CONSUMPTION ANALYSIS

ENGLISH

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SCA CONTROL - Control systems for your processes

1 Introduction

In this report, we make a comparison between the AC and the PID controller in terms of consumption. By consumption, we refer to the energy of the control action signal, namely the signal energy E of the control action $u(t)$ over the period from t_1 to t_2 is:

$$E = \int_{t_1}^{t_2} u(t)^2 dt \tag{1}$$

Clearly, in practice, what we need is the electric energy consumption, but it depends on the specific process to control. However, it is strictly related to the control action energy, often with a proportional relationship[1]. Therefore, the study of the control action energy provides meaningful indications regarding the actual energy consumption.

2 Experimental setup

The experiments are performed in a simulated environment with ideal conditions (no noise, perfectly known parameters, etc.). Given a particular process structure, both AC and PID controllers are designed for a specific combination of specifications (α, β...). See "*preliminaries*" document for the explanation of such parameters. To measure the consumption, a step reference is applied and (1) is used on the control action, taking the settling time as the integration interval. For AC and PID controller respectively, we obtain E_{AC} and E_{PID}. Now let us define the ratio between E_{PID} and E_{AC}:

$$E_r := E_{PID}/E_{AC} \tag{2}$$

Therefore $E_r > 1$ means that the AC controller generates a control action with less energy consumption. The test is then repeated for other values of specifications and all the outcomes are plotted in a graph. All this is repeated with different process structures[2].

2.1 1p-processes

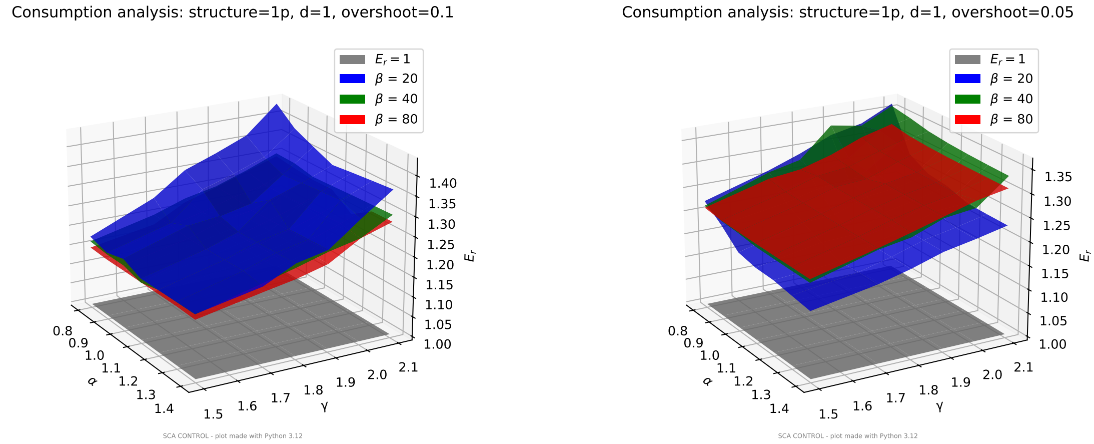
In Fig. 1, we plot the values of E_r for the 1p-process case. As one can observe, E_r slightly increases as α decreases and γ increases. There is not a clear dependence on β and overshoot requirement. Moreover, for every combination of specifications, E_r is greater than one, namely, the AC controller always provides a control action with lower energy consumption.

2.2 1p1z-processes

In Fig. 2, we plot the values of E_r for the 1p1z-process case. The results are similar to the 1p-process case. In particular, E_r slightly increases as α decreases and γ increases. There is not a clear dependence on β and overshoot requirement. Moreover, for every combination of specifications, E_r is greater than one, namely the AC controller always provides a control action with lower energy consumption.

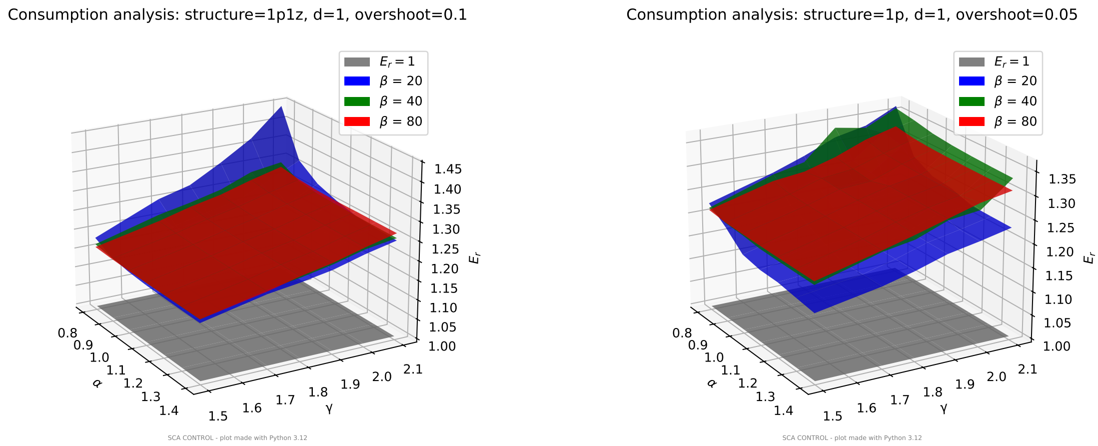
[1] To know exactly the consumption of the electrical energy, a process-specific analysis is required, since it also depends on several parameters that are not considered here, such as the working point of the system.

[2] It can be proved that E_r does not depend on the static gain of the process, so the results will have a general meaning.



(a) (b)

Figure 1: Test for 1p-processes: a) 10% overshoot, b) 5% overshoot.



(a) (b)

Figure 2: Test for 1p1z-processes: a) 10% overshoot, b) 5% overshoot.

