Synthesis of a multivariable control of a thermic power plant

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Abstract

We are presenting here the results of the application of the EICAS method to the synthesis of a law of command for a thermic, electrical plant**.** The multivariable linear model (2 inputs, 2 outputs) has been obtained by identification from real tests. Through the EICAS application, we can highlight the advantage of the multivariable law of command comparing to the juxtaposition of the monovariable regulators

Keywords: EICAS, Linear control, MIMO.

1 Introduction

The present control of the set generator of steam turbine-alternator is a monovariable type, with a PID structure without feedforward. We can note excesses when following instructions and when rejecting perturbation which imply a risk of releasing alarms and an excessive solicitation of the drivers. These two points motivate the study of a multivariable control aiming to minimize them.

2 Plant description

The process to control is the set generator of steam turbine-alternator showed on figure 1.

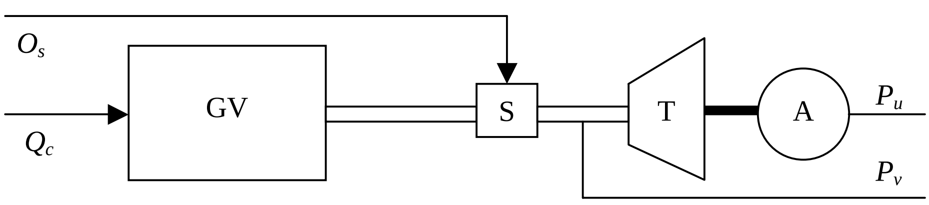

Fig. 1. The plant

The alimentation pumps of the generator of steam GV (a level regulation deals with this alimentation output) are not shown on figure 1.

The two commands are :

1. The opening of the steam inlet valve to the turbine, noted Os.
2. The output of the fuel, noted Qc.

The outputs to control are :

1. The electrical power provided by the alternator, noted Pu.
2. The steam pressure at the turbine inlet, noted Pv

The linear model of conception, necessary to the synthesis of the law of command has been identified from inputs-outputs data recorded on the real process, as shown on figure 2.

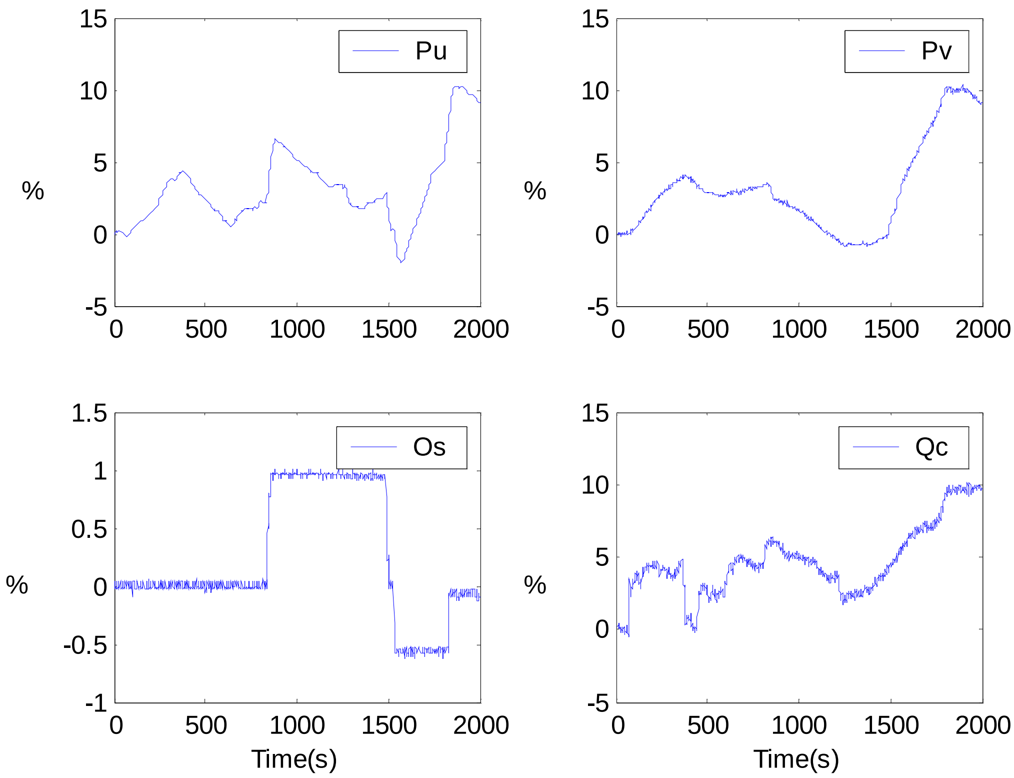

Fig. 2. Plant measure

A method of innovation of least square [1] has allowed to set up the continuous time model rate 3 as follows :

$$\dot{x}(t)=\begin{bmatrix}-0.03134 & 0.1 & -0.08252\\ -0.005968 & 0 & -0.001468\\ -0.002405 & 0 & -0.002428\end{bmatrix}x(t)+\begin{bmatrix}0.268 & -0.0009587\\ -0.01171 & 0.006941\\ -0.01326 & 0.004912\end{bmatrix}\begin{bmatrix}Os(t)\\ Qc(t)\end{bmatrix}$$

$$\begin{bmatrix}Pu(t)\\ Pv(t)\end{bmatrix}=\begin{bmatrix}1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}x(t)+\begin{bmatrix}0 & 0\\ 0 & 0\end{bmatrix}\begin{bmatrix}Os(t)\\ Qc(t)\end{bmatrix} \quad (1)$$

The open loