S.N. SINGH, RAKESH KUMAR, PREETI SAW / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 4, June-July 2012, pp.727-732

Holographic Solar Powered House For Rural India

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Abstract:

In this paper, technical viability of holographic solar module as an alternative energy source in rural India has been studied . The working principle of solar tracking with HPC has been explained. The design aspect of PV system components such as PV module, Battery sizing, Inverter module have been reflected. The system has been tested with hardware simulated input parameters for the desired optimal power output. The application of such system has been discussed as rural electrification.

Keywords *: HPC holographic photovoltaic concentrator, PV : Photovoltaic, kWh : Kilowatt hour etc.*

1. Introduction

During the past energy crisis in the latter part of the past century, it was widely believed that solar energy was going to be our savior. A virtually infinite amount of energy from the sun arrives on the earth each year. All we had to do was harness it and our energy problems would be over......forever! Things have changed a lot in the past few years as the development of solar energy appears finally to be moving at a fast pace. This advancement of solar energy technology is reflected in some of the alternative energy stock funds where the solar stocks represent the largest percentage holding of any of the alternative energy stocks.

Although establishment of solar power plant is costly affair at the initial stage but the advancement in the solar energy field is gradually reducing the cost of electricity. This cost is reported to have dropped to about 1/100 of the past cost. The design of most new buildings and some new homes now consider the use of solar energy when assigning for heating, cooling or electrical generation. Solar energy has a great future, as the solar energy technology is now growing rapidly and there are undoubtedly technical means to improve the conversion rate using thin film technology embedded with holographic film[1.2,3,4].

Worldwide solar energy output has grown dramatically in recent years, particularly in Europe, China and U.S. The total output from all solar installations worldwide, however, still remains around seven giga - watts, only a tiny fraction of the world's energy requirement. High material and manufacturing costs, low solar module efficiency and a worldwide shortage of refined silicon all have limited the scale of solar-power development required to effectively compete against coal and liquid fossil fuels. A number of approaches are being explored to improve the cost per kilowatt of solar power, primarily by improving the efficiency of the solar-collecting cells that comprise solar modules, or by concentrating greater amounts of solar energy onto the cells. The Holographic Planar Concentrator (HPC) is one solution that achieves both of these goals. (Fig.1)

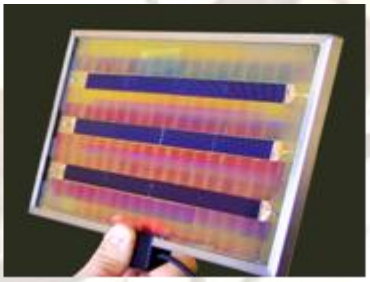

Fig.1: HPC solar module

2. Solar Powered Homes are becoming more popular

Solar panels capture the sun's heat and light, and convert it into electricity to power appliances In some cases, the entire electricity needs of a home can be met by solar energy. Of course, aside from the power needs, factors such as the location of the home, weather conditions and seasons have to be considered. In most cases though, home owners opt for a low cost hybrid system with grid/DG as primary source wherein solar energy acts as a supplement to traditional energy.

3. Solar Cells

Have you wondered that you can use calculators without batteries? In this age of technological revolution where saving energy and using renewable sources of energy such as solar energy etc are stressed, it is indeed possible to save energy, if you use solar powered products[4,5]. Not only they are environment friendly but they have many more advantages to them. Solar powered products such as solar calculators, watches, radio, TV and solar home lights etc are already popular in the existing market. Solar cells provide more energy than other conventional sources with an additional advantage of being light weight and cost effective. Developing cheaper alternatives to solar cells such as amorphous silicon and polycrystalline silicon are also in the pipeline. A wide range of solar products such as car battery chargers, calculators, pumps, power inverters, solar lights, solar robot etc are available to the consumers today. Solar cells are also noiseless and non-polluting. We do not need huge plants or heavy machines in their manufacture and hence no carbon dioxide or other harmful greenhouse gases are produced in the process. The life cycle is more than 15 years or even more. Solar energy works by converting the sun's rays into electricity with the use of solar panels to supply power to the AC or DC appliances used in our homes/ offices.

