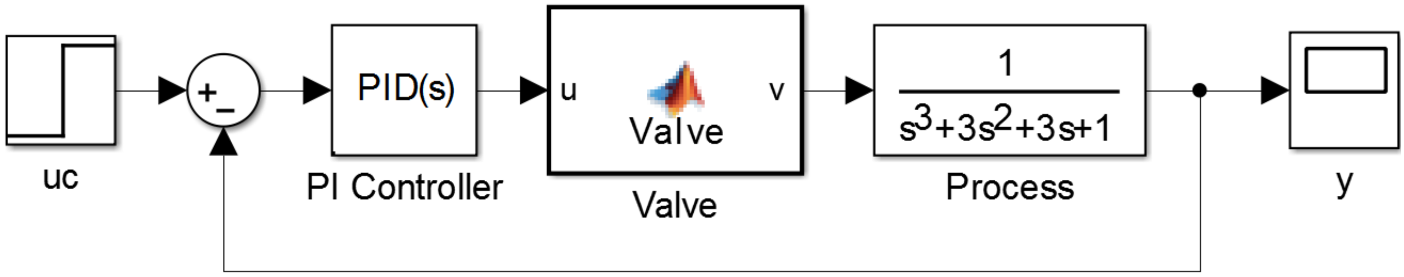
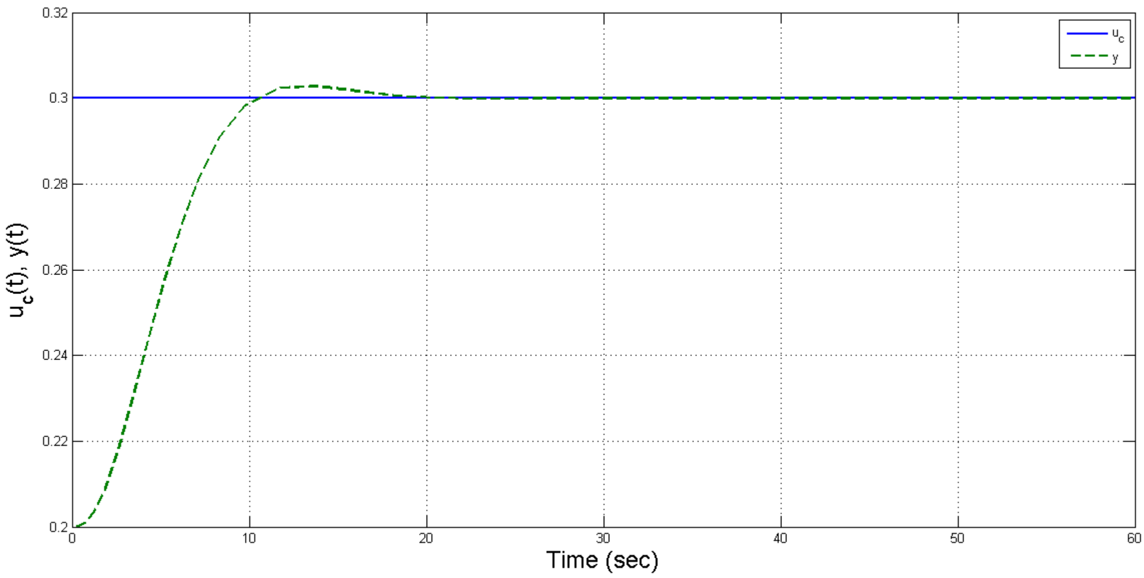
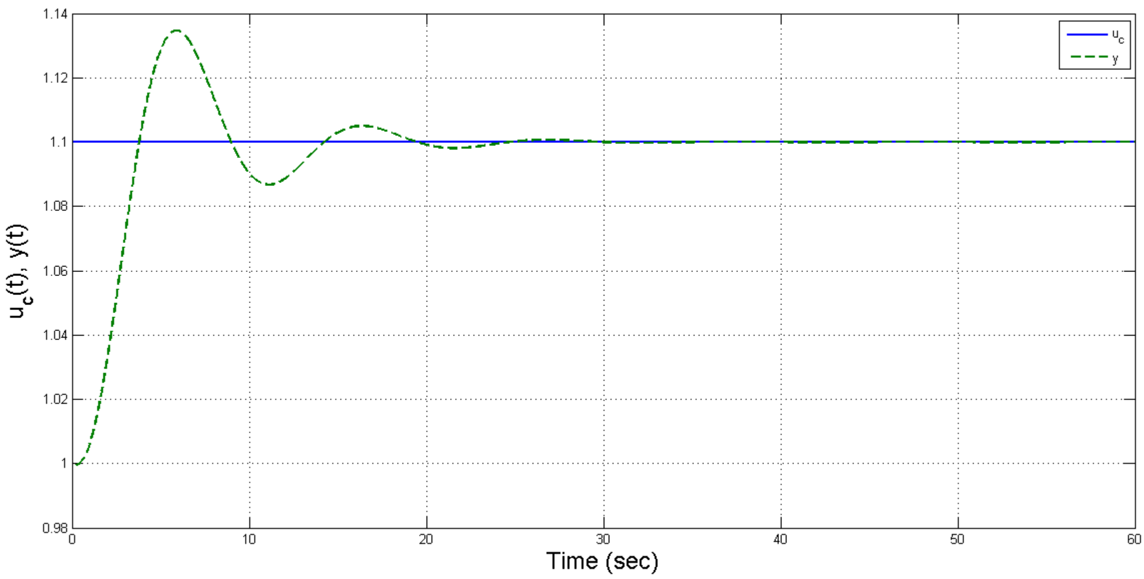
Non-linear Valve:

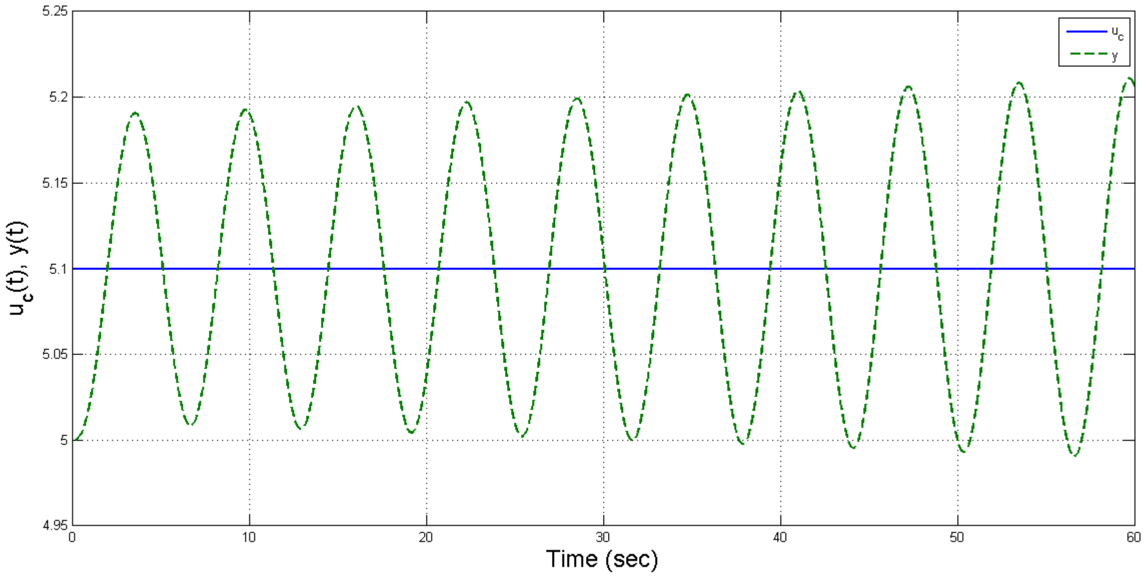
The figure below slows a process $\left(G(s) = \frac{1}{(s+1)^3}\right)$ with non-linear valve $v = f(u) = u^4$, controlled by PI controller $G_c(s) = k\left(1 + \frac{1}{T_i s}\right)$



