Centre for Modeling and Simulation
Savitribai Phule Pune University

Modeling and Simulation Overview

Home Insulation System

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Guide
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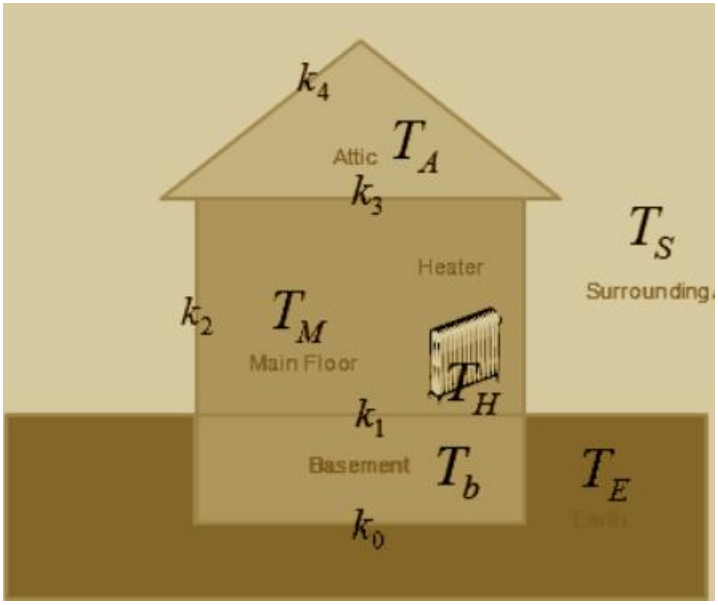
Problem statement:



Consider a typical home with *at least* three sections. (Say: Main room, basement and attic. You can choose different design.) There is one heater or air-conditioner.

Build a model that describes the temperatures of various sections of the house as a function of time (as the temperature outside fluctuates). For your model any and all the parameters you need, you have to find out their values on your own. If not found, make a judicial choice.

Introduction:

We can use heat transfer approach to determine the Inside Room Temperature, Heat required for heating the room, Attic Temperature, and Basement Temperature on the basis of outside Temperature with some other parameters.

I got the Temperature data (with other parameters like; velocity of air, etc) from the below website:

https://www.meteoblue.com/en/products/historyplus/download/sitka_united-states-of-america_5557293

The data is recorded on hourly basis.

I have total data for 193 hours and I used below important Parameters for calculation:

- Temperature
- Wind Speed (Velocity)

My Approach:

I considered only the heat transfer by Conduction and Convection phenomenon.

(I have ignored the radiation part, as this will be very less as we are not maintaining the very high temperature)

For the generalized Model I have used below details:

There is a room in Alaska (United States) having Length, Breadth, and Height is 10 feet. The room is built by using wooden material. This room also have Attic (The top portion) and basement (Below the room). My goal is to maintain the room at 25 deg C and calculate the energy requirement to heat the room by using heater. (Heating is required as in Alaska the outside Temperature is too low)

To maintain the Room Temperature we need to keep the heater in room and also provide energy to heater so that the room gets heated.

Below are the parameters that need to be considered while Modeling:

- Outside Temperature : **(I took from CSV file)**
- Inside Temperature: **(Need to maintain)**
- Heat required to maintain the Room Temperature: **(Need to check pattern/variation)**
- Attic Temperature: **(Need to check pattern/variation)**
- Basement Temperature: **(Need to check pattern/variation)**
- Volume of the room: **(Initially I assumed 10 cubic feet)**
- Thickness of the wall: **(Initially I assumed 0.15 m)**
- Outside wind speed (velocity): **(I took from CSV file)**
- Thermal Conductivity of building material (wood): **(Initially I assumed 0.12 w/m/C)**
- Heat Transfer Coefficient of Air: **(I calculated by using the velocity of wind)**
  $HTC_{air} = 10.45 - v + 10*v^{1/2}/2$
  Where v = velocity of air

I have used Python Language for the Simulation.

Heat required maintaining the Room Temperature (in KW):

$Q = V \times \Delta T \times K / 859.85$

Where,

V – Volume of area to be heated (Width x length x height) in m3.
ΔT – Difference between the external temperature and the desired internal temperature (in°C).

