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Study of Solar PVT-PCM Hybrid System with Possible Modifications to Increase Module and Thermal Efficiency

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ABSTRACT: The present research paper work has been undertaken to study the feasibility, stability and commercial analysis of storing solar energy & heat using Phase Change Materials (PCM) for reducing the PV Panel temperature as much as possible to increase the power generation up to considerable extent. This will also assure that hot water is available throughout the day. Electrical power is produce by solar irradiations during day time only, using hybrid technique Panel over temperature can be reduce and same time waste heat will stored & recycle by PCM material which can be used later when we need. In this article we flows water through heat pipes accommodate with insulated case as. we are using compound PCM as paraffin wax with low melting point according Indian average weather & climate. By this kind of one unit integrated system both type of energy conversion is possible up to its upper level, with much better efficiency in lower cost with fewer components.

Keywords: Hybrid**,** Phase Change Materials, Photovoltaic, Temperature Regulation, Paraffin wax, low melting point

I. INTRODUCTION

Dual Energy 2 in 1 PVT/PCM Hybrid Photovoltaic-thermal systems integrates photovoltaic and solar thermal technologies and has the extra advantage of producing both type electrical and thermal energy simultaneously. Photovoltaic (PV) system is one of the renewable energy in the world. Till now market placed solar PV System conversion efficiency is around 5 to 16 % and reduces with temperature rise. Usually per K it dropped by 0.5% more or less it depends on PV Module grade also**.** To improve electrical efficiency as well as to achieve maximum of its thermal conversion by panel we can recycle, remove otherwise absorb the extra heat from PV module`s backside is most important issue and problem statement in solar PV thermal energy application and conversion concept. Solar Photovoltaic/thermal (PVT) system is an application to recycle the heat and reduce operating temperature from PV panel. The heat can transfer to hot water or hot air and can be used to bath, industrial pre-heat, air heating purposes. The PVT system can be separated in natural convection and forced convection depending on the flow dynamics. PVT developed an integrated photovoltaic and thermal solar system (IPVTS) consisted of the PVT collector, storage tank, pump and controller. The daily average thermal efficiency reaches 0.38% and the daily overall efficiency reached 0.5%.The natural convection photovoltaic thermo-siphon water heating system can be applied with aluminium-alloy flat box frame and electrical efficiency can read till (9-12) % and the thermal efficiency is 35% to 48% in summer and cloudy days respectively. When sun light enters the PV cell, a part of the energy of the photons is absorbed by these micro-conductor’s atoms, which release electrons from the negative outer layer of the cell. By flowing through a circuit, these electrons or atoms reach the positive layer and generate electricity continuously till the time solar irradiation available on PV panel.

PV power production depends on various factors**:**

(i) The kind of semiconductor material grade used.

(ii) The operating temperature of the cell.

(iii) The intensity of the solar radiation and area covered.

According to the literature, six basic techniques of PV thermal management can be classified:

1. Natural circulation
2. Forced air circulation
3. Hydraulic cooling
1. Thermoelectric cooling
2. Heat pipes as heat exchanger
3. Implementation of phase change material

The most commonly used technology that requires no initial costs and maintenance is natural air circulation method. The low surface heat transfer coefficient as well as heat capacity of air makes this technique lower efficient and in the case of passive cooling and BIPV system where the space backside panels and air mass flow rates are significantly low and limited. Other side, active techniques like forced air circulation can provide more effective cooling, but also consumes additional energy which could be utilize to enhancement of system performance, requires proper maintenance and in some cases are taken as noisy polluting systems. Finally thermal management technique utilizing PCM is very promising and fruitful approach but requires well design in many aspects covered with these method also utilize PVT/PCM System up to maximum of its benefits throughout the year.

The objective and motive of this study is to design, make and explain system with comparative study of selecting low melting point phase change storage module to increase solar PV efficiency. This characterized module will be used as alternative of fuel and power runner. aim of research topic is to make the more efficient and cost effective hybrid energy conversion system by using paraffin wax in much better way to make dual PVT-PCM System portable and gives maximum of its energy output in both aspects.

(i) Stabilize system at low melting point that lies between (10-35^{o}C), which is closer to STC 25^{o}C.

(ii) Use waste heat as heat extraction for solar thermal.

(iii) Reduce recombination as much as possible.

(iv) Increase PV panel efficiency at least by 4%-8%.

(v) Making Hybrid Technology fully convenient and easy to use.

