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Triple-Generation (Electricity, Heat & Cooling) Using Roof Top Solar Photovoltaic Systems

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Abstract:
In this research paper the problem whether the roof top “photovoltaic system” can be employed for the generation of electricity, heat and cooling usable in the underneath building. The solar energy balance in traditional modules is considered and it is pointed out that about 80% of solar energy is transformed into heat. For collection and storage of this heat the PV/T modules are suggested as appropriate. The temperature of the heat generated in “PV(T)” module in the location of composite climate is estimated during the year round cycle. It is found that the average temperature is 71.06 ^{o}C in Summer, 56.95 ^{o}C in Winter and 66.63 ^{o}C in Equinox which are of the right order of magnitude for conversion into heat and cold in accordance with the requirement of the building using organic fluid compressor or vapor absorption or hybrid cooling cycle.

***Keywords**: Triple generation(electricity, heat and cold), phase change material , solar cooling cycles , PV/T modules, roof top SPV systems*

INTRODUCTION

In recent decades, electricity production from renewable energy sources has been used to close the gap among international production and consumption of electricity. Solar has a strong potential and direct solar photovoltaic conversion engineering has a few positive characteristics. Solar PV systems built to date have shown outstanding technical viability for various applications. Total global production of SPV modules has already crossed 5K MW equivalent. The technology continues to be primarily (over 90%) dominated by the standardized and reliable monocrystalline and multicrystalline silicon based material. Photovoltaic now finds widespread application from small standalone power supplies to large (60MW or more) power stations. In India roof top grid integrated photovoltaic systems have received steadily increasing attention; both private and government agencies are promulgating these systems; the cost also has come satisfactorily down to Rs 40 per watt. However installation of solar photovoltaic system on roof surface is not always possible due to constraints of land use. In this paper we investigate some value additions whether the roof top solar photovoltaic systems can caters to all the total energy needs of buildings of composite climate which need cooling in summer and heating in winter for indoor comfortable climate and electricity for the year round cycle. This in turns envisages solar photovoltaic as a foremost power resource, progressively inexpensive and demonstrating to be more dependable than utilities.

1. System configuration

The modules made from single/poly crystalline silicon cells are presently the dominant commercial products. Mono-crystalline cells are composed of pure mono-crystalline silicon with an almost no flaw or impurity. Such cells have a sunlight conversion efficiency of around 15-17%. It's expensive to

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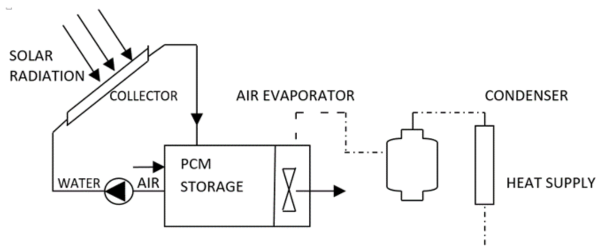
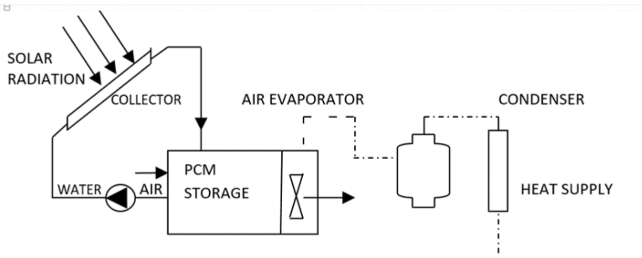
manufacture. The most cost effective and time consuming single-junction silicon cells confirmed to have approximately 22 percent efficiency [6]. Polycrystalline cells are manufactured from significantly poorer scores of monocrystalline silicon or semiconductor grade silicon. Cells include white spots on the substrate owing to impurities; they are generally less costly because easier methods are used in their processing. They get the utilization of solar conversion of about 12-14%. These conversion efficiencies indicate that about 80% of solar energy is converted into heat in solar module configuration. In this paper we investigate whether this heat energy can be utilized for air conditioning the underneath buildings.

