Assignment 4: On/OFF Water Heater Control System

Submit by: 07-04-2021 (Wednesday) 1700 Hours

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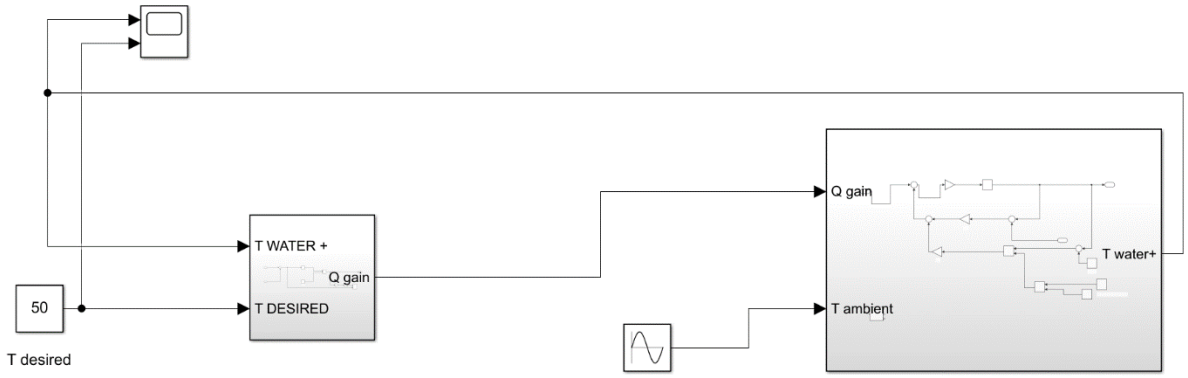
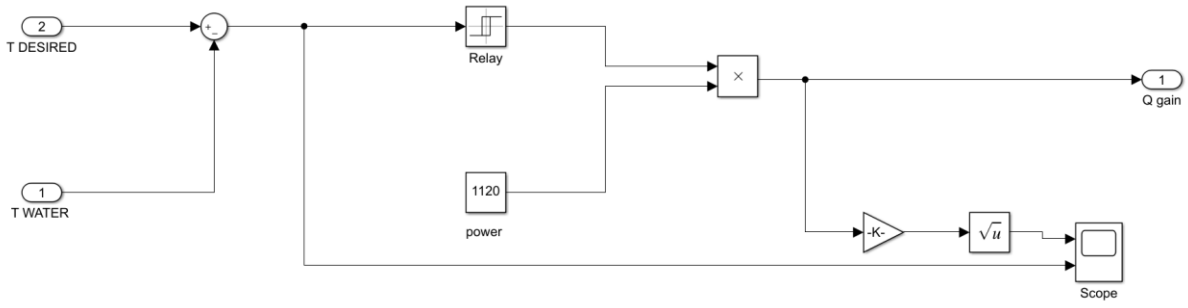
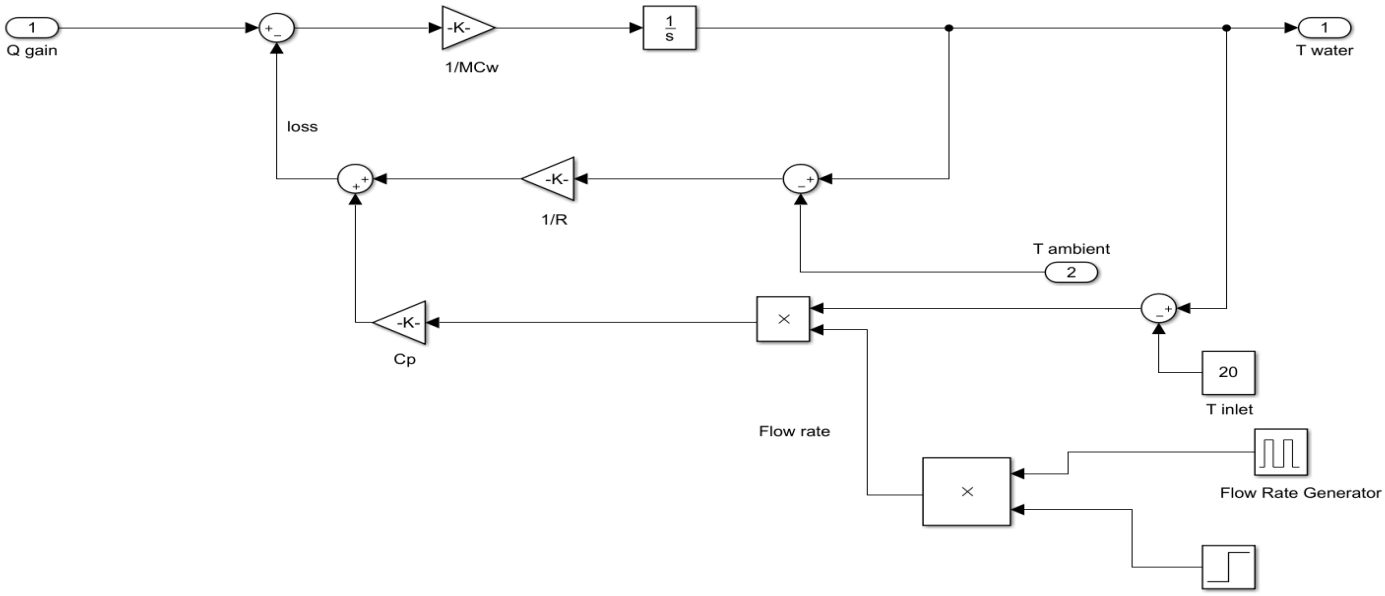
Schematic of Water Heater