K – Dispersion coefficient.
(Reference: http://www.mcsworld.com/how-to-calculate-the-heating-requirements,213.html)

For Determine the Attic and Basement Temperature I used the below formula:

$R_{Total} = 1/h_o + x_1/k_1 + \ldots\ldots\ldots\ldots + 1/C + x_2/k_2 + 1/h_i$

Where,

ho, hi are the outdoor and indoor air Heat Transfer Coefficient
k1, k2 are the thermal conductivity of materials
x1,x2 are the wall thickness
C is the air space Heat Transfer Coefficient

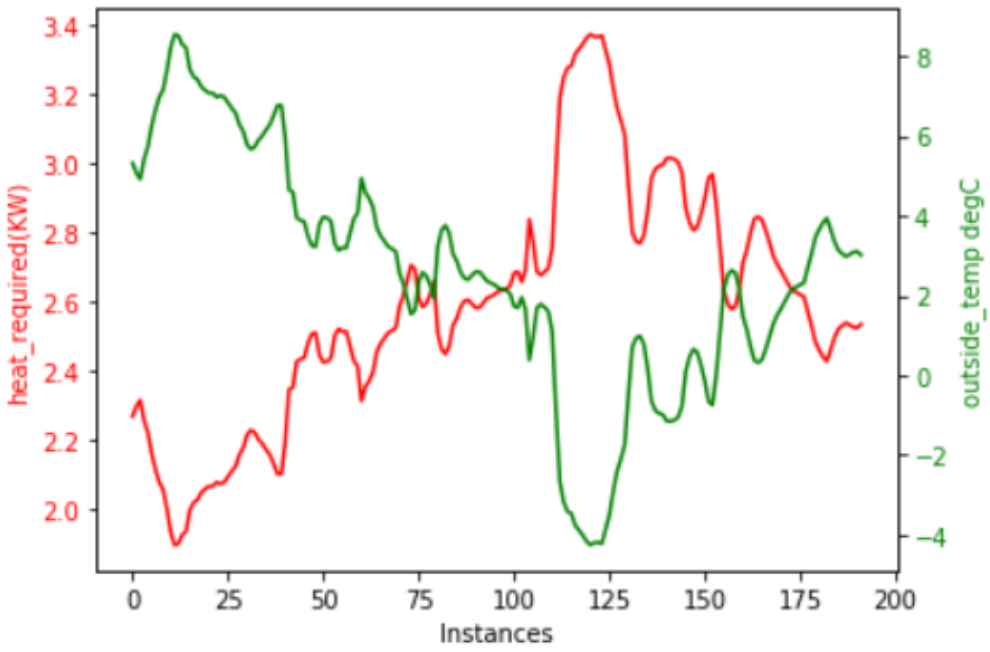
$Q/A = Delta(T)/ R_{Total}$

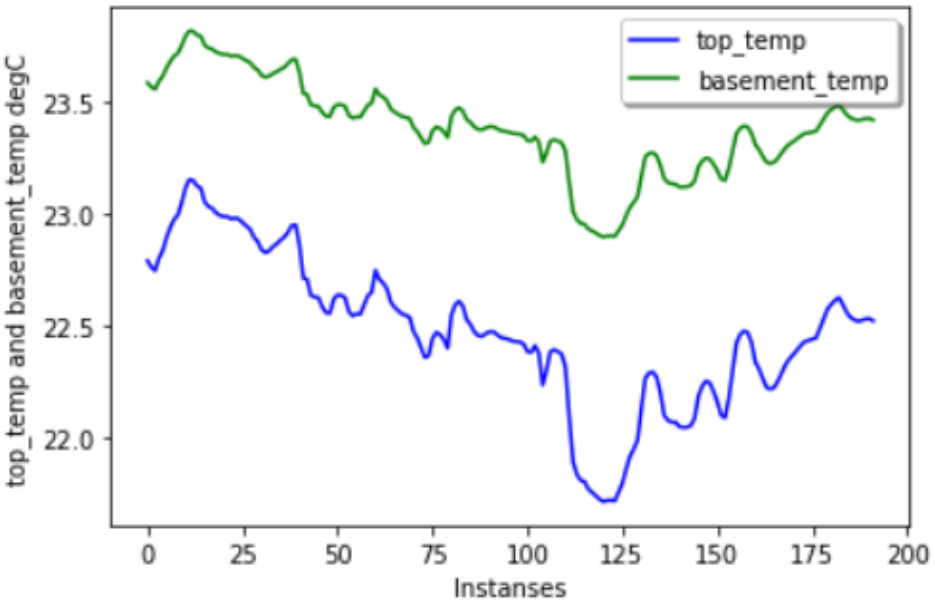
From above I have determined the Temperatures.