4. Holographic Concentrator

An HPC is built up from several layers of gelatin - on - PET films (Figure 2). In each film holographic optical elements (HOE) is imprinted using diode-pumped, solid state lasers. The holographic stack diffracts wavelengths that are usable by the solar cells while allowing unusable wavelengths to pass through, unabsorbed. The usable energy is guided via total internal reflection at the glass/air interface to strings of solar cells, resulting in up to a 3X concentration of energy per unit area of photovoltaic material.

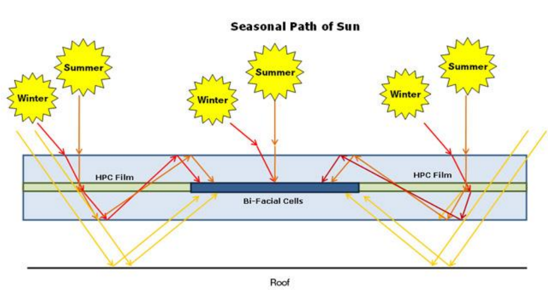

Fig.2: Bi - facial module of solar plate

Figure 2 shows a bi--facial module based on this design. Because of the HPC film this module uses 50% less PV material than a traditional, fully populated module. The reduction in expensive silicon greatly lowers the module's material cost and also results in manufacturing savings through reduced assembly and processing requirements.

Moreover, unimaginable as it may seem, over a million people in the world do not have access to electricity specially in rural areas. Solar energy would be the cheapest and most efficient maintenance free energy source available to them.

5. Solar Energy is a Growth Industry

The industry behind solar energy is shining brighter than ever. Credit it to the global-wide environmental awareness, rising oil prices, dwindling supply of fossil fuels or threats of global warming. Scientists, economists, environmentalists and engineers predict that solar energy will only grow in popularity and demand in the coming years. The generation of electricity and its use in village houses for charging batteries of home light, pumps, fans, and other domestic appliances will be the major markets.

Here are some more encouraging facts, highlighting the growth of the solar energy industry in the past few years :

- The global demand for solar energy has grown at around 30% - 50% in the past 10 years. In the developing country like India, this figure is much higher, as demand shows a 57% growth.
- Aside from the US, Japan and Germany, country like India, and its nearby country are the biggest markets for solar energy. This is largely due to funding provided by the government/NGOs and market incentives.

Solar energy is definitely a promising industry. Its growth also heralds in cheaper electricity bills, a cleaner environment and an overall positive change for humanity.

6. How do solar cell work ?

a) Rays of sunlight hit the solar panel (also known as a photovoltaic(PV)) and are absorbed by semi-conducting materials such as silicone or Ga-As.
b) Electrons are knocked loose from their atoms, which allow them to flow through the material to produce electricity. This process whereby light (photo) is converted into electricity (voltage) is called the photovoltaic (PV) effect.
c) An array of solar panels converts solar energy into DC electricity which is stored in Battery.

d) The DC electricity then enters an solar converter (inverter).

7. Solar Converter

The inverter turns DC electricity obtained from PV cell or battery into 220V, 50Hz AC electricity needed by home appliances. The block diagram of PV power supply and its integration with grid inverter is shown in Figure 3[5,6].

The hybrid solar power supply system makes use of the solar (PV) module to produce DC electricity and subsequently convert it into AC power. This is supplemented by a stand by grid inverter/diesel generator as and when needed. The dual battery system of PV unit controlled through DPDT switch S1 as shown in Fig.3 feed power to load from one of battery (i.e B1/or B2) bank while other bank of battery (i.e B2/or B1) store energy from PV source and thus could be able to deliver power for 24 hours in a day.

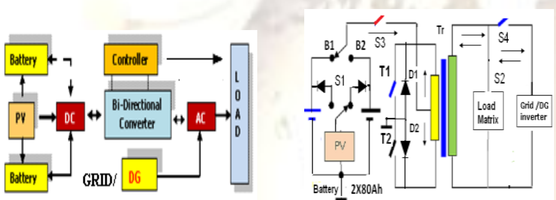

Fig. 3 : Proposed system and Power circuit model of a DG integrated HPC Home solar (PV) Power supply

Load power sharing is done by smart switches (Figure 4) with other sources like utility(DG/grid) etc on varying load demand at user end.

