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Research Article

Commercial viability of cooling of solar photovoltaic panels using Ground Coupled Central Panel Cooling System (GC-CPCS)

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Abstract

Ground-coupled central panel cooling system (GC-CPCS) is a system developed to cool the solar PV panels. This system has been designed at Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, India and prototype testing is done. There are several experiments performed for the cooling of solar PV panels. This paper highlights the attributes and novelty of GC-CPCS and how well it compares with the other systems. It also evaluates the commercial viability of GC-CPCS.

Keywords: *Ground coupled central panel cooling system (GC-CPCS); Economy; Cost benefit analysis; Commercial viability*

1. Introduction

[1]There is a need for a low-cost cooling system for the Solar panels is to maintain its conversion efficiency at an acceptable level. (Cruey Bryce *et a*l, 2006; Katkar A A *et al*, 2011; Khan B H, 2004; Royne Anja, 2005) The various methods for cooling of solar photovoltaic panels are the following (Sahay Amit *et al*, 2015).

(i) *Hybrid PV-T systems*: Here fluid is run through the rear of the panels which absorb the heat. This concept offers an opportunity to increase overall efficiency by making use of waste heat generated in the PV module.
(ii) *Use of Heat Pipe*: Heat Pipe is a device for transferring heat from a source to sink by means of evaporation and condensation of a fluid in a sealed system.
(iii) *Heat Sink*: Fins are attached at the rear face of the panel.
(iv) *Mist sprays (Evaporative cooling)*: The Solar panels are cooled by spraying them with a mist of water.
(v) *Micro-channel cooling:* In this systems water gushes through the base of Solar cells. It is similar to microprocessors with deep water coursing through micro-channels carved deep inside them.
(vi) *Thermo-electric cooling system*: The cold side of thermo-electric device is used to cool while the hot side is connected to a heat sink to dissipate the excess heat.

Nomenclature

Symbols

oC: Degree centigrade
η: Conversion efficiency (%)

Abbreviations

ANOVA: Analysis of variance
CPC: Central Panel Cooling System
GC: Ground Coupled
GC-CPCS: Ground Coupled Central Panel Cooling System
GCHEX: Ground coupled heat exchanger
PV: Photovoltaic
PV-T: Photovoltaic-Thermal
RGPV: Rajiv Gandhi Proudyogiki Vishwavidyalaya
STC: Standard test condition
WECS: Wind energy conversion system

A new solar panel cooling system is developed and it is named as Ground Coupled Central Panel Cooling System (GC-CPCS). [Fig. 1] (Sahay *et al*, 2013; Sahay Amit *et al*, 2014; Sahay Amit *et al*, 2015) This system has various attributes which are explained in section 2.

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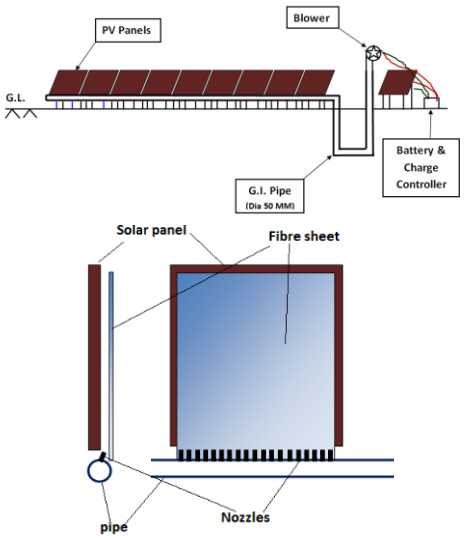

Fig. 1: Schematic design of GC-CPCS and arrangement of nozzles and fibre sheet (Not to scale)

2. Attributes of Ground-coupled central panel cooling system (GC-CPCS)

This system has the following attributes which makes it operationally and commercially viable.

2.1 Ambient air as working fluid

GC-CPCS uses air as working fluid. Air is ubiquitous. The air is cooled in a Ground coupled Heat Exchanger (GCHEX) before being used for convective cooling of solar PV panels. Ground coupled Heat Exchanger (GCHEX) is used for the first time in any PV Panel Cooling System. Further use of air makes it suitable for being used in diverse geographical locations; even in desert. This system surpasses the systems which uses water as the working fluid because cost of makeup water owing to the high evaporation rate of water is prohibitive (Sahay Amit *et al*, 2013).

2.2 Low capital cost and operating cost hence viable

The design is cost effective. Further the concept of central cooling allows use of blower economically as the capital cost is significantly reduced. Operating cost is mainly the power required to run the blower which is hardly 2% to 5% of the total power output of the system (Sahay Amit *et al*,2013).