Generalized Model Output:

These plots are generated by using generalized model to maintain the Room Temperature at 25 deg C.

This simulation gives the variation in the Heat required to maintain the Temperature, Attic and Basement Temperature.





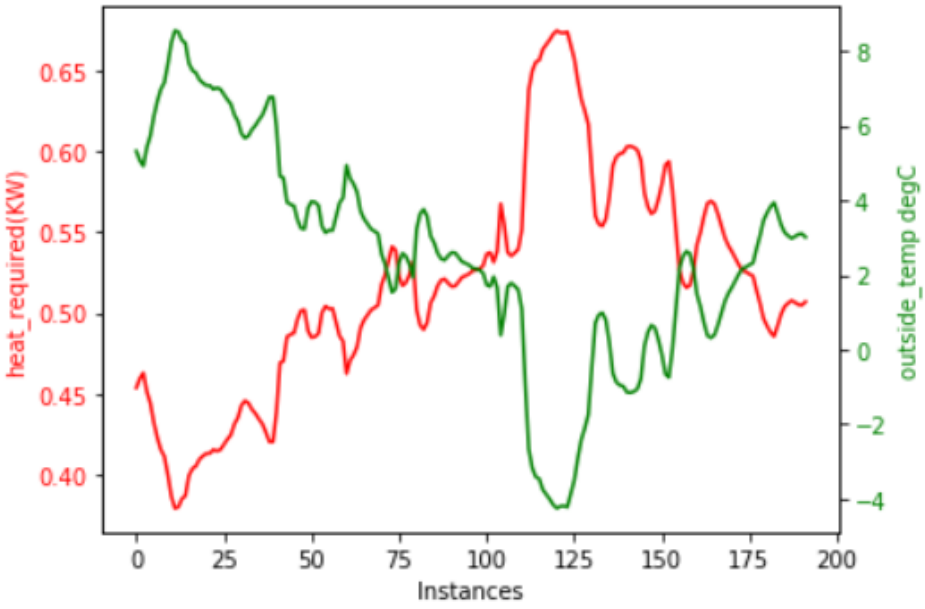
Questions, Answers and results:

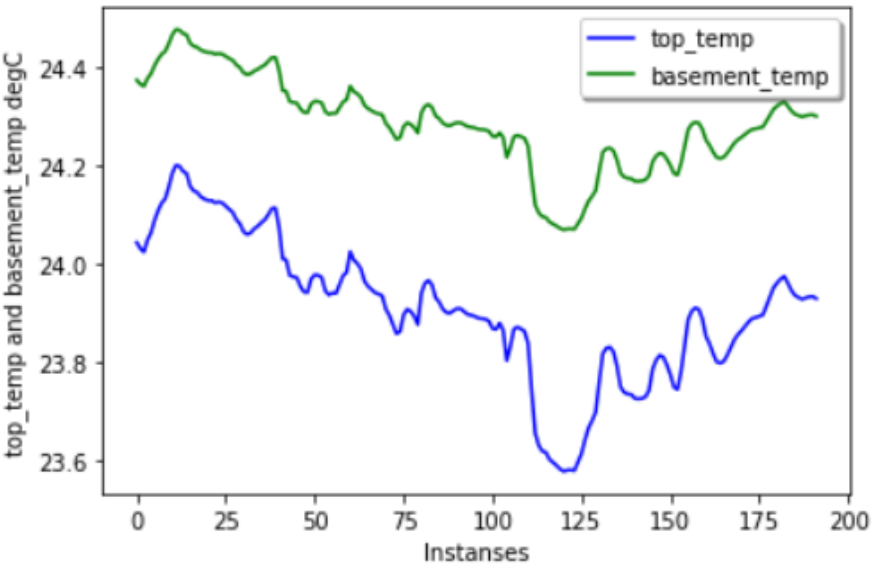
First Question/Modification in the model:

What happen if we change the material of the wall?