On Off Controller



Schematic of Tank



1. **Setting of Scale:** The time axis of the plot is from 0 to 7200sec. (1 unit = 1000 seconds). The temperature axis of the plot is from 15°C to 55°C. (1 unit = 5°C). For current axis also the scale is 1 unit = 5A.

2. **Initial Rise Time:** defined as the time required to change from the initial temperature to reach 90% of the steady state temperature. From the figure 1, the steady state temperature is 46.63 °C and the initial temperature is at 20°C. Therefore, the change in temperature = (46.63 - 20) °C = 26.63 °C. 90% of change in temperature = 90 % of 26.63 °C = 23.9 °C. Hence, the final value of temperature up to which the rise time is calculated is (20 + 23.9) °C = 43.9 °C. Estimate the time at which water reaches this temperature from the graph.

3. **Time of start of Withdrawal Cycle:** During the initial rise time, there is no withdrawal of water. The time at which hot water is withdrawn and it is replaced by the cold water. From figure 1, the cold water enters the system at t = 2500 sec.

4. **Flow rate of Inlet of Cold Water:** For the above figure, the water enters the system at the rate of F litres/min, where 'F' is variable. The time period of the inlet of cold water is 300 seconds with a duty cycle of 60%. This means cold water will enter the system for 180 sec and will remain close for 120 sec and this cycle will repeat for every 300 sec. (starting from t=2500 sec for figure 1)

5. **Computing Heat Gain and Heat Loss in 1 cycle time of 300 seconds:**
    - **In Transient State:** In first 180 sec, water is withdrawn at F litres/min, where 'F' is variable and is replaced with same amount of water at 20°C. The temperature of water in geyser falls to T_{ft} (i.e., final temperature of water in transient state) and the overall fall in temperature is T_{fall}. From this, the loss of heat can be calculated. As the temperature falls a drive current, 'I' is supplied by the controller. This I^2Rt

will supply the heat to water to again increase its temperature. Compute T_{ft} from the equations and hence, calculate heat gain and heat loss.

- **In Steady State:** Again, find the temperature of water in steady state i.e., T_{fs} and verify it by the simulation results.

6. **Peak-to-Peak Ripple:** In the steady state, there is continuous variation in temperature. This is called ripple. From the above figure, the maximum value of ripple is 47.43 °C and minimum value of ripple is 45.83 °C. Therefore, peak-to-peak ripple temperature is (47.43 – 45.83) °C = 1.6 °C.

7. **Steady state Temperature or Mean value of temperature:** defined as the average value of the maximum value and minimum value of the ripple. From the above figure, mean value of temperature is the (47.43 + 45.83)/2 = 46.63 °C.

8. **Ripple Period:** The time difference between the two consecutive maximum values or two consecutive minimum value of the ripples is called the ripple time period. For the above figure, the ripple period is equal to 300 sec.