II. REVIEW OF HYBRID PVT SYSTEM WITH PCM COMPARATIVE STUDY

Main property of PCM material is to stored and absorb/release heat as is hidden latent heat at close to a constant temperature during its melting and freezing, solidification transition phases. This is a very unique property in power generation process, where a very high temperature or heat source is required within a narrow or low restricted temperature range as heat input for the Energy. These materials can store energy by the melting at a constant temperature**.** There is no perfect PCM Material without draw backs, so the selection of a PCM for a given application requires very careful consideration including its compounds, having low melting point. For the research lots of material have been considered as PCM, including individual component systems for this paper study, that could be congruent mixtures, eutectics etc.

The isothermal characteristics as charging or discharging heat at a nearly constant temperature during the solidification phase and melting phase or liquidification phase processes which are most required for efficient operation of solar thermal system. The latent heat capacity of selected PCM or heat storage duct must be very high level range. According these aspects we can select this from several materials. Before selecting final PCM we should be very conform for its chemical and thermo physical behavior. Over all system should be safe and non-toxic. Wax is the most commonly used commercial organic heat storage PCM. After salt the paraffin waxes are cheaper and have moderate thermal energy storage density but low thermal conductivity and, therefore we require large surface area to in cress thermal output due to PCM.

In our current project we are considering the same PCM as paraffin wax it abundant and can be inbuilt within PVT frame properly. Beside that Latent heat of fusion of paraffin wax is very large.

In Table:1 the most important physical properties of different kind paraffin and PCM are showed. Normally Paraffin starts melting at 46.45^{o}C and ends at 48.68^{o}C and Paraffin wax melting temperature are 64^{o}C.

The main features of these materials during the phase transition are:

(a) Cheap and economical, abundant

1. High heat energy with huge heat storage capacity;
2. No performance decay;
3. No toxicity; Non -polluting, non -Flammable
4. Chemical neutrality.

(b) No phase separations.

(c) Study on PVT-PCM system.

A theoretical analysis of buoyancy driven air flow in such an opening behind a façade integrated PV showed a maximum of 5°C temperature reduction in averaged monthly temperature resulting in a net 2.5% increase in yearly electrical output of the PVT.

Table 1: Comparative thermo physical properties of different PCM.

S. No.	Property Of PCM Material	Mixed Paraffin /Controlled	Paraffin Grades C14 To C25	Organic Non-Paraffin	Metal Eutectic	Salt Hydrated
1	Specific Heat Capacity (J/kg-K)	0.50-0.70	2.14-2.10	High	Medium	High
2	Latent Heat of Melting Point (K or °C)	High	5.5-49	High/Sharp 7-254	300-500 Sharp	Low
3	Density(kg/m^3)	High	700-810		900-2200	
4	Cooling Capacity (%)	No	No	No	No	Strong
5	Latent Heat of Fusion kJ/kg	180	173.6 High	120-240	30-90	170-340 High
6	Thermal Expansion (1/K)	Moderate	High	Strong	Low	Low
7	Corrosion(%)	Low	Low	Some Times	Some Times	Strong
8	Conductivity (W/m-K)	1.2	0.21 Low	0.18	20	0.6-1.2
9	Toxicity (%)	Sometimes	No	Some Times	Conditional	Mostly High
10	Phase Transition Temperature (° C)	42-45	High	Some Times	Low	Low

Because the temperature reduction in not up to the satisfactory level to improve overall efficiency of system thus directly absorption of overheating from PV Panel is best option using strongly thermo siphons pipes heat exchanger which will boost PV Performance. The advisable operating Temperature limit for PV ranges from −40°C to 85°C. However in hot and arid climates PV temperature frequently rises above upper limit of temperature range, which results in temperature induced power loss as well as PV cell delimitation and rapid degradation makes a desirable need for PV module temperature control to maximize both panel power output and performance. Already in past researches Passive cooling of BIPV with solid-liquid PCMs were experimentally and numerically studied using a paraffin wax as PCM material and a rectangular framed aluminium container having selectively coated front surface with a selective solar absorbing filmwill which will protect outer side heat losses. Temperature distribution on the front surface and inside the PCMs was predicted through finite volume area heat transfer models and was experimentally validated .Building on this work and research.

III. METHODOLOGY AND PLAN FOR PROPOSED SYSTEM

In that undertaking research, the majority of the research is through study &literature review, in creating all possibilities and idea pertinent to this particular topic.