I used 'Double Insulated brick' instead of wooden wall for the simulation with Thermal Conductivity of 0.05 W/moC.

As we can see the Attic and Basement Temperature has been increased with decrease in Heat loss, this concludes that the heat loss rate has been decreased.

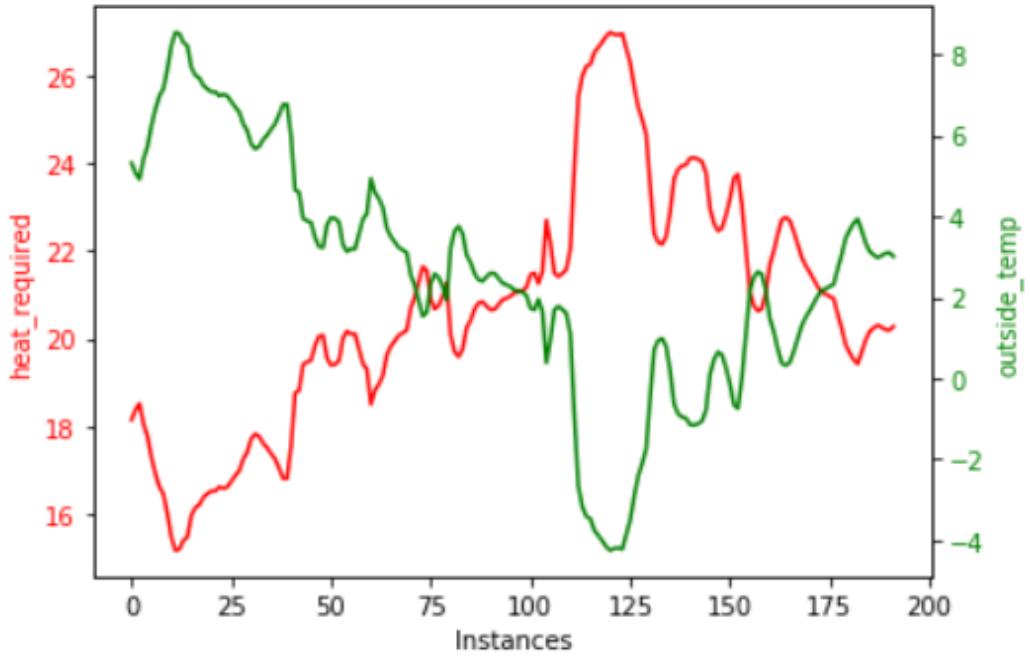


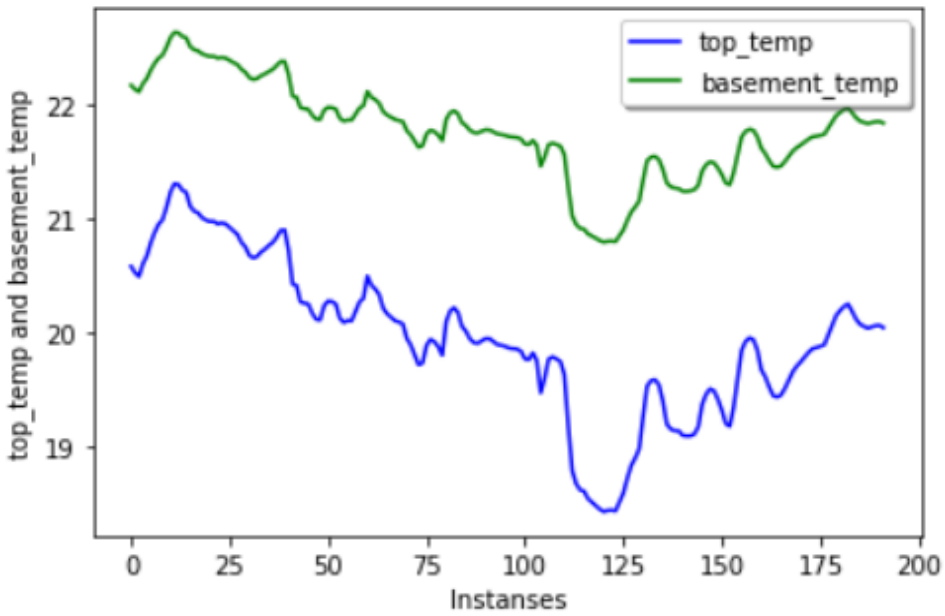


Second Question/ Modification in the model:

What happen when we change the volume of the room?

