MPC Project Report

Yuliang Zhong

May 2021

1 Question 1-5

Check solutions to task 1-4 in **compute_controller_base_parameters.m**. The figure 1 shows the open loop sim without control (Task 5). We can see that the T_{vc} decreases and breaks constraints after 35 minutes. T_{F1} and T_{F2} increase and break constraints after 8, and 15 minutes, respectively.

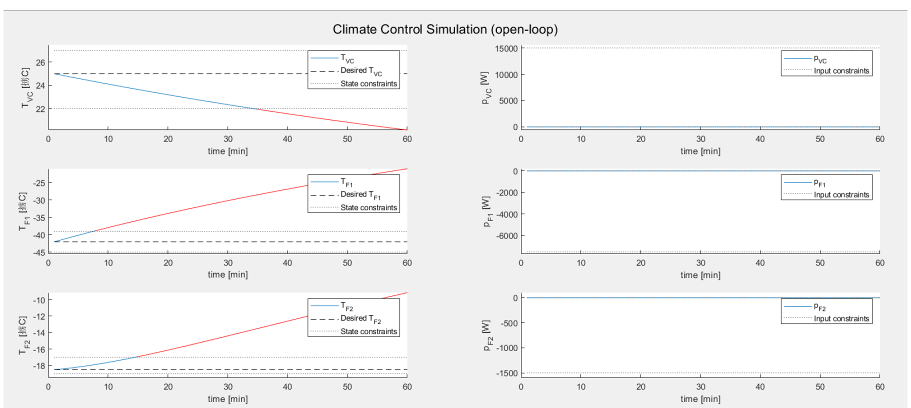

Figure 1: Open loop sim without control

2 Question 6

Check solutions to task 6 in **heuristic_LQR_tuning.m**. The figure 2 shows the tuning results. We can see that only three Q violate state constraints. Most Q's that violate input constraints form a blue lower bound in the figure. To satisfy energy constraint and decrease deviation, we choose that:

$$Q = diag[4973679, 5427908, 4949349]$$

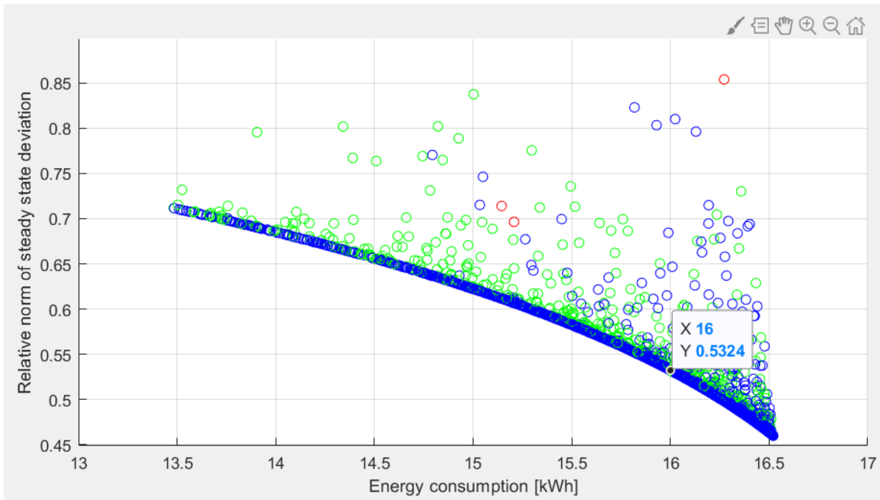

Figure 2: heuristic LQR tuning

3 Question 7-8

The blue line in the figure 3 shows the closed-loop simulation plot of the system under LQR controller,starting from initial state T_{01}, with best Q mentioned above. The red line is the performance of anther Q. By change of Q, the time cost to equilibrium increases.

Figure 4 shows the closed-loop simulation plot of the system under LQR controller, starting from initial state T_{02}. The state constraint of T_{F2} is violated from 4 to 12 minutes.

4 Question 9

Figure 5 and 6 show the feasible set X of the MPC problem. All closed loop control trajectories start from X do not violate state and input constraints. Figure 6 shows the position of T_{01} and T_{02} with respect to X.

