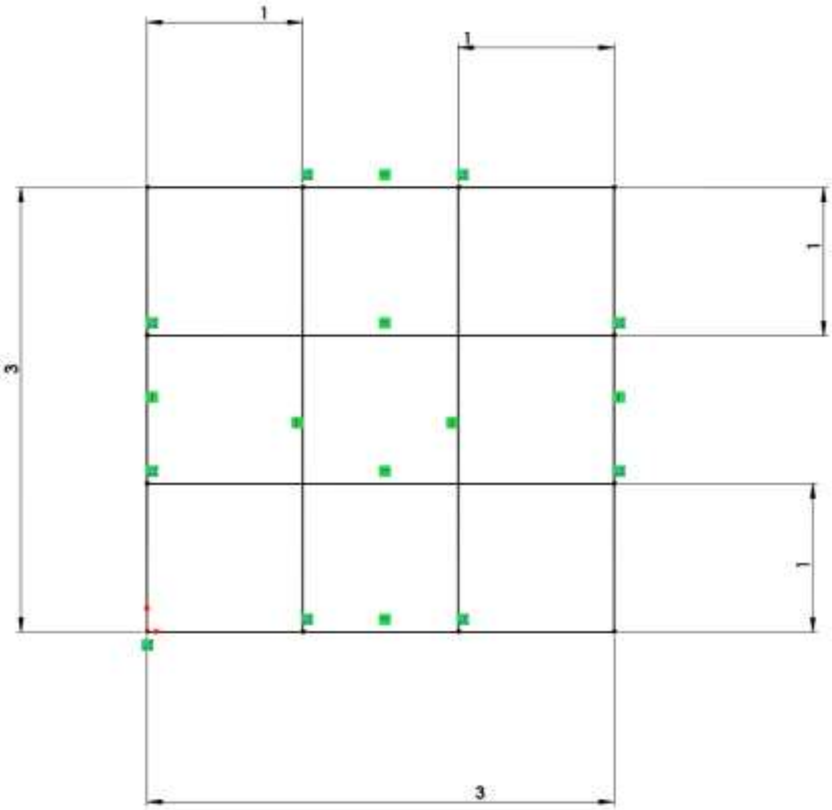
η_{Batt} = Energy efficiency of the battery (Watt hour efficiency of battery is typically 70-80%)

Average solar insolation incident on Indian subcontinent is 6KWh/m2 per day. The efficiency of Mono-crystalline solar cells is 8.39% hence amount of electrical energy generated = 503.4 Wh/m2. For a 9m2 (which I am planning to design area total energy generated will be 453060 Wh per day=4.53 KWh/day.

RESULT

- Battery size required = 191 Ah
- Inverter size required = 300Wp
- PV module area = 9m2 area
- Total Energy that can be generated theoretically = 4.53 KWh/day
- No of sample households that can meet their energy demand =7

INITIAL PLANNED DESIGN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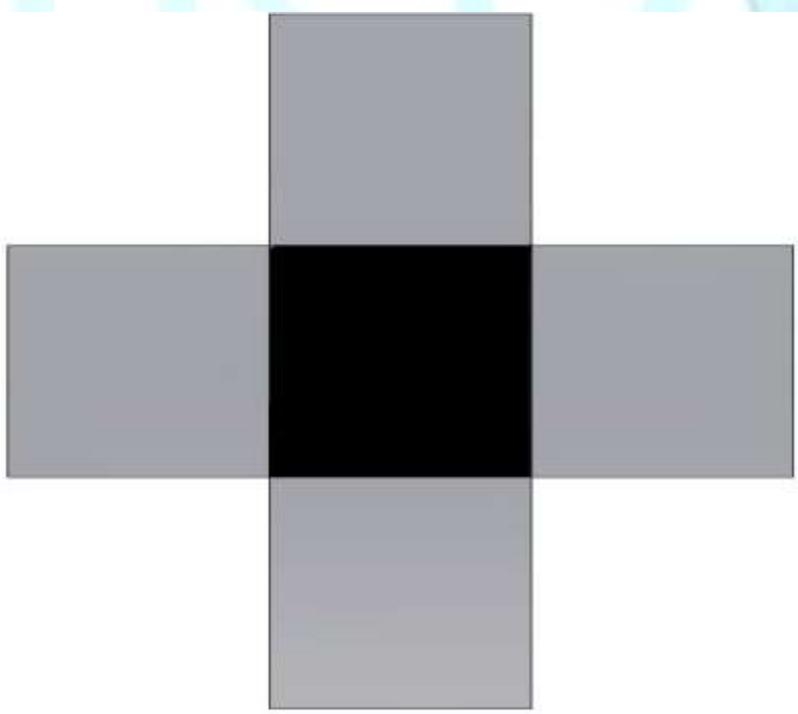

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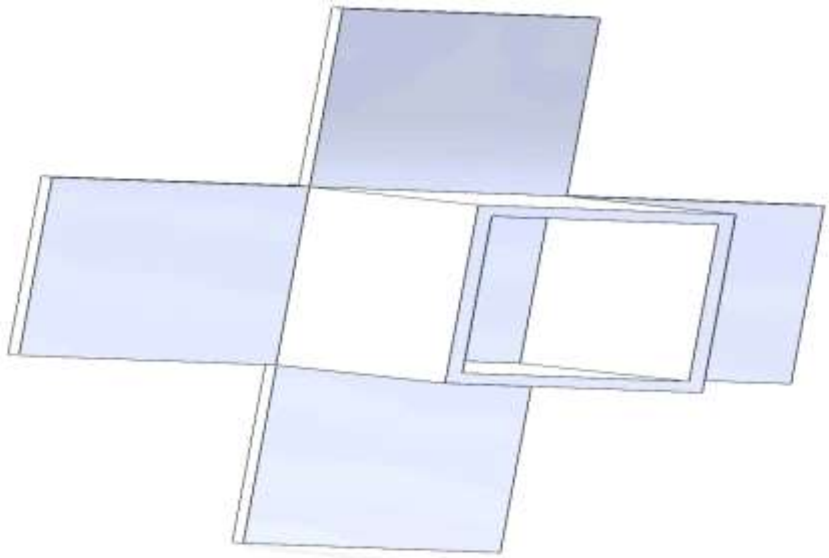

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