From the plots we can see that the heat requirement has been increased tremendously as we increased the room volume to 80 cubic feet from 10 cubic feet. And also there is drop in Attic and Basement Temperature.

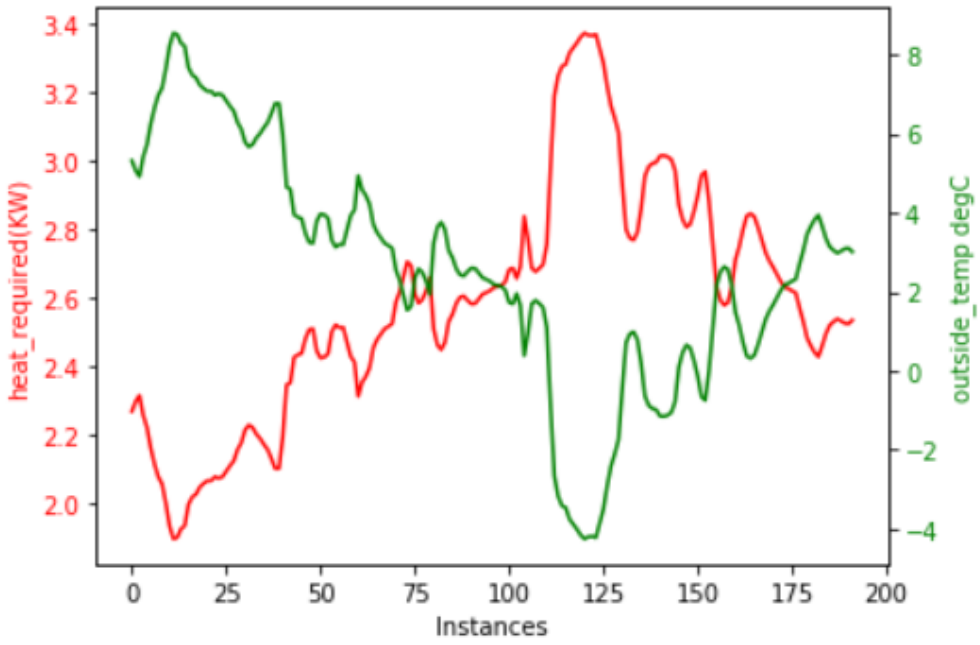


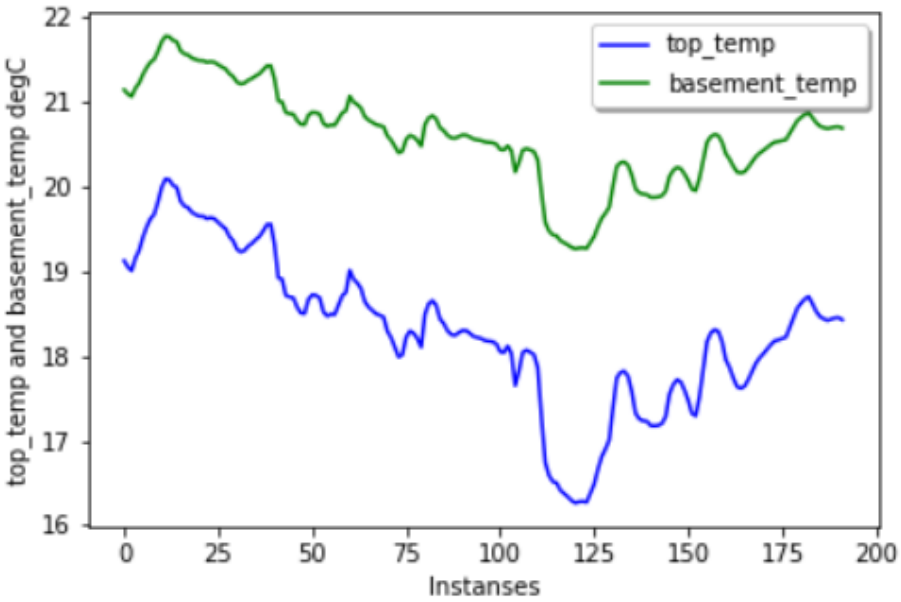


Third Question/ Modification in the model:

What happens if we change the thickness of wall?

If I triple the thickness of wall i.e. 0.45 m. I found that there is decrease in Attic and Basement Temperature; this can conclude that there is higher heat loss.

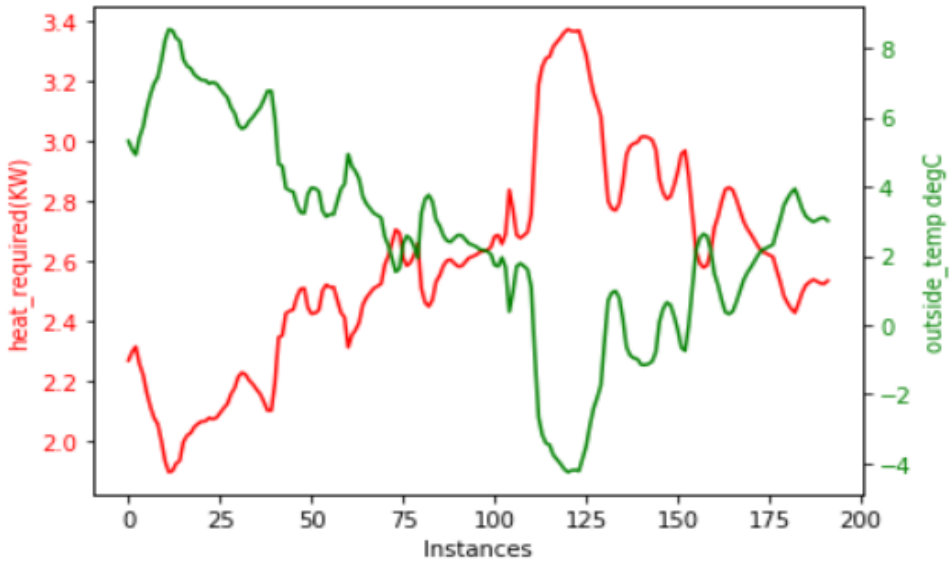


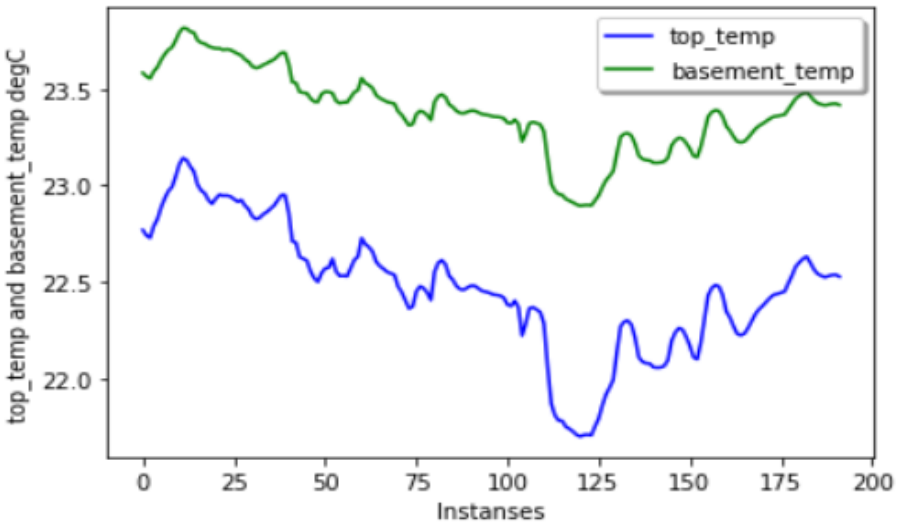


Fourth Question/ Modification in the model:

What will happen if the velocity of air increases suddenly to twice of current?

We can notice that there is drop in Attic and Basement Temperature; this can conclude that the heat loss has been increased to the surrounding.