From this, the technology was used to adopt a working design that was investigated to determine if there was merit in the approach or retract to consider different avenues. Once satisfactory information was obtained and a concept established, the next step entailed a hypothetical design that was used to base assumptions and form conclusions. We decide to make fully well sealed container PVT-PCM System using proper insulated design. Firstly PV Panel will dually laminated by metallic sheets in between choose phase change material will filled providing no leakage with proper space to freeze or melt, after that thermo coal or chicken wings up to (1.5-2mm) inches as insulated part that will protect heat loss. Outer frame of overall PVT/ PCM system will make by blacked Aluminum metallic body which significantly reduce heaviness and cost of conventional system. Without compromising much with efficiency as regard of Indian climate scenario, IT is well known to get maximum electrical output by PV System the temperature should not exceed, for this two ways can be used. We choose the paraffin grade having Low Melting Point between 5C to 50°C because this specific PVT/PCM System is going to design regarding Indian whether condition and average temperature. Though PV system will gives its maximum power output because panel best performance lies between 20°C to 39°C Mostly. We will conceive this kind of Strategies like-

(i) By combination cooling pattern of PV Panel.

(ii) By extra waste heat absorption from PV contributes to lower PV operating temperature.

(iii) By selecting PCM of low melting point considering Indian climatic condition.
(iv) By using mixture of different grade paraffin in proportions to lower the Paraffin wax volumetric expansion which will Control system.
This paper gives the idea and strategies to hybrid the PV system and solar thermal hot water system into a single unit. Thus all specifications of each individual system will be taken into consideration. The following algorithm will represent the general plan to operate the overall unit. Mostly the PV operating temperature is hard to maintain or even some times it crosses higher temperature range, which directly Affect the performance of Module.

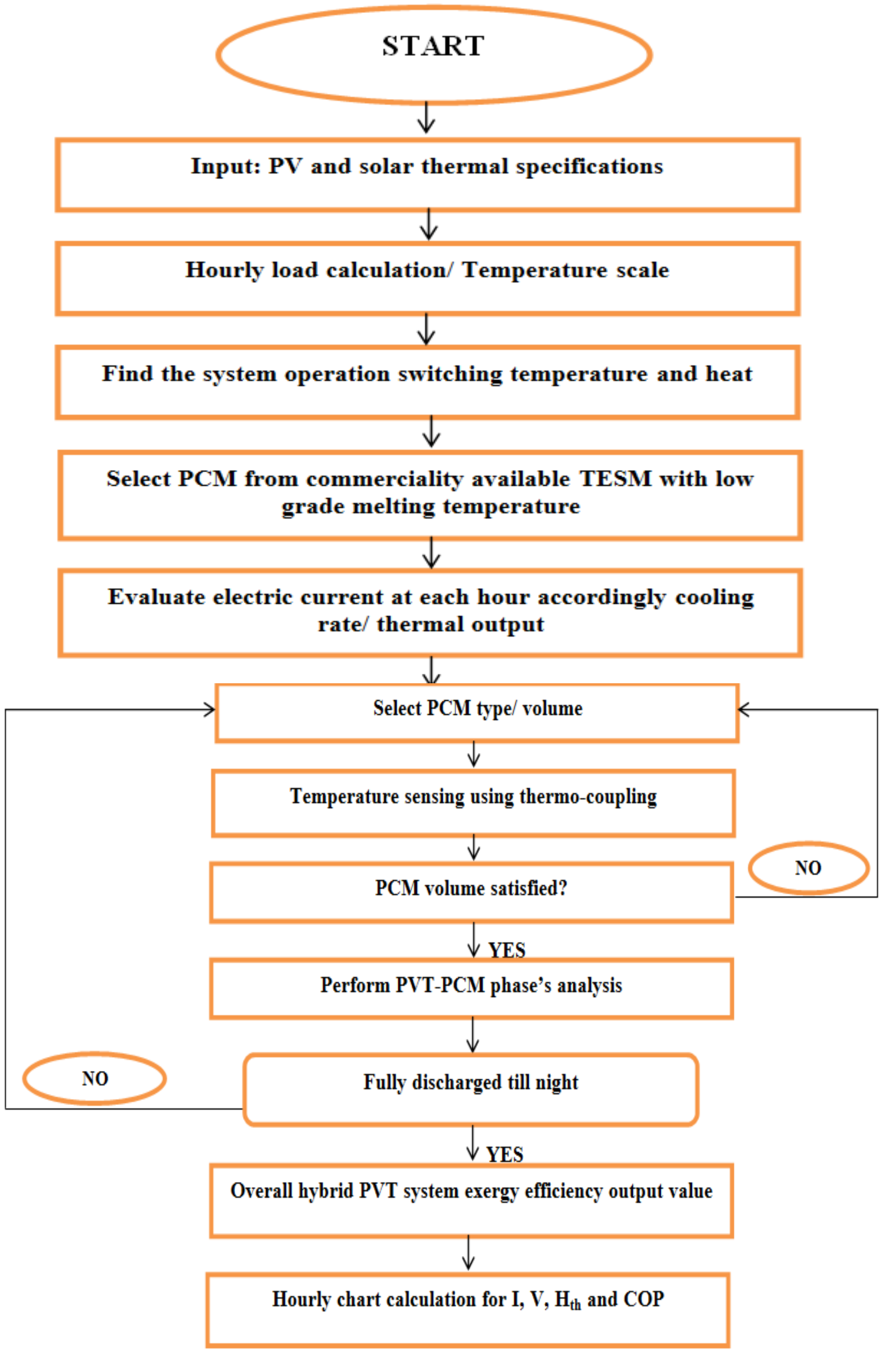

Fig. 1. Flow chart for the PVT-PCM project operation.

