Solar Water Heating System with Phase Change Material

(SWHS)

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Background info

- Solar energy is a renewable, environmentally friendly alternative to fossil fuels
- Regular solar water heating tanks must be large to facilitate the storage of sufficient thermal energy
- Phase Change Material (PCM) can store thermal energy in the form of latent heat
  - Allows for smaller solar water heating tanks

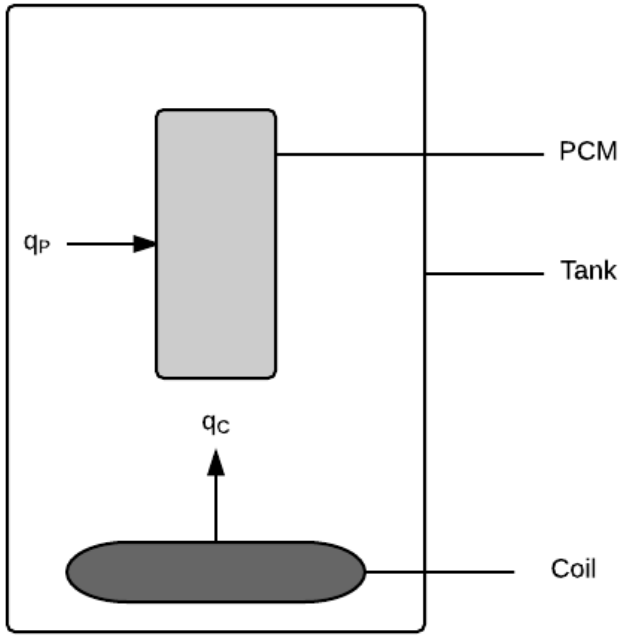


Figure: Simplified diagram of a solar water heating tank

Purpose of the software

The purpose of the software, called Solar Water Heating System (SWHS), is to:

- simulate the charging of a single solar water heating tank incorporating PCM
- predict the temperature and thermal energy profiles of water and PCM
- predict the start and end times for the melting process of the PCM

Inputs

SWHS accepts a text file containing numerical values for the following parameters:

- Properties of coil:
  - Surface area, temperature
- Properties of tank:
  - Length, diameter
- Properties of water:
  - Density, specific heat capacity, convective heat transfer coefficient between water and PCM and between water and coil, initial temperature
- Properties of PCM:
  - Volume, surface area, density, specific heat capacity as solid and as liquid, specific latent heat of fusion, melting temperature, initial temperature (same as water)
- Parameters for numerical algorithm:
  - time step size, end time, relative tolerance, and absolute tolerance

Outputs

Running the SWHS software outputs the following:

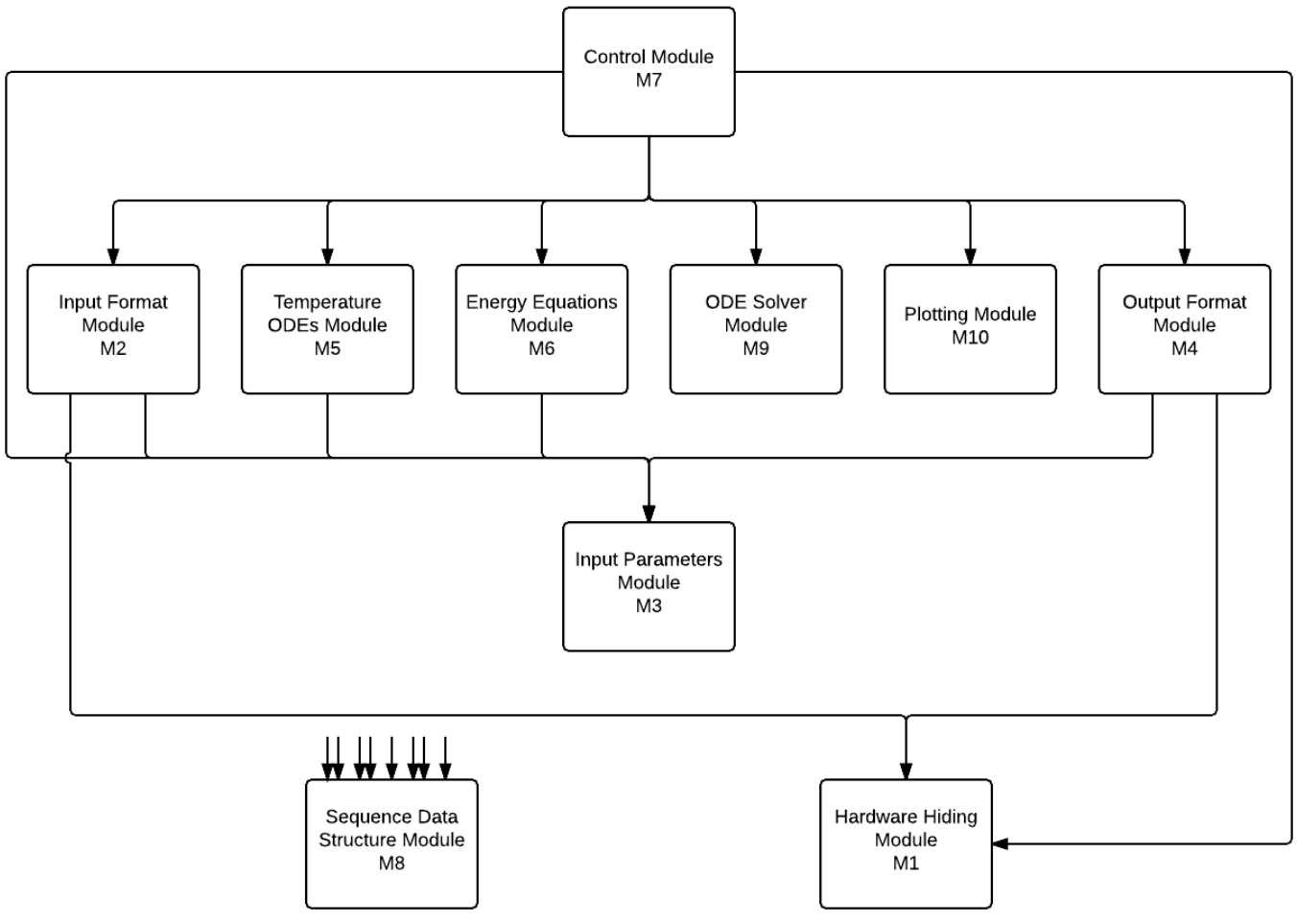
- Input parameters, values of temperature and energy throughout simulation time
  - Written to text file
- Graphs of temperature and energy of water and PCM over time
  - Saved as PDF and PNG files
- Start and stop times for melting of PCM
  - Printed to screen

System Design
Module Hierarchy

The software is divided into modules, which themselves can be sorted into two levels of hierarchy.

Level 1	**Level 2**	**Implemented by**
Hardware Hiding Module		OS
Behaviour Hiding Module	Input Format Module Input Parameters Module Output Format Module Temperature ODEs Module Energy Equations Module Control Module	SWHS
Software Decision Module	Sequence Data Structure Module ODE Solver Module Plotting Module	MatLab