5 Question 10

The infinite horizon cost under the LQR control law should be $J^{\infty}_{LQR}(x(0)) = x(0)^T * P_{\infty} * x(0)$, where P_{∞} is the positive definite solution of Discrete Algebraic Riccati Equation.

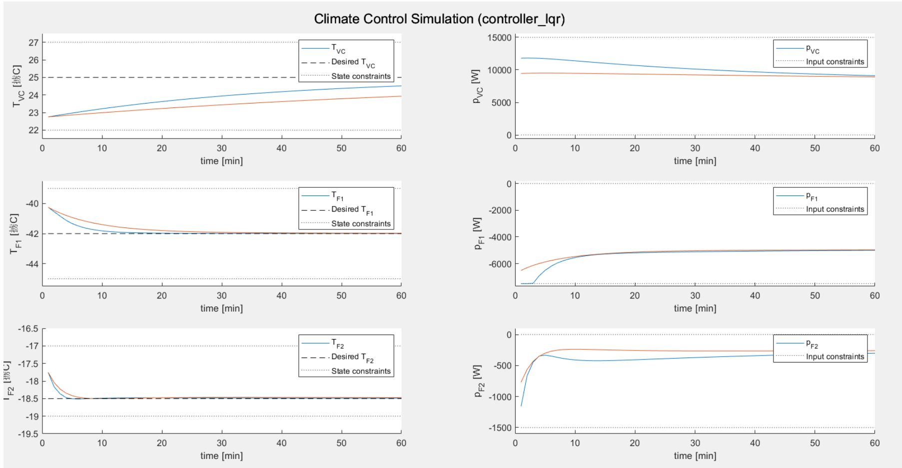

Figure 3: LQR controller, T01 (different Q)

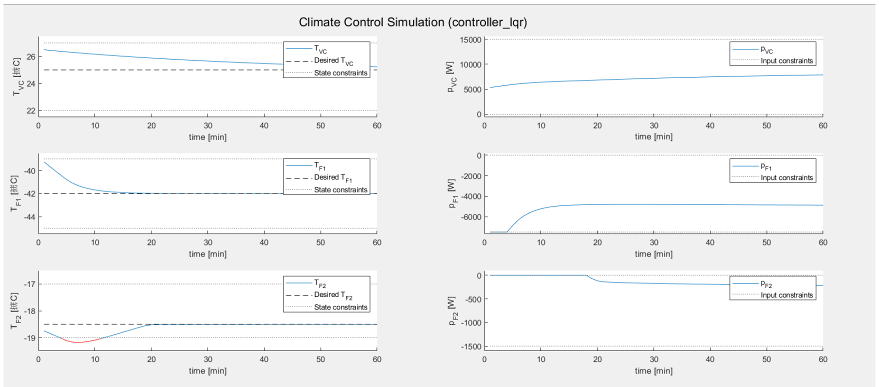

Figure 4: LQR controller, T02 (different Q)

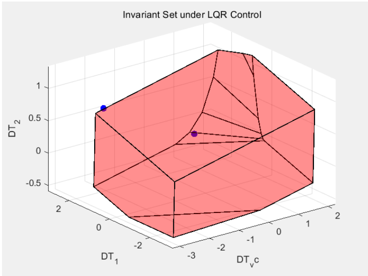

Figure 5: feasible set

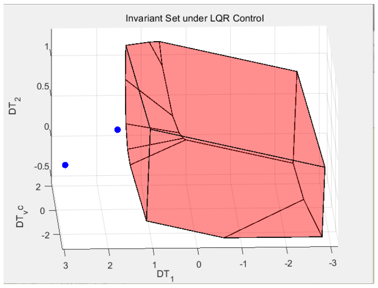

Figure 6: feasible set (anther view)

6 Question 11

Figure 7 shows the closed loop trajectory under MPC controller. The blue line starts from initial state T_{01} and the red line starts from initial state T_{02}. The main difference from task 7/8 is the state constraint of T_{F2} is not violated anymore.