9. **Offset Error in temperature:** defined as the difference between the desired temperature and steady state temperature. From the above graph the desired temperature is 50°C and the steady state temperature is 46.63 °C. Hence, the offset temperature is equal to (50 - 46.63) °C = 3.37 °C.

10. **Mean current:** Calculate Mean Current from the current graph.

Volume of water in tank	20 L ($M_w \approx 20$ kg)
Resistance of heater coil	17.5 Ω
Power of Heater	$I^2 * 17.5$
Specific heat of water	4200 J/kg ℃
Ambient Temperature (T_{amb})	25 ℃ ± 10 sin(0.00005t)
Temperature of Water	T_w (variable)
Flow Rate	1L/min
Flow Rate Time Period	3 min
Duty Cycle	60 %
1/ R (where R is Thermal Resistance of Insulator)	0.219 W/ ℃

(This is just a sample graph)

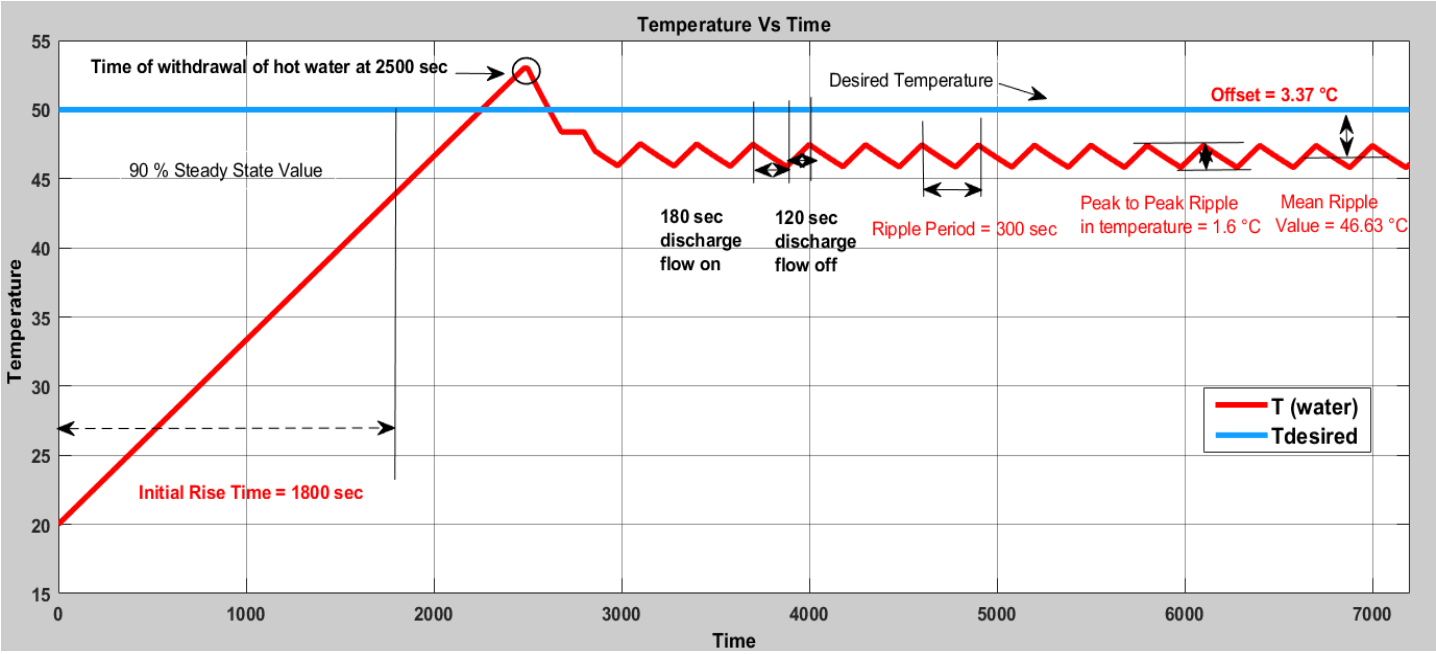


Fig 1: Temperature v/s Time Plot

(This is just a sample graph)