System Design
Module Use Hierarchy



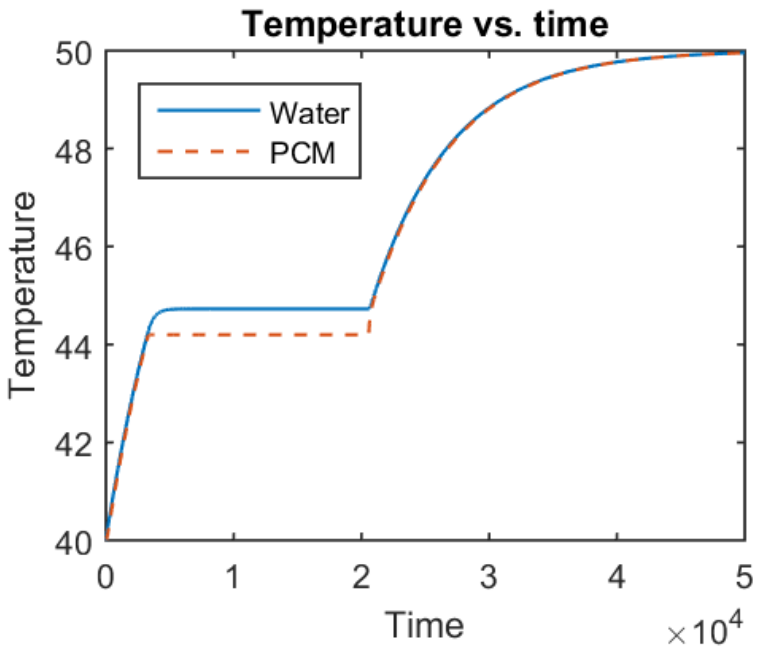
Running the software

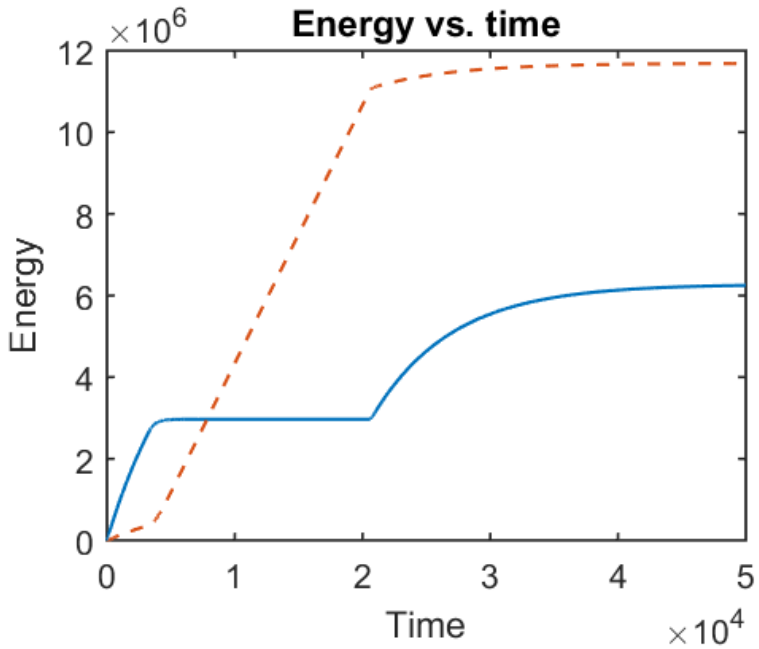
The SWHS software was written in MatLab code. The Control Module is implemented by the main.m function. Calling this function in MatLab with the filename for the file containing the input values as the only parameter will run the program.
For example:

```
>> main('test.in')
PCM has started to melt at time 3322.065744
PCM has finished melting at time 20571.368997
>>
```

Running the Software
Example output graphs

These are an example of the graphs that the function outputs:





Sample Test Cases
Faulty Input

Input:
Standard input with one parameter changed to a value outside of the physical constraints.

Expected Output:
Error message specific to the faulty parameter.

Example:

Input: Tank length of -2 m, standard input for remaining parameters.
Expected Output: `error: Tank length must be > 0`

Sample Test Cases
Comparisons to Similar Programs

Example:

Input: Standard input to both the MatLab implementation of SWHS and the original FORTRAN implementation of the program.
Expected Output: Numerical output values with a relative error of 0.01 between the two versions of the software.

Example:

Input: Standard input to both the current SWHS version and an alternative that uses the `ode23` numerical algorithm for solving ODEs instead of `ode45`.
Expected Output: Numerical output values with a relative error of 0.01 between the two versions of the software.

Sample Test Cases
Unit Tests

Example:

Input: Standard input and a time `t=100` and a temperature vector `T=[44.2, 44.2]` to the event1.m MatLab function.
Expected Output: Row Vector `[0, 1, 0]`

Example:

Input: Standard input and a temperature matrix `T=[40:44; 40:44]'` to the energy1.m MatLab function.
Expected Output: Change in energy of water and of PCM, where `Ew1=[0; 627795.094; 1255590.188; 1883385.281; 2511180.375]` and `Ep1=[0; 88616; 177232; 265848; 354464]`

Thank you!