Performance Analysis of Uneven Span Greenhouse integrated Semitransparent Photovoltaic Thermal (GiSPVT) System

Sugandha Singh

Department for Energy Science & Technology
Indian Institute of Technology Delhi, New Delhi

FEBRUARY 2023

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by

Sugandha Singh

Department for Energy Science & Technology

Submitted

in fulfilment of the requirements of the degree of Doctor of Philosophy

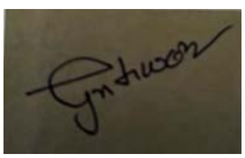
to the

Indian Institute of Technology Delhi

February 2023

Certificate

This is to certify that the thesis entitled "**Performance Analysis of Uneven Span Greenhouse integrated Semi-transparent Photovoltaic Thermal (GiSPVT) System"** being submitted by **Sugandha Singh** to the Indian Institute of Technology Delhi, is worthy of consideration for the award of the degree of **'Doctor of Philosophy'** and is a record of the original bona fide research work carried out by her under our guidance and supervision. The results contained in the thesis have not been submitted in part or full, to any other University or Institute for the award of any degree or diploma.



(Dr. G.N. Tiwari)

President
Bag Energy Research Society (BERS)
11-B, Gyan Khan IV
Indirapuram
Ghaziabad, U.P- 201010
India
(http://bers.in/)

(Dr. T. S. Bhatti)

Professor
Centre for Energy Studies
Indian Institute of Technology Delhi
Hauz Khas, New Delhi-110016
India

Acknowledgements

I am deeply indebted to my supervisor, **Prof. (Dr.) G.N Tiwari** for his stimulating motivation, continuous guidance, encouragement, and immense knowledge throughout my research work. His guidance helped me immensely during the research and writing of this thesis. I cannot imagine having a better supervisor and mentor for my research work. I am very thankful to **Prof. (Dr.) T.S. Bhatti** for his valuable time, support, encouragement, and guidance which helped me complete this work.My sincere gratitude to **Prof. (Dr.) Ashu Verma** for providing moral support and encouragement from time to time and for being the best mentor .

A heartfeltmemory to my late father **Dr. Vikram Singh** for motivation to pursue research.

I cannot thank enough my mother **Dr. Suman Yadav** for her endless love and support and my brother **Mr. Harshul Yadav**for his constant encouragement.

Also, thanks to my 3-year-old daughter **Ms. Shreenika**for continuous cheer which helped me sustain trying times in my Ph.D. completion.

I would like to thank and convey my deep gratitude to my colleaguesfor theirsupport and cooperation, without which my work would have undoubtedly been more difficult.

(Sugandha Singh)

Abstract

In this thesis, an uneven span greenhouse is considered which is integrated with semitransparent photovoltaic thermal (PVT) system for agriculture (pot cultivation), aquaculture and algaculture applications (solar pond) to meet the ever-increasing food and energy demands. For the analysis of uneven span Greenhouse integrated Semitransparent Photovoltaic Thermal (GiSPVT) system, heat and mass transfer correlations are considered and basic energy balance equations as a function of climatic, operational and design parameters have been written for each component of a given uneven span GiSPVT system analytical expressions for solar PV module, greenhouse room air, and water temperature have been derived. For the proposed system, hourly variations in the temperature of water in pond, greenhouse air and solar cell temperature has been determined using IMD Pune weather data for New Delhi, India. Further, thermal energy (low grade energy) is calculated using these expressions obtained by thermal modeling of uneven span GiSPVT system considering four cases for variation of solar pond depth. Similarly, high grade energy which is electrical energy is calculated for uneven span GiSPVT system. Also, the result of modification in PV module packing factor for south roof of uneven span GiSPVT system is taken into consideration. Additionally, weather conditions for Indian cities are considered to evaluate annual performance of Uneven Span GiSPVT system. Microsoft Excel 2011 and MATLAB 2015 have been used to evaluate various unknown parameters as stated above. Furthermore, experimental set up for three configurations of uneven span GiSPVT system is prepared, which is divided into 6 zones (I to IV) for three different configurations of PV module namely, 80 Wp, 50 Wp and,25 Wp PV modules, integrated at the south roof of greenhouse in Ballia, Varanasi (U.P.) India. Periodic model for uneven span GiSPVT system is derived as well.

