AVINASH SAROJ
JID202552
8127723776

Assignment 5
Water Heater Model Analysis

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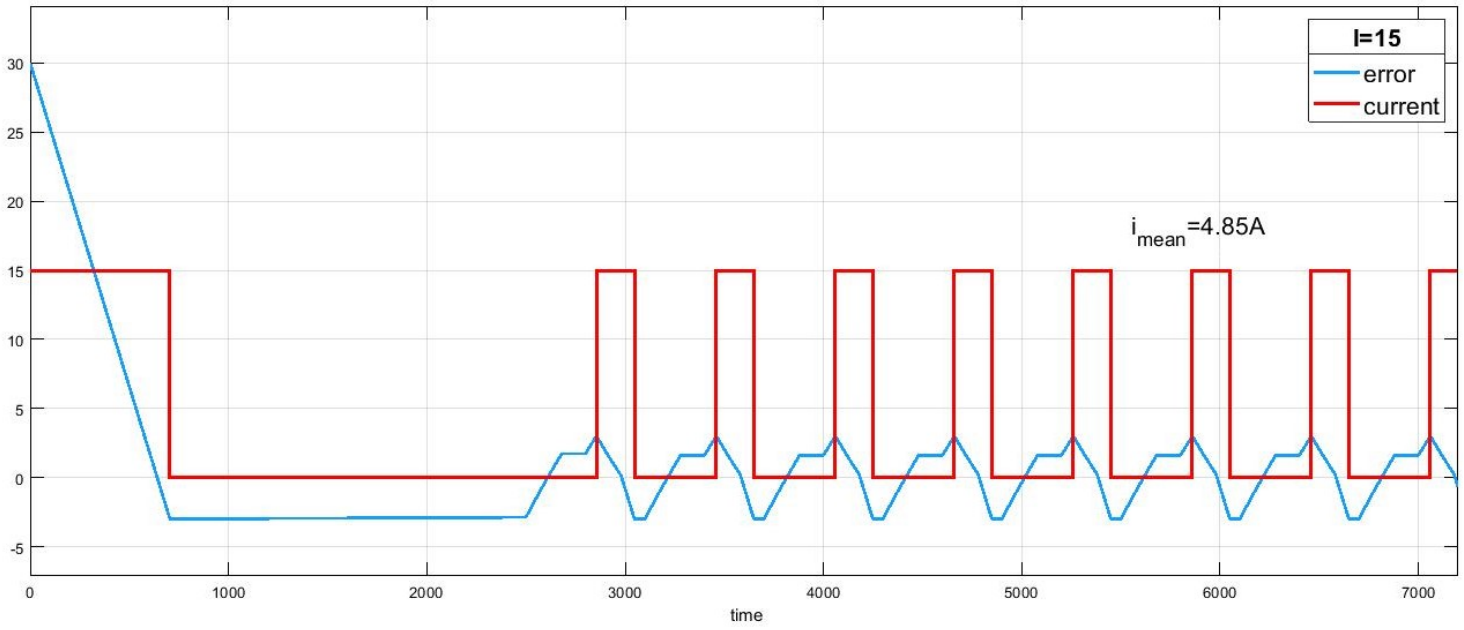
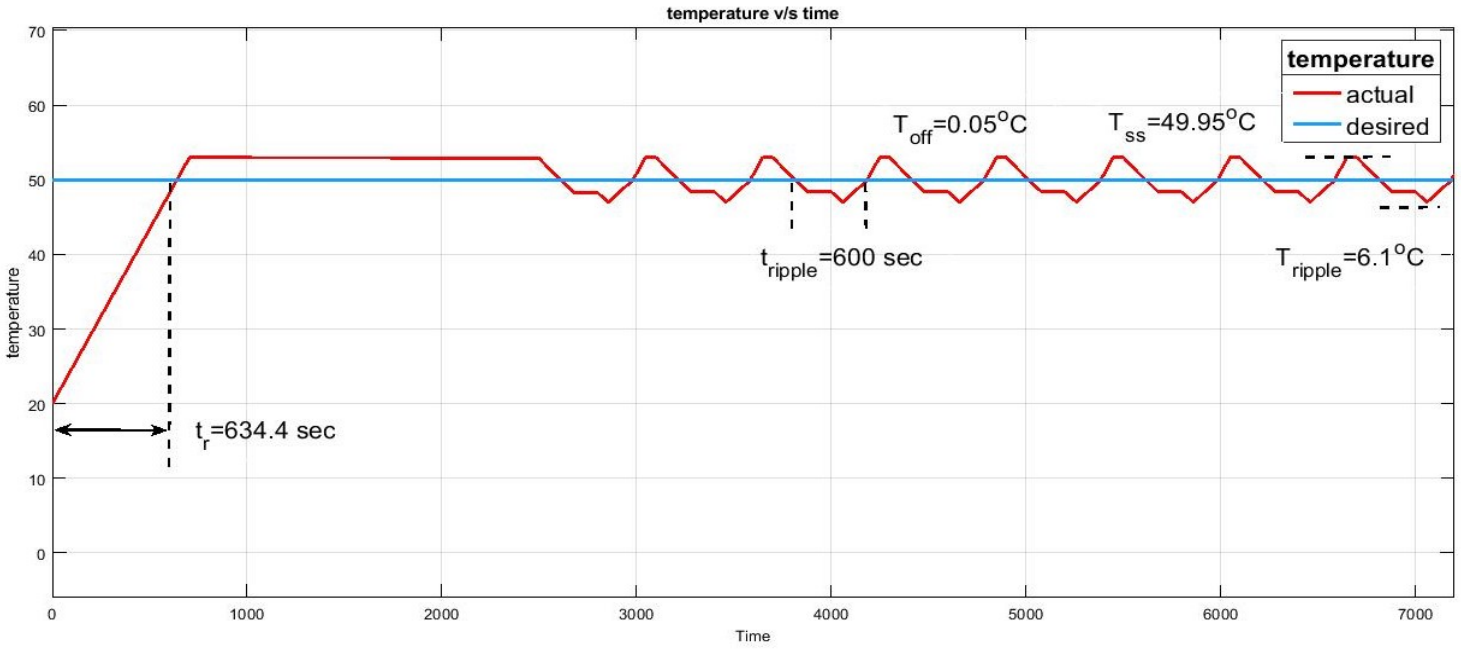
1 On Off Control