if $k = 0.15$, $T_i = 1$ we get the following results

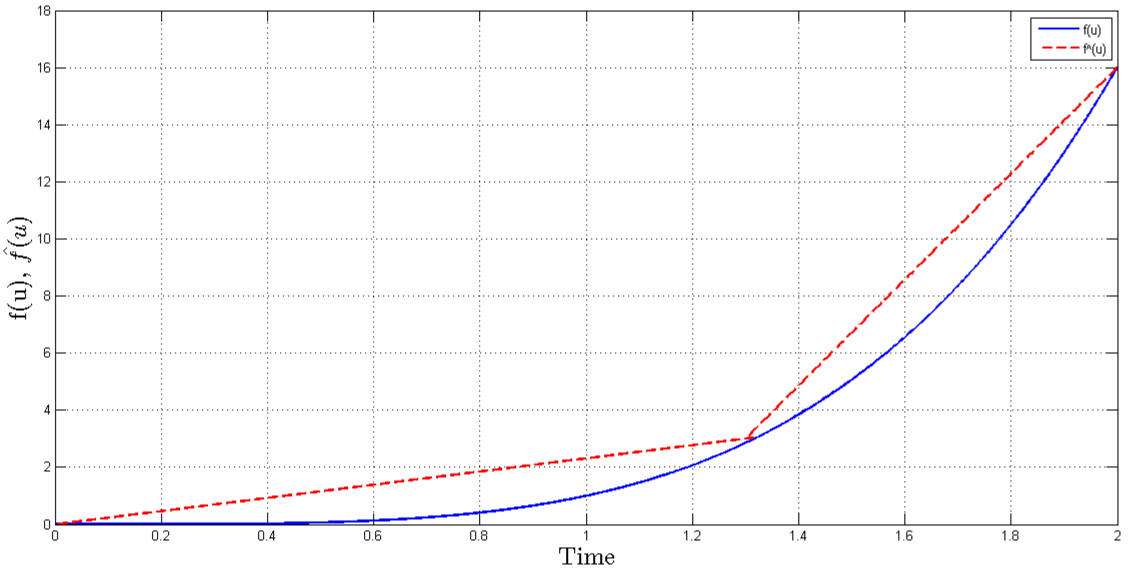






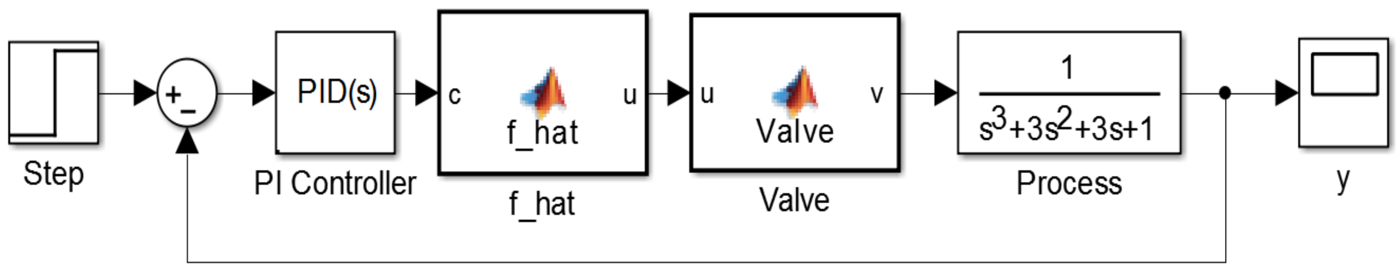
Valve Approximation:

Because of non-linearity of the valve, so we split the valve characteristic line to two regions as shown,