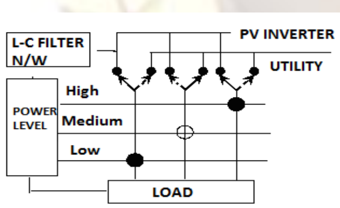

Fig.4 : Power Sharing Load Matrix

The bi-directional inverter converts DC power from the 12V battery to SPWM AC power 220V +/- 20%, 50Hz for the load. The battery (B1/or B2) will supply power to load to its maximum discharge level 10.4V. The base drive pulses generated by controller using IC oscillator circuits CD 4047 switch on and off the transistor devices T1 and T2 alternatively for 10ms and thus produces 50Hz AC voltage waveform across load due to centre tap transformer (Tr) action. The base load upto 300W per hour is normally fed from primary PV inverter source whereas the peak load demand beyond this value is shared with grid inverter/DG unit. Further, excess PV energy stored in its battery on low load power demand is also transferred to charge the battery of grid converter unit and thus saves grid power in charging its own battery. The sustainability in the grid supply system is thus maintained by the battery back up system during the period of grid failure. The controller unit monitors, control the bi-directional flow of energy between both PV and grid power supply units and optimize the load power drawn from them. The L-C filter network smoothen the load waveform and produces less harmonics content.

8. Optimal Design of PV System Component

A)PV Sizing: The standard energy balance principle has been used to compute the optimal size of PV module as expressed by equations (1), (2)and (3)) to meet the load energy requirement of literacy house in a day over 24 hours.

PV stored energy (Wh) = Load Energy(Wh) * S.F (1)

i.e P_{PV} (Wp) * Sun hour * Area of equalization = P_{TL} (Wh) * S.F (2)

Where,

- P_{PV} (Wp) is the required peak power of PV power delivered at noon @STP
- Area equalization factor = 0.5 (approx)
- Sun hour = 6.2hr (total duration during day time in a day) for adopted area
- P_{TL} is total load energy in watt- hours (i.e Total load power over a period of 24 hours in a day assuming hourly load power (P_L) as constant.)

$$\text{i.e } P_{TL}(\text{Wh}) = \sum_{0}^{24} (P_L) \quad [\text{Watt-Hours}] \qquad (3)$$

- Safety Factor (S.F) = 1.5 for cloudy weather/low insolation (sun radiation)

From equation (2) and equation (3), considering the PV to Holographic ratio for optimum output :

The optimal number of HPC PV module = (PV to Holographic Ratio x P_{PV} (Wp)) / Standard (75Wp or dual 2x36Wp) PV Module (4)

Where,

PV to Holographic ratio can be considered as 0.5 or even less.

The system is designed and tested (Figure 5) for load energy requirement of a rural literacy house (a case study) with the following specifications

Load-Energy	=	1800 - 2000 Watt-hours over a period of 24 hour in a day
PV with HPC	=	75 Wp, 12 V, Sun-hour- 6 hours, Temp - 25 degree C
Battery- Size	=	PV converter : Dual(2x80Ah), 12V Grid Inverter : 150Ah,12V
Load(s)	=	CFL and LEDs lamps, Fans, TV and literacy house teaching equipment including pump motor
Converter	=	300W/750 VA, 12VDC ~ 220 V SPWM AC, 50Hz

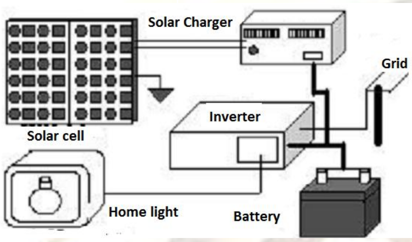

Figure 1

Fig.5 : System Test bench

9. Discussions

The prototype PV inverter was tested and verified in the laboratory with simulated PV power and load profile for maximum 300W power as per data acquired from user end. Load energy computation (1800 – 2000Wh) has been done based on the power consumption in load per hour basis of various loads (i.e wattage of load x duration in hour) used in the literacy house. The system can be used as an autonomous power supply or in hybrid configuration with grid /DG or any other conventional sources like hydro or renewable sources like wind, biogas, fuel cell etc
The cost is also reducing with a payback period ranging from five to six year. In India Govt. is taking initiative to promote entrepreneur to establish home PV power plants .

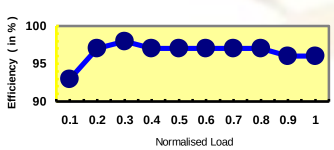

Fig.6: Efficiency of PV inverter

The efficiency of solar inverter system has been observed as almost constant (94% - 97%) over all

values of load(s) power ranging from 10% - 100%. (Figure 6) The load profile vary as per the consumption by end users. The distortion parameter has been measured and recorded as 5% or even less.

10. Rural Home Electrification : a few case study

A) ***Solar powered village home lighting Systems:*** Solar lighting systems are one of the measures to utilize the unbound sun's energy.

Figure 7 : (a) A visit to village basket weaving solar powered house by author (b) observing battery charging room for a portable home light

Solar lights are cost effective, hassle free and don't have any maintenance cost. These are the answer to the energy problems of the present as well as the future. The solar lighting systems(Figure7) help the people in going green, who want to save the nature for future.
B). Solar village street lights : Solar street lights (Figure 8) are a step taken up in that direction only. This is gaining more popularity and acceptance by end users day by day as the technology has become simple and virtually there is no maintenance. The cost has also stablised and are easily available in almost all local market. The villages near hilly area, the system is gaining more popularity.

Fig.8 : Village street light

These lights don't run on conventional power, but are run by the solar energy. Solar street lights are the products of latest technology. They help in reducing the electricity consumption of any country.. Installation cost is the only cost, which the village committee funded by the government/NGOs has to bear, rest it doesn't call for any maintenance. Solar village street lights are no doubt the lights of the future. They are getting accepted by the day, by all the villagers because of their numerous advantages. Village street lights are necessity of every country and going solar with these lights, will definitely have a huge impact in the conservation of power. That day is not far away, when every street of the village will be lit up by the solar street lights and every country will go green with its usage.

C). Solar Literacy centres: *In* every village, the community halls are engaged for conducting literacy classes to impart training to potential youth (Figure 9) in various vocational trades. Teaching learning material like Television play an important role in spreading vocational literacy. The reason behind this is the best learning tool, which impinges on the human brain very easily. Televisions are being used in these literacy canters for almost 24 hour and 7 days.

Fig. (9) Literacy Community Hall

These televisions are not popular right now but the scientists and engineers are working day and night to improve these solar televisions, so that they are used ubiquitously.

11. Conclusion:

Hence, we need to start thinking about the alternatives and solar power is the most effective and beneficial alternative to power the various appliances in the village house.. They will not only help in saving the energy for the future but they will also help the present generation to use this source as an alternative or primary source. In this paper, an attempt has been made to use HPC plate on solar module for getting optimal power output. HPC has been used to extract optimal power reducing size of solar cell from solar plate. Study reveal that cost of solar plate can be reduced with the use of holographic film. Further from the research study, it may be anticipated that power in the range of 1 giga-watt or even more can be produced with the existing technology at 50% or even less cost. The scheme can be implemented in rural as well as urban sector of the country like India.

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Biographies

Dr S.N. Singh had completed doctoral PhD degree at the Department of Electrical Engineering, National Institute of Technology Jamshedpur (India). He obtained his B.Tech degree in Electronics and communication engineering from BIT Mesra (A Deemed university), Ranchi - Jharkhand (India) in 1979/80. Presently his area of interest is *solar energy conversion technology.* He had published more than 50 papers in National and International journals based on his research work. He had remained *Head of Department of Electronics and*

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Ms Preeti Saw is pursuing her B.Tech degree in Electronics and Communication Engineering from R.V.S College of Engineering & Technology, Jamshedpur(India). She has keen interest in doing innovative research project on solar power conversion technology. She had published one paper in International journal. Presently she is doing project on '*Technical viability of holographic film on solar panels for power generation'*. She is also investigating the impact of solar electricity on socio- economic development of Indian rural tribal sectors in the Jharkhand state.