1.1 $I_l = 15A$



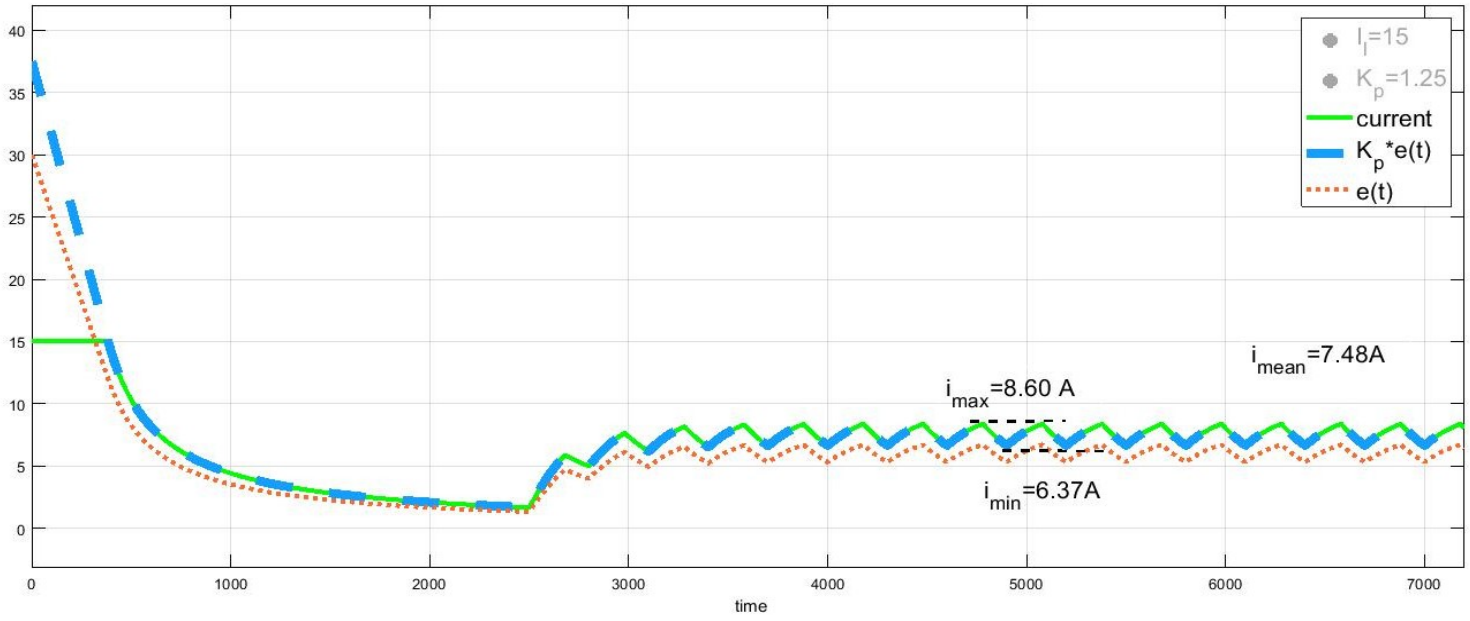
(a) current v/s time



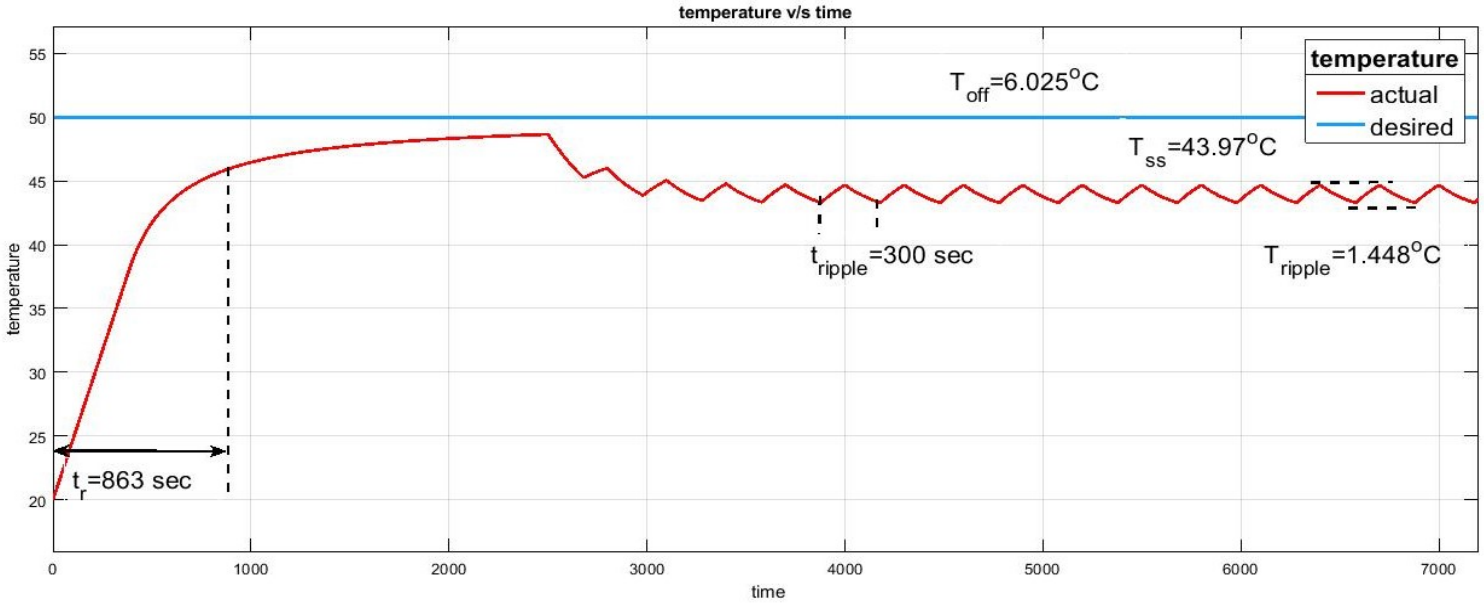
(b) temperature v/s time

2 Proportional Control

2.1 $I_l = 15A, K_p = 1.25$



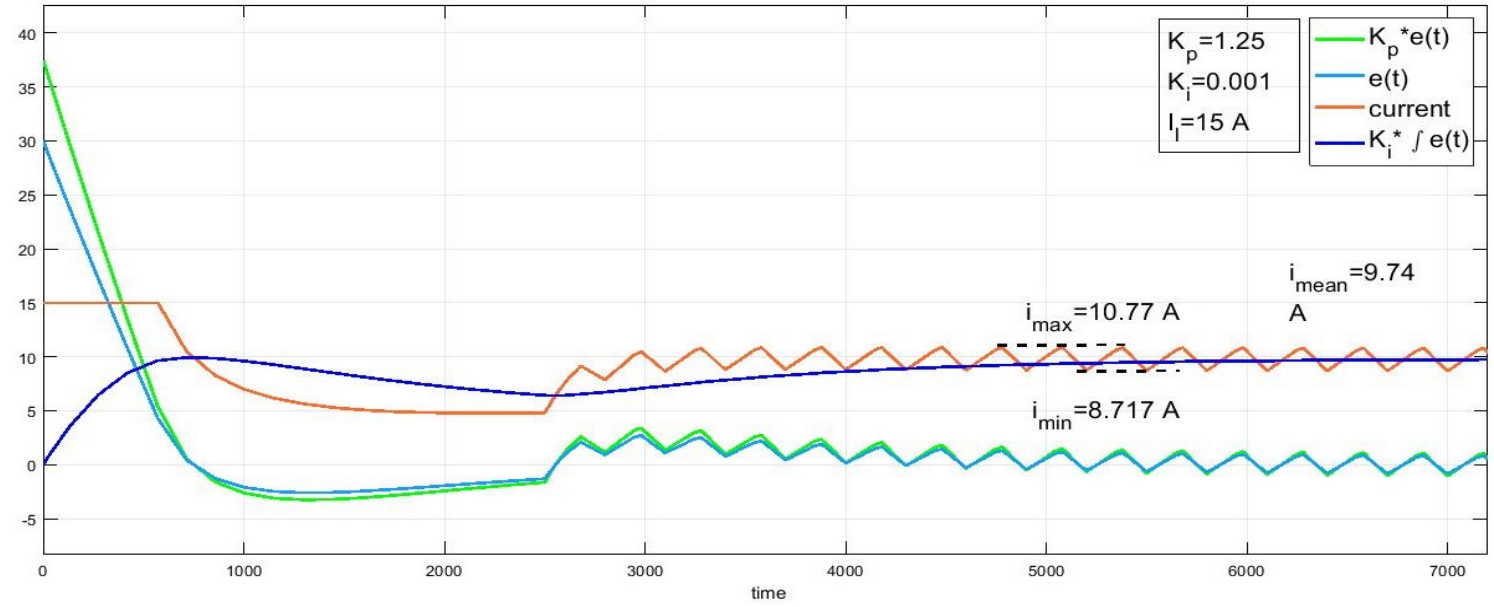
(a) current v/s time



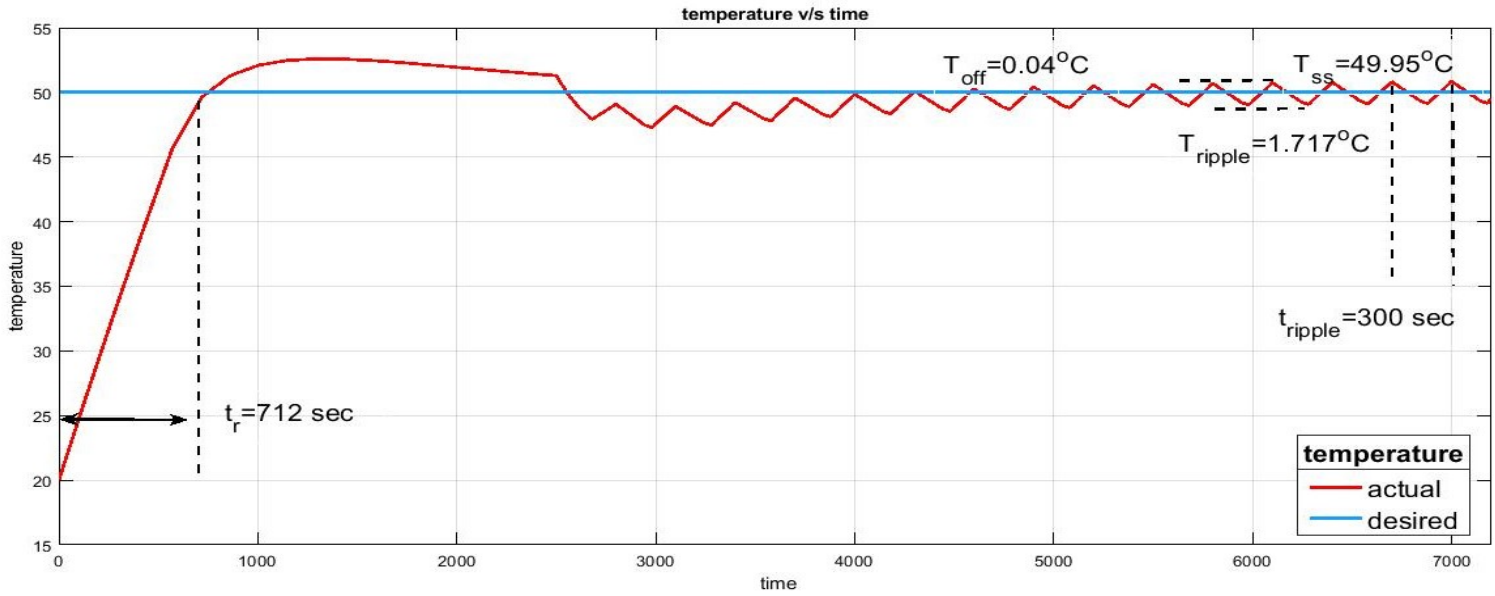
(b) temperature v/s time

3 Proportional Integral Control

3.1 $I_l = 15A$, $K_p = 1.25, K_i = 0.001$



(a) current v/s time



(b) temperature v/s time

4 Analysis

4.1 $I_{limiting} = 15A, K_p = 1.25, K_i = 0.001$

Controller	I_{mean}	t_{rise}	t_{ripple}	T_{ss}	T_{off}	T_{ripple}
On Off	$4.85s$	634.4 ms	600 ms	49.95^oC	0.05^oC	6.1^oC
Proportional	$7.48s$	863 ms	300 ms	43.97^oC	6.025^oC	1.448^oC
PI	$9.7s$	712 ms	300 ms	49.95^oC	0.04^oC	1.717^oC

Table 1: Data for all three graphs[1]

4.2 Parameter wise comparison

4.2.1 I_{mean}

The average current for the ON Off controller is minimum because the relay puts off the current as the desired state is reached,

$$I(t)\ \alpha\ e(t)$$

while the average current in the PI controller is high because the current is never in OFF state , it's just the magnitude that varies due to the current limiter.

4.2.2 $\mathbf{t}_{rise}$

In On Off controller the rise time is minimum because the relay puts off the current only when the desired is reached and till then maximum current is supplied to the system and hence less rise time , since

$$heat = I^2Rt$$

In proportional controller the rise time is maximum because,

$$I(t) = K_p * e(t)$$

and hence as the desired state is reached the value of current decreases drastically and consequently the rise time increases.
The rise time is average in PI controller because the current traces the error because of the integral action.

4.2.3 $\mathbf{t}_{ripple}$

In On Off controller the ripple time is maximum because of the mechanical switching of the relay , sufficient time is consumed in the switching and rise and fall of the current.
Ripple time traces the input and output cycle of the water due to proportional and integral controller and hence the current is never zero and hence the average time.

4.2.4 $\mathbf{T}_{ss}$

Average steady state temperature of the system with proportional controller is far from desired because it amplifies the steady state error of the system.
Average steady state value for the on of controller is close to desired because of the fact that the ripple in the temperature is high (see table1) and hence the average comes out to be close to the desired value.
Average steady state value for the PI controller is close to the desired value because the Integral controller reduces the steady state error of the system.

4.2.5 $\mathbf{T}_{off}$

Since the steady state value for the proportional controller is low hence the offset for the proportional controller is high and that for the on off and the PI controller is low , since

$$T_{off} = T_{desired} - T_{ss}$$

4.2.6 $\mathbf{T}_{ripple}$

Ripple in the temperature is high because the tolerance limit for the relay is set at 3 that is,

$$upperlimit = T_{desired} + 3^oC$$

$$lowerlimit = T_{desired} - 3^oC$$

Ripple is low in the PI controller because the Integral action reduces the steady state error.
In case of the proportional controller the ripple is low because the output closely follows the input changes.