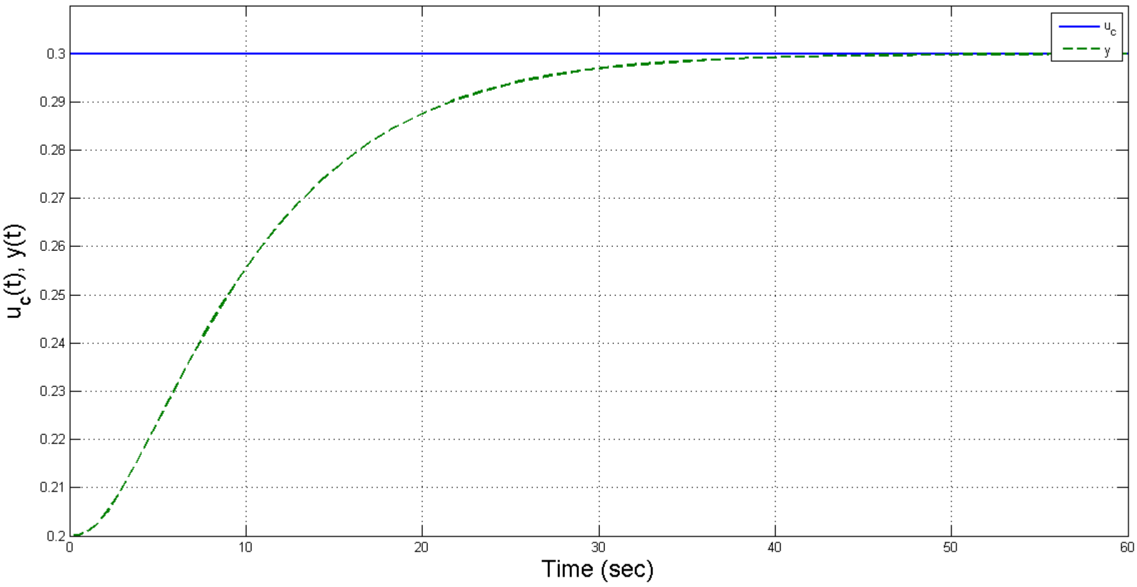


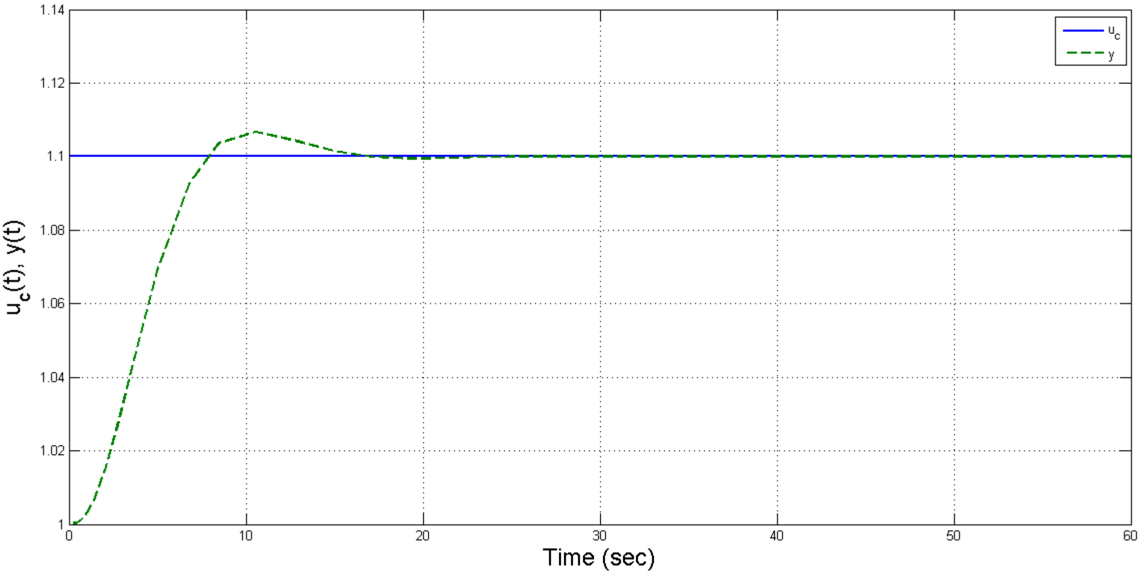
as $\hat{f}^{-}1(c) = \begin{cases} 0.433\ c & 0 \leq c \leq 3 \\ 0.0538\ c + 1.139 & 3 \leq c \leq 16 \end{cases}$