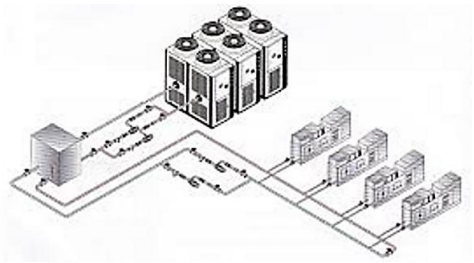

Fig 2: A typical arrangement for centralized cooling where in multiple spaces are served by plant installed from one base location (Bhatia A)

2.3 Concept of central cooling is utilized which makes it viable

Central cooling makes it possible to cool multiple panels by using a single blower. from one base location. (Fig. 2) It is a breakthrough technology in the field of photovoltaic solar panel cooling. It makes it economically viable. (Bhatia A; Sahay Amit *et al*,2013)

2.4 On site testing simulating the actual conditions

Prototype testing is done on site under actual Solar Irradiance unlike most of the studies that are conducted in laboratories under Standard Test Condition (STC). .(Sahay Amit *et a*l, 2014)

2.5 Validation of the system using physical as well as statistical tools

Smoke Flow visualization technique is utilized to have the feel of the flow. Here smoke is advected through the blower to get the information about the flow. (Rathakrishnan E, 2009)

Statistical analysis is done to validate the causal effect of the GC-CPCS. ANOVA analysis is done to ascertain the causal effect of GC-CPCS. After the analysis it was found that the effect of cooling is significant. (Kothari C R, 2008; Sahay Amit *et al*, 2014)

2.6 Costing of the system and cost benefit analysis

Detailed costing of the system has been done and cost benefit analysis is performed. The system is found to be viable. .(Sahay Amit et al, 2017)

3. Comparison of Ground-coupled central panel cooling system (GC-CPCS) with other solar panel cooling systems

How well does the attributes of the various solar photovoltaic panel cooling systems compare with the attributes of GC-CPCS are given in a tabular form in the Table 1. It is found that the system GC-CPCS excels in most of the parameters and hence it is considered as commercially viable.

Table 1: Comparison of attributes of various solar PV panel cooling systems

Attributes System	Economy – comprises of capital as well as operating costs	Centralized cooling	Onsite testing done on power plant	Commercially viable
GC-CPCS	HIGH	YES	YES	YES
Hybrid PV-T system	POOR	NO	NO	NO
Use of heat pipe	POOR	NO	NO	NO
Heat sink	POOR	NO	NO	NO
Mist spray	POOR	NO	NO	NO
Micro channel cooling	POOR	NO	NO	NO
Thermo electric cooling	POOR	NO	NO	NO

4. Further scope for development and research

4.1 Dedicated manifold design

The Ground Coupled Central Panel Cooling System (GC-CPCS) is retrofitted on the Solar PV panels at the Energy Park of Rajiv Gandhi Proudyogiki Vishwavidyalay. To facilitate flow of air passage is provided at rear surface of the panels by providing Transparent PVC Flexible Sheets (Sahay Amit *et al*, 2013; Sahay Amit *et al*, 2014).

If a manifold is incorporated in the design of the panels then it is very likely that it increases the heat transfer hence more cooling of panels. Therefore better result i.e. more efficient solar to electrical energy conversion is expected.

4.2 System design for higher number of panels

The current system is designed to cool 9 nos., solar PV panels. Systems to cool 50, 100 panels may be designed.

4.3 Control system for GC-CPCS

This system can be run by using a control system. Therefore suitable control logic and control system may be developed.

4.4 Use of compressed air as working fluid

Similar systems can be designed to run using compressed air. Therefore for the locations where compressed air is available a system can be designed and tested which uses compressed air instead of blower.

4.5 Hybrid system using wind energy conversion system (WECS)

Ground Coupled Panel Cooling System (GC-CPCS) can be combined with a Wind Energy conversion System (WECS) to form a hybrid system. The battery can be charged with the help of power from wind mill. Energy from wind mill is available even during the time when the solar power is not available. The schematic diagram of such system is given in Fig. 3.

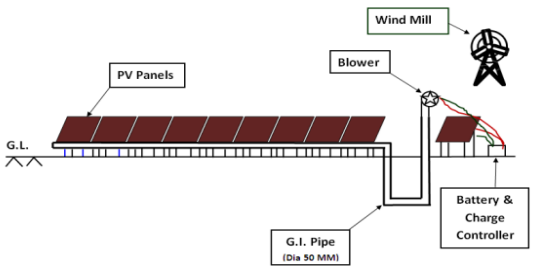

Fig 3: Schematic diagram of hybrid WECS and GC-CPCS

Conclusions

GC-CPCS seems to be a viable solution for solar PV panel cooling. The attributes which makes it a viable solution are discussed in this paper. Scopes for further developments are also discussed.

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