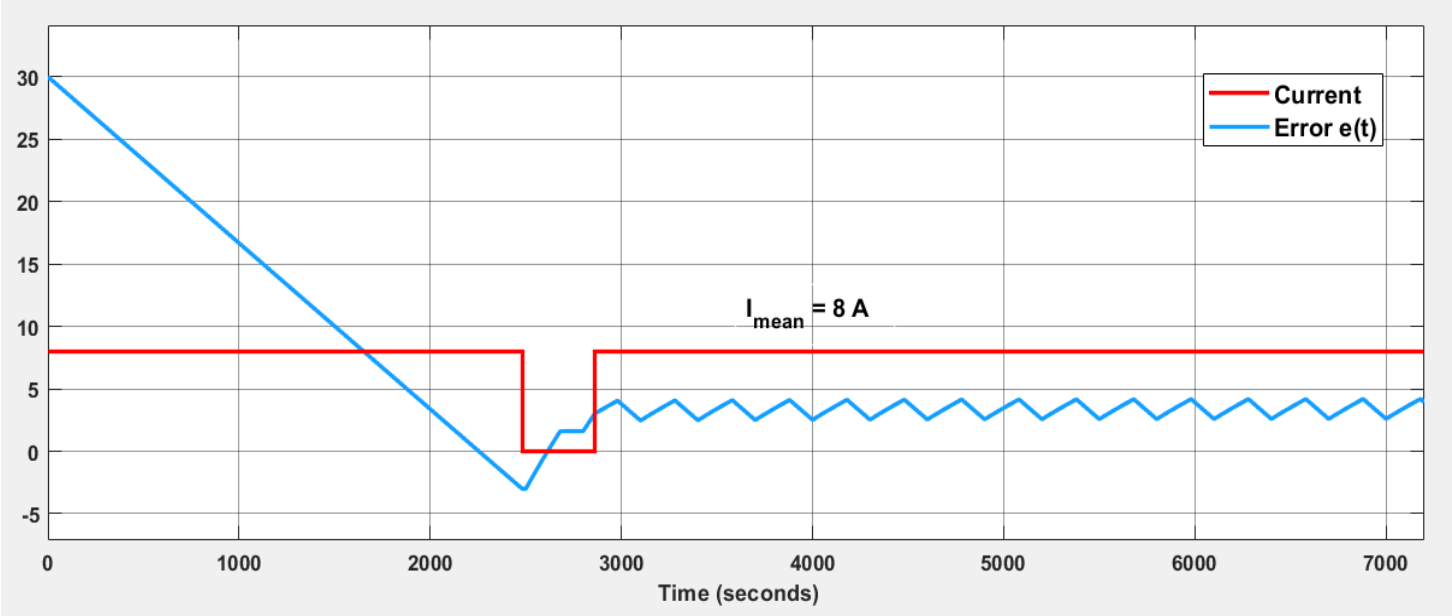


Fig 2: Current and error v/s Time Plot

Assignment Problem:

1. Make a water heater model which has an ON-OFF controller in which the desired temperature of water is 50℃. The time of withdrawal of hot water is 2500sec and at the same time cold water enters the geyser. The temperature of cold water is 20℃. The flow rate of inlet water is f = 1 litre/min and 60% duty cycle with the time period of 300 sec. Take the inlet temperature of water at 20℃.

   ON-OFF Controller with input current as 8A (set the relay cut off at 3℃ above and below the desired temperature of water i.e., the relay is turned on when the temperature of water falls to (50 – 3) = 47℃ and turns off when the temperature rises to (50 + 3) = 53 ℃.

2. Plot vs time the following graphs (keep the simulation time for 7200 seconds.
   Part b) and c) are to be plotted in the same graph with different colours. Use dash line if there is overlapping of two parameters. You can refer the figure 2 for better clarity. Keep the scale of time axis as mentioned and paste all the graphs of a particular case in one page.

   a) Water of Temperature (Tw) (take the temperature axis from 15 ℃ to 55℃)
   b) Error, e(t)
   c) Current

3. Calculate the following parameters from the temperature vs time plot:
   a) Initial rise time
   b) Heat gain and heat loss in 1 cycle of flow of 300 sec.
      1. in transient state
      2. In steady state
   c) Peak-to-peak ripple of temperature in steady state
   d) Steady state temperature
   e) Offset error in temperature
   f) Ripple period

4. Calculate the Mean current from the current vs time plot.

Repeat all the above steps for 4 cases:
I = 8 A, 10 A, 12 A, 15 A

Compare the above results (3 (a to f) and 4) for the 4 cases in a tabular form and explain your observations.