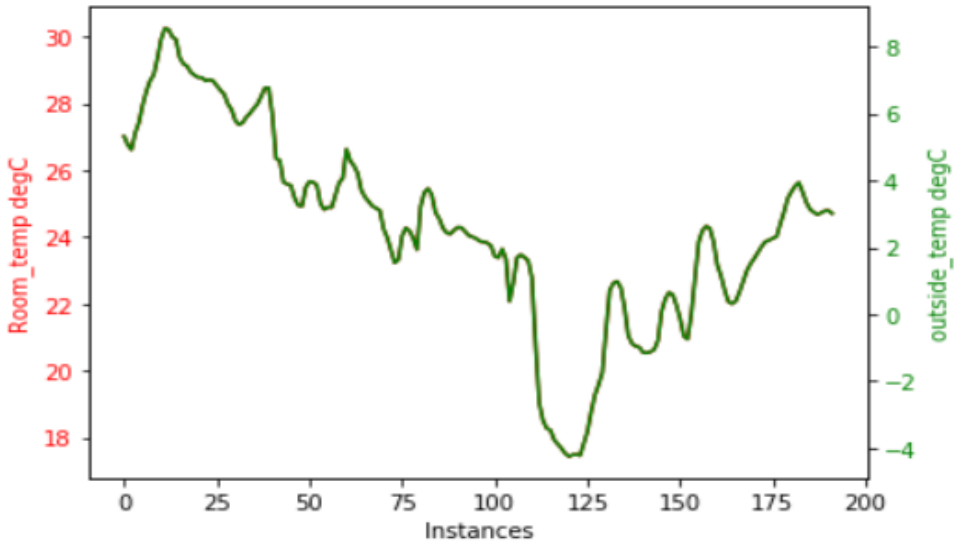


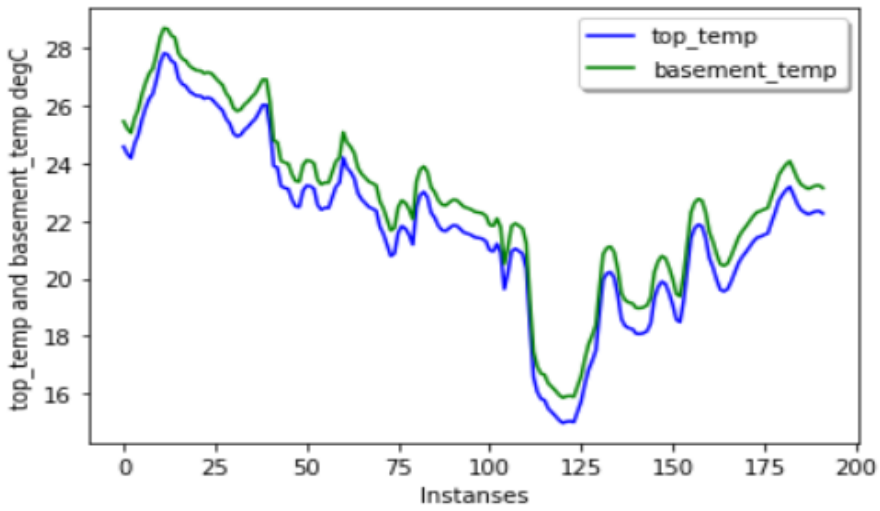


Fifth Question/ Modification in the model:

What if I provide a constant amount of heat (2.5 KW) rather than maintaining Temperature of the Room to 25 deg C?

We can see there is change in Room Temperature as surrounding Temperature is changing continuously. Also the Basement Temperature is higher than Attic Temperature.





Conclusion:

From the basic model and variations in the model, I can conclude that the best model will be the one which have minimum energy requirement and maintaining the Room Temperature at 25 deg C. Surely there will be variation in heat required to maintain the temperature of the room but if we use insulated wall then we can decrease the heat loss/energy requirement.

References:

1. http://www.mcsworld.com/how-to-calculate-the-heating-requirements,213.html
2. https://www.meteoblue.com/en/products/historyplus/download/sitka_united-states-of-america_5557293
3. https://www.researchgate.net/figure/The-convective-heat-transfer-coefficient-as-a-function-of-the-air-speed_fig12_7952030
4. **Frank P.Incopera, David P Dewitt**, Fundamentals of Heat and Mass Transfer.
5. **Github Code Link:** https://github.com/sssalam1/Home-insulation-system