Design and Implementation of a Retrofit Solar-Assisted HVAC System for Residential Applications

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Summary

• Overview of Solar Decathlon Competition
• ‘The Journey to Datong’
• The Team UOW Illawarra Flame House
• Photovoltaic Thermal System and Phase Change Energy Storage systems
• Solar Assisted HVAC System
  – Design
  – Modelling
  – Initial results
THE SOLAR DECATHLON

• A competition for University students to design, build and operate sustainable, net-zero energy, attractive and affordable homes.

• Objective: accelerate the development and adoption of advanced building technologies.

• Since 2002:
  • 8 competitions
  • 5 in US
  • 2 in Europe
  • 1 in China

• Total of 164 teams
THE SOLAR DECATHLON CHINA 2013 COMPETITION

- Team UOW was a collaboration between UOW and TAFE NSW Illawarra Institute.
- Team UOW the first ever team from Australia to win entry to a Solar Decathlon.
- 270,000 people attended the competition site.
- 35,000 people were toured through the Illawarra Flame House throughout the competition week – one every 8 seconds!
SUB-COMPETITIONS
TRANSFORMING OUR HOUSES...
The Base Plan
INTO SUSTAINABLE HOMES
ILLAWARRA FLAME HOUSE FEATURES

- State of the art photovoltaic panels
- Greywater treatment system
- Natural ventilation and automated high level windows
- Innovative HVAC system featuring
  - Photovoltaic-Thermal solar system and
  - Phase Change Material (PCM) Thermal Store
- Innovative Building Management System

ILLAWARRA FLAME HOUSE IN DATONG 2013
PHOTOVOLTAIC THERMAL SYSTEM

Daytime generation

Night time radiant cooling
PVT AND PCM

PVT ROOF

ILLAWARRA FLAME HOUSE – DATONG 2013

BLUESCOPE LYSAGHT TRIMDEK
PVT AND PCM

For optimization it was necessary to develop:

- Thermal Model
- Mechanical Model (Fan Consumption)
- Electrical Model (electrical generation efficiency is a function of PV temperature)

THERMAL NETWORK MODEL
There is generally a significant offset between the thermal generation and the house demand.

Thermal energy storage has been included in the design, through the latent heat of Phase Change Material (PCM). Melting temperature has been identified at 22°C.
SOLAR ASSISTED HVAC SYSTEM
ILLAWARRA FLAME HOUSE – 4X

First build at TAFE

Dress rehearsal at UOW Innovation Campus

3rd build at competition site
Construction in China
PVT AND PCM – INITIAL RESULTS

ELECTRICAL MODEL VALIDATION

- PV Generation, Model, South side
- PV Generation, Model, North side
- PV Generation, Model, Total
- PV Generation, Measured

Time [min]

Power [W]
SOLAR ASSISTED HVAC SYSTEM

- HVAC System Managed by a Residential type of control system.
- Customized logic and non-standard use of devices to automate the system and control the subcomponents.

ILLAWARRA FLAME BMS
SOLAR ASSISTED HVAC SYSTEM

PCM Charging with PVT Optimization Example

\[ C = P_{th} + \alpha(\Delta P_{e,gen} - P_{e,cons}) \]
SOLAR ASSISTED HVAC SYSTEM

![Graph showing Solar Assisted HVAC system performance with various components like Heating Load, Charging, Hmiss, Discharge, and Charge.](image-url)

- **Energy stored [Wh]**
- **Power [W]**
- **Time [h]**

Legend:
- Black: Heating Load
- Red dashed: Charging
- Green dashed: Hmiss
- Purple dashed: Discharge
- Cyan: Charge
## SOLAR ASSISTED HVAC SYSTEM

### Simulated Performance Results

<table>
<thead>
<tr>
<th></th>
<th>Winter July (Heating)</th>
<th>Summer February (Cooling)</th>
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<tbody>
<tr>
<td>Total demand, Thermal (kWh)</td>
<td>206</td>
<td>165</td>
</tr>
<tr>
<td>Thermal Energy supplied through PV-T/PCM (kWh)</td>
<td>139</td>
<td>116</td>
</tr>
<tr>
<td>Electrical Energy for Discharging (kWh)</td>
<td>6.1</td>
<td>9.6</td>
</tr>
<tr>
<td>COP Discharging</td>
<td>22.8</td>
<td>12.1</td>
</tr>
<tr>
<td>Thermal Energy Charged (kWh)</td>
<td>131.4</td>
<td>163.6</td>
</tr>
<tr>
<td>Electrical Energy for Charging (kWh)</td>
<td>5.0</td>
<td>10.1</td>
</tr>
<tr>
<td>COP Charging</td>
<td>26.4</td>
<td>16.2</td>
</tr>
<tr>
<td>COP Overall</td>
<td>12.3</td>
<td>6.9</td>
</tr>
</tbody>
</table>
Team UOW Win!

- Overall winner of Solar Decathlon China 2013
- Highest overall score in the history of Solar Decathlon Competitions (957.6/1000)
- Placed first in five out of the 10 competitions:
  - Architecture
  - Engineering
  - Solar Application
  - Hot Water
  - Energy Balances
- Second by one point in:
  - Communications
  - Market Appeal
- >35,000 people toured through house (1 person every 8 seconds!)
- >270,000 members of the public attended competition site
Illawarra Flame and SBRC at UOW
Summary

• Team UOW first:
  – Australian Team to win entry to a Solar Decathlon
  – Team ever to demonstrate a retrofit of an existing building
  – Place at SD China 2013, with highest ever overall score
• Air-based PVT system linked with PCM store and conventional heat pump.
• The Team UOW/BlueScope Solar Assisted HVAC system winner of the 2013 Denis Joseph competition.
• Illawarra Flame house now reconstructed and will be a long-term test bed for solar and HVAC technologies at the SBRC@UOW.
Acknowledgements

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