For this we are going to select TESM as phase change material like paraffin wax with some other material by this technique the melting point of PCM can be reduced up to considerable extent this will directly reduce the high operating temperature of PV module so electrical output will increases as well as the thermal energy will double In its efficiency output thus PCM will start is work much before then going up to higher temperature scale. The paper work will be continue under these all consideration ,specifications and in further work the better options will be accepted to make hybrid system much better in performance. (Flow chart for the PVT-PCM project operation is given in fig. 1).

IV. POSSIBLE OPERATINGMODES WITH ALL PVT- PCM PHASES CHANGES

There are a total of five operating modes including three conditioning modes and two PVT modes, which are mutually controlled system specifically designed for this project.

Table 2: Operating modes of PVT-PCM system.

A **PVT modes/ there is no conflict with other modes**	**B** **Conditioning modes**
PCM Charging. If there is no demand from require area, and the PCM part is not fully charged and it is convenient to charge it, in this case the PVT collector will charge the PCM part.	Normal Conditioning Mode- If there is no PVT thermal power generation and no thermal energy available in the PCM store then PVT-PCM work normally.
PVT Exhaust. If the energy used by the user is less than the increase in PV generation, then air will be drawn underneath the PV panels and exhausted directly to ambient atmosphere.	Direct PVT Supply Mode- If the generation of heating during daytime or cooling during night time occurs at the same time as the demand. If the demand is greater than the energy extracted from the PVT system.
NIL	PCM Discharging mode-If the demand is higher than the energy extracted from the PCM storage unit.PCM Discharge Mode. If thermal energy is available in the PCM part the return air and fresh air will be pre conditioned by the PCM again, decreasing or increasing the supply air temperature.

V. PROPOSED MODEL APPROACH FOR EFFICIENCY IMPROVEMENT

Two techniques are used to enhance the efficiency of the PV thermal system. First is known as enhancing the thermal capacity energy of the hybrid PV/T system by huge heat storage and second decreasing the temperature of back surface for PV modules to enhance electrical output by PVT.

A. Reduce PV overheat by back surface water flow and air cooling: To reduce the access temperature of the solar heat the continuous water circulation is designed at the back side of PV by copper pipes which will act as a heat exchanger. This thermos phones act as a heat exchanger and continuously transfer additional heat from module to water and keep PVT system under control. The overall electrical efficiency is depends on the PV temperature thus if surface heat goes down significantly then recombination process also denominate. Due to this result finally efficiency increases.

B. Making PVT-PCM system portable and Easy to operate: We are focusing on better use of packed Wax PCM To inbuilt the single framed PVT –Hybrid system. We will use the phase change material with high heat of fusion and large heat storage property considering that is should not raise overall cost by result of this hybridization gives much benefits.

C. Improve thermal conductivity of PCM by effective additives into PVT: This study gives the some cost effective alternatives which can easily enhance the conductivity like powder of any low cost metal, moderate metallic sheet, charcoal, thermoelectric materials etc.

VI. PROBLEM STATEMENT AND GAPS IN RESERCH

The main problem is overheating of the panel which decreases the performance of system. Our work will continue to make the better idea for integrated technology to build hybrid PVT-PCM System which can be easily operate in lower temperature also with good efficiency in both aspects as power output as well as hot water that is thermal energy output.

VII. ANALYSIS

The technical prediction and approach is determined from literature study and research papers, this analysis is mainly proposed for Indian climatic conditions.

Other survey with key industry stakeholders, including local PCM manufacturers, PV solar panel sellers were conducted to provide focus and insight to this study to make best effective and cheaper PVT-PCM design.

VIII. RESULTS AND DISCUSSION

The results from the studies summarized above show that PCM In a hybrid PVT is an effective tool for reducing energy consumption, while maintaining satisfactory system performance and indoor thermal comfort the overall system was designed for operation during both winter and summer, using daytime solar radiation and night sky irradiative cooling. Clearly such systems are financially viable in higher temperature and higher solar irradiation environment Also, with cheapest PCM mixture and totally pollution free without any maintenance cost with minimum accommodation.

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