सारांश

इस थीसिस में, एक असमान स्पैन ग्रीनहाउस पर विचार किया गया है, जो लगातार बढ़ती खाद्य और ऊर्जा मांगों को पूरा करने के लिए कृषि (बर्तन की खेती), एक्काकल्चर और अल्गाकल्चर अनुप्रयोगों (सौर तालाब) के लिए अर्धपारदर्शी फोटोवोल्टिक थर्मल (पीवीटी) प्रणाली के साथ एकीकृत है। असमान स्पैन के विश्लेषण के लिए ग्रीनहाउस एकीकृत अर्धपारदर्शी फोटोवोल्टिक थर्मल (GiSPVT) प्रणाली, ऊष्मा और द्रव्यमान हस्तांतरण सहसंबंधों पर विचार किया जाता है और जलवायु, परिचालन और डिजाइन मापदंडों के कार्य के रूप में बुनियादी ऊर्जा संतुलन समीकरण दिए गए असमान स्पैन के प्रत्येक घटक के लिए लिखे गए हैं। सोलर पीवी मॉड्यूल, ग्रीनहाउस रूम एयर और पानी के तापमान के लिए सिस्टम एनालिटिकल एक्सप्रेशंस निकाले गए हैं। प्रस्तावित प्रणाली के लिए, नई दिल्ली, भारत के आईएमडी पुणे मौसम डेटा का उपयोग करके तालाब, ग्रीनहाउस हवा और सौर सेल तापमान में पानी के तापमान में प्रति घंटा भिन्नता निर्धारित की गई है। इसके अलावा, तापीय ऊर्जा (निम्न ग्रेड ऊर्जा) की गणना सौर तालाब की गहराई के परिवर्तन के लिए चार मामलों पर विचार करते हुए असमान स्पैन GiSPVT प्रणाली के थर्मल मॉडलिंग द्वारा प्राप्त इन अभिव्यक्तियों का उपयोग करके की जाती है। इसी तरह, उच्च ग्रेड ऊर्जा जो कि विद्युत ऊर्जा है, की गणना असमान स्पान GiSPVT प्रणाली के लिए की जाती है। इसके अलावा, असमान स्पैन GiSPVT सिस्टम की दक्षिण छत के लिए PV मॉड्यूल पैकिंग फैक्टर में संशोधन के परिणाम को भी ध्यान में रखा गया है। इसके अतिरिक्त, असमान स्पैन GiSPVT सिस्टम के वार्षिक प्रदर्शन का मूल्यांकन करने के लिए भारतीय शहरों के लिए मौसम की स्थिति पर विचार किया जाता है। Microsoft Excel 2011 और MATLAB 2015 का उपयोग ऊपर बताए गए विभिन्न अज्ञात मापदंडों का मूल्यांकन करने के लिए किया गया है। इसके अलावा,

असमान स्पैन के तीन कॉन्फिगरेशन के लिए प्रायोगिक सेट अप GiSPVT सिस्टम तैयार किया गया है, जिसे PV मॉड्यूल के तीन अलग-अलग कॉन्फिगरेशन के लिए 6 जोन (I से IV) में विभाजित किया गया है, अर्थात् 80 Wp, 50 Wp और, 25 Wp PV मॉड्यूल, पर एकीकृत बलिया, वाराणसी (यूपी) भारत में ग्रीनहाउस की दक्षिण छत। असमान स्पान GiSPVT सिस्टम के लिए आवधिक मॉडल तैयार किया गया है।

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Nomenclature

A	Area (m^2)
b	width of the roof (m)
C	Specific heat (J/kg K)
E	Electrical Energy (kWh)
$\dot{E}$	Rate of energy (W)
h	Heat transfer coefficient (W/m^2 K)
h_c	Convective heat transfer coefficient (W/m^2 K)
I(t)	Solar intensity (W/m^2)
K	Thermal conductivity (W/m K)
L	Thickness (m)
M	Mass (kg)
N	Number of air changes per hour
P	Partial pressure (N/m^2)
Q	Heat transfer (W)
$\dot{q}$	Rate of heat transfer (W/m^2)
Qu	Thermal energy (J)
$\dot{Q}u$	Rate of hourly energy (W)
T	Temperature (˚C)
U	Overall heat transfer coefficient (W/m^2 K)
v	Velocity of air (m/s)

Greek symbols

α	Absorptivity
β	Packing factor
β_0	Temperature coefficient ($˚C^{-1}$)
γ	Relative humidity (%)
ΔT	Temperature difference (˚C)
η	Efficiency
η_0	Electrical efficiency at standard test condition
ρ	Density (kg/m^3)
τ	Transmissivity

Subscript

a	Ambient air
b	from floor to the area below the room under study
c	Solar cell
daylight	Solar energy through non- packing area of PV module
e	Electrical
eff	Effective
ew	East wall
f	Floor of room under study
g	Glass
i	Inside
m	PV module
max	Maximum
min	Minimum
NB	Room under study
NR	North Roof
nw	North wall
sc	Solar cell
s	Side walls
sr	South roof
sc,s	From solar cell south roof
tcw	From solar cell to water
th	Thermal
w	water
ww	West wall

Design parameters

Parameters	Values
A_w	150.0 m^2
A_b	150.0 m^2
A_s	63.0 m^2
A_{ew}	19.0 m^2
A_{sw}	224.0 m^2
A_{ww}	19.0 m^2
A_{nw}	224.0 m^2
A_{sr}	121.23 m^2
A_{nr}	40.410 m^2
C_w	4190 J/Kg ^{o}C
K_g	0.78 W/m °C
L_b	0.2 m
L_s	0.3 m
L_g	1.0 m
M_w	75000 kg
T_o	25 ^{o}C
V	610.40 m^3
v	0-0.3 m/s
α_w	0.90
τ_g	0.95

List of abbreviations

BF	Basement Floor
BiPV	Building integrated Photovoltaic
BiPVT	Building integrated Photovoltaic Thermal
BiOPV	Building integrated Opaque Photovoltaic
BiOPVT	Building integrated Opaque Photovoltaic Thermal
BiSPV	Building integrated Semitransparent Photovoltaic
BiSPVT	Building integrated Semitransparent Photovoltaic Thermal
c-Si	crystalline Silicon
DL	Daylight
EC	Evaporative Cooling
EE	Embodied Energy
EPBT	Energy Pay Back Time
EPF	Energy Production Factor
ETC	Evacuated Tubular Collector
FF	First Floor
GF	Ground Floor
HVAC	Heating, Ventilation and Air Conditioning
LCCE	Life Cycle Conversion Efficiency
NV	Natural Ventilation
OPV	Opaque Photovoltaic

OPVT	Opaque Photovoltaic Thermal
PC	Passive Cooling
PV	Photovoltaic
PVT	Photovoltaic Thermal
SBC	Sodha Bers Complex
SF	Second Floor