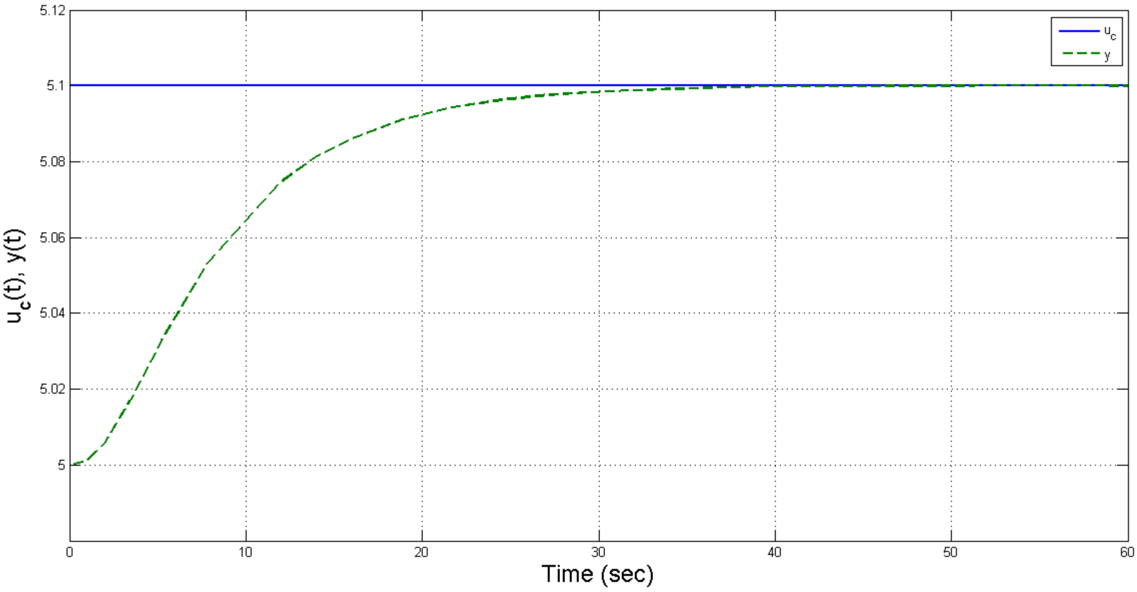
Finally we get,



For the same values of k and T_i and same inputs we get,





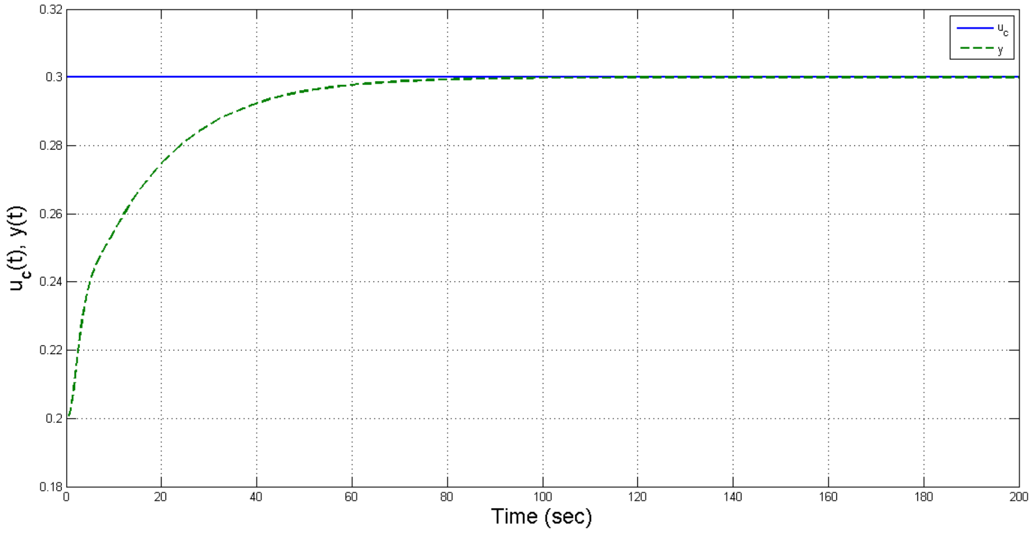


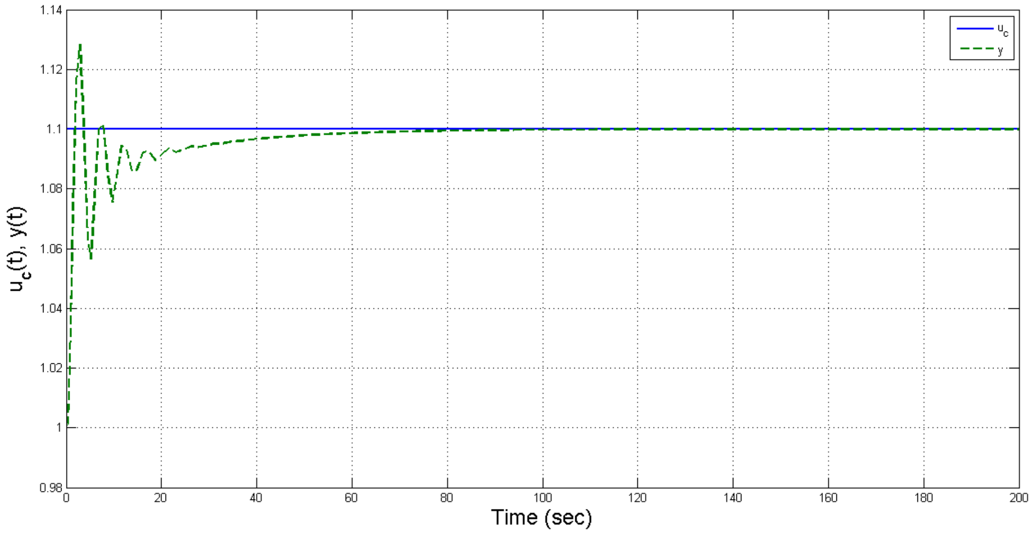
Controller Gain Change:

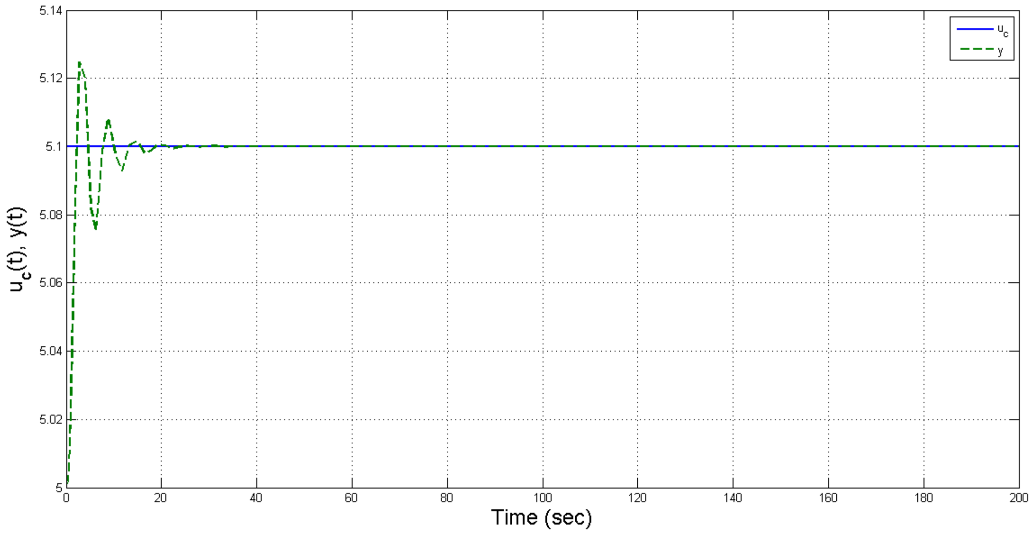
Another solution of the problem is to change the controller parameter as I choose,

$$T_i = 0.05 \;, \qquad k = \begin{cases} u_c & if\ u_c \leq 1 \\ \frac{1}{u_c} & if\ u_c \geq 1 \end{cases}$$

For the same inputs we get,







Controller Parameter Change:

Another solution of the problem is to change the controller parameter as I choose,

$$T_i = \begin{cases} 0.05 & if\ u_c < 1 \\ \frac{1}{4u_c} & if\ u_c \geq 1 \end{cases}, \qquad k = \begin{cases} u_c & if\ u_c \leq 1 \\ \frac{1}{u_c} & if\ u_c \geq 1 \end{cases}$$

For the same inputs we get,