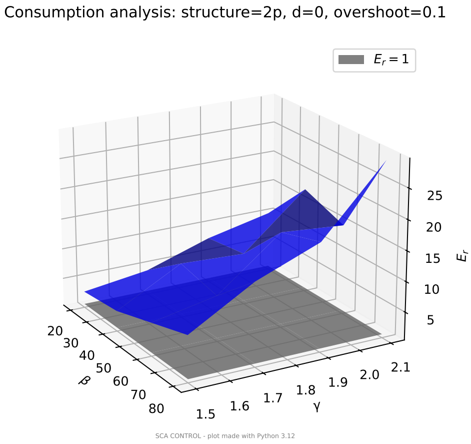
2.3 2p-processes

In Fig. 3, we plot the values of E_r for the 2p-process case[3]. Regarding the case of real-coincident poles (Fig. 3.a and Fig. 3.b), E_r generally increases as β and γ increase. It remains almost constant varying the overshoot requirement. Finally E_r is always much greater than 1, so the AC controller provides a control action with significantly lower energy consumption. Regarding the case of complex-conjugate poles (Fig. 3.c), the considerations are the same, with greater values of E_r, therefore with an even lower energy consumption of the AC controller as a result.

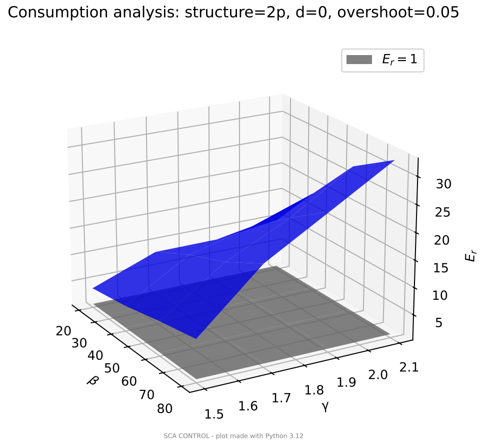
2.4 2p1z-processes

In Fig. 4, we plot the values of E_r for the 2p1z-process case. The results are similar to the 2p-process case. So, E_r generally increases as β and γ increase. It remains almost

[3]For 2p-processes and 2p1z-processes it was not possible to design the PID controller as a function of α, so the dependency on α is not considered.



(a)



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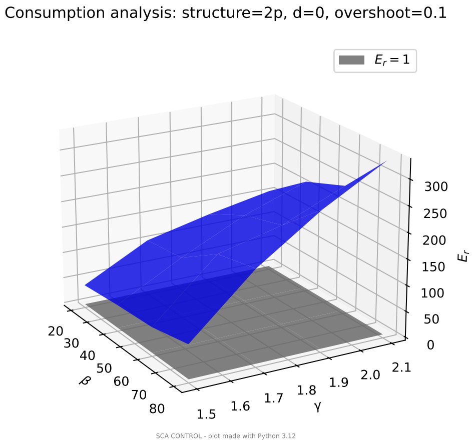


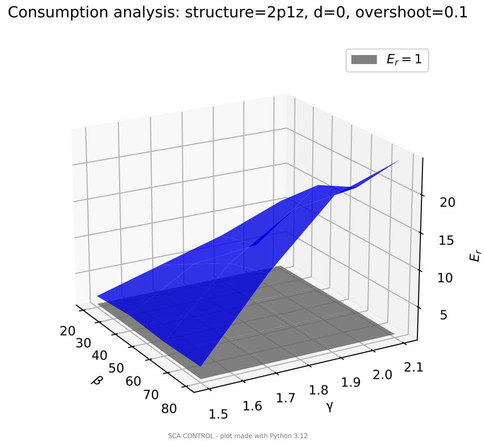
(c)

Figure 3: Test for 2p-process with a) 10% overshoot and real and coincident poles, b) 5% overshoot and real-coincident poles, c) 10% overshoot and complex-conjugate poles.

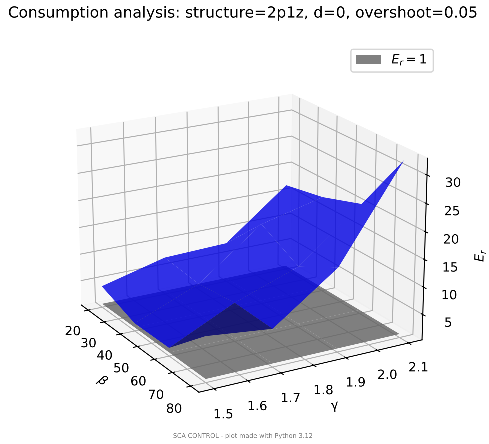
constant varying the overshoot requirement. Finally E_r is always much greater than 1, so the AC controller provides a control action with lower energy consumption.

3 Conclusion

The experiments suggest that in general the AC controller provides a control action with lower energy consumption. This effect is particularly evident for the 2p-process and 2p1z-process cases. The reason is the impulsive shape of the control action step response. Indeed, for the 2p-process and 2p1z-process experiments, the design of the PID controller was possible with small values of α which implies a greater derivative contribution (see 'preliminaries' document). In contrast, the smoother step response of the AC control action leads to lower energy consumption.



(a)



(b)

Figure 4: Test for 2p1z-processes: a) 10% overshoot, b) 5% overshoot.

References

[1] P. Cuff, *ELE 301: Signals and Systems*, Princeton University, 2011-12.

[2] J. C. Willems, *Dissipative Dynamical Systems, Part I: General Theory*, Massachusetts Institute of Technology, 1972.

[3] D. J. Hill, P. J. Moylan, *Dissipative Dynamical Systems: Basic Input-Output and State Properties*, University of California, Berkeley, 1980.

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