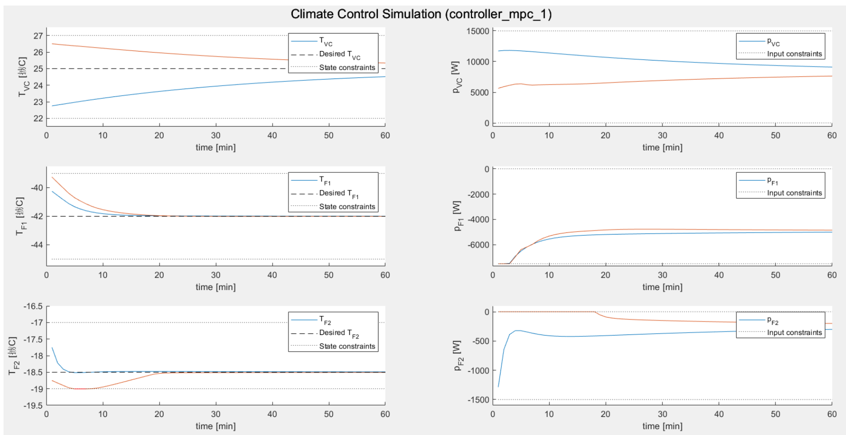

Figure 7: MPC controller, T01 (blue), T02 (red)

7 Question 12-13

TODO: Why is the origin an asymptotically stable equilibrium point for the resulting closed-loop system, given that (8) is feasible for x(0)?
Proof:

Figure 8 shows the closed loop trajectory under MPC controller, with $x_N = 0$. The blue line starts from initial state T_{01} and the red line starts from initial state T_{02}.

8 Question 14

Figure 9 shows the closed loop trajectory under MPC controller, with $x_N \in X$, where X is computed in task 9. The blue line starts from initial state T_{01} and the red line starts from initial state T_{02}.

9 Question 15

The optimization costs J_{MPC} for three MPC controllers on initial state T_{01} and T_{02}.

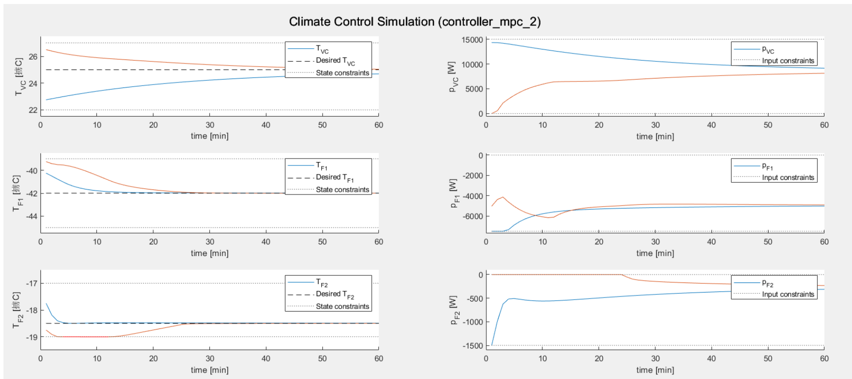

Figure 8: MPC controller, origin terminal, T01 (blue), T02 (red)

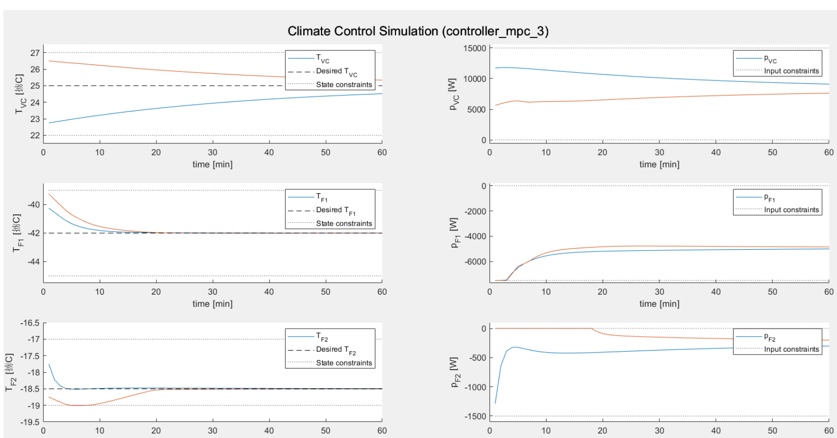

Figure 9: MPC controller, T01 (blue), T02 (red)

10 Conclusion

"I always thought something was fundamentally wrong with the universe" [1]

References

[1] D. Adams. *The Hitchhiker's Guide to the Galaxy*. San Val, 1995.