In traditional modules of roof top SPV systems, the heat energy generated in modules is dissipated in the environment. However this heat can be collected in glazed hybrid modules[1] often referred to as PV/T(Thermal) modules. For heat retrieval from these modules several configurations involving air and water as heat retrieval fluids have been proposed and tested. The configuration with air type PV module has received more attention. For triple generation these modules are proposed. If the heat is to be used for continuous basis appropriate Phase change material (PCM) storage unit should also be added. The heat retrieved from the modules may be utilized for conditioning the air in the buildings using the low temperature organic fluids heat pumps/cooling technique as illustrated in Fig.1



a) Air Source Evaporator



b) Water Source Evaporator

Fig1.AIR CONDITIONING CONFIGURATION

2. Thermal model

In roof top SPV systems the modules/arrays are generally mounted so to maximize the productions of yearly mediocre electricity on a constant tilt angle. It is therefore proposed that modules be used and tilt might be seasonally attuned in accordance with the heat requirement such that relatively high temperature heat is produced which can be easily converted into cooling using organic Rankine cycle compressors and low temperature heat is produced, that can be further used for direct or through solar boosted heat pump for space heating in winters. We have estimated in the following section that for New Delhi (28.5degree latitude) a location of composite climate the array tilt angle should be 52.5 degrees in winter (Nov-Feb) and 5 degrees for summer (May-Aug) and 30 degree in equinoxes (Mar-Apr, Sept-Oct) [4]. In this configuration the generation of electricity is also increased by 4% in comparison to fixed tilt array systems.

3. Analysis and computational results

PV thermal module is a flat plane single glazed solar collector having the cellular plane as its absorber which converts about 15-20% into electricity and the rest in heat. The temperature required for operation of the solar cell plane can be obtained as follows[5]:

$$T_c = T_{amb} + (T_{diff} - (T_{grad} V_w)) \qquad \text{---(A)}$$

Where ,

T_c = Operating temperature of solar cell (^oC)

T_{amb} = Ambient Temperature (^oC)

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T_{diff} = Temperature difference between solar cell and ambient :

T_{grad} = Temperature gradient of solar cell with respect to wind

V_w = Wind speed in (km/h)

The data of mean (monthly) or ambient temperature, wind speed, solar radiation on flat solar plane and the resultant solar cell temperature are illustrated in Table1. For the difference of temperature between a solar cell and ambient air preferably at a zero wind speed, T_{diff} has been considered as 45 ^oC. The gradient of temperature belonging to such a solar cell along with respect to wind speed, T_{grad} has been taken to 0.5 ^oC h km^{-1} . Hourly wind speed and ambient temperature date at Delhi [7]have been employed to compute functioning temperature of the cellular plane.

Table1: The monthly mean data for "ambient temperature, wind speed, solar radiation on flat solar plane" and the resultant solar cell temperature

Month	Monthly mean daily ambient temperature(°c)	Monthy mean daily wind speed(kmh-1)	Operating temperature of solar cell (°c) $T_c=T_{amb}+(T_{diff}-(T_{grad}V_w))$
JAN	13.58	8.78	54.19
FEB	17.62	11.46	56.89
MAR	22.67	11.33	62.005
APR	29	11.28	68.36
MAY	32.66	11.85	71.735
JUNE	34.17	14.26	72.04
JULY	31.02	11.19	70.425
AUG	29.25	8.42	70.04
SEP	28.54	8.88	69.1
OCT	25.68	7.26	67.05
NOV	19.8	7.48	61.06
DEC	14.48	7.68	55.64
Mean	24.87	9.99	64.875

The table shows the average temperature in summer is 71.06 ^oC, in winter it is 56.95 ^oC and in Equinox it is 66.63 ^oC. This temperature will yield heat which seems to be of the right order of magnitude for air conditioning using various low temperature techniques for air conditioning such as low temperature vapour compression or vapour absorption or hybrid.

Findings and Conclusion

In this research paper we have done an investigation on the rooftop "solar photovoltaic system" can be used for triple generation (Electrical/heat/cold) usable in the building. This paper suggest that instead of traditional module, the Power – temperature module be used as 80% of the solar energy incident on the modules is converter into heat. The temperature of the solar cell plane has been investigated for all months of the year when the tilt of the modules are kept perpendicular to the sun rays. It is found that the temperature average temperature in summer is 71.06 ^oC, in winter it is 56.95 ^oC and in Equinox it is 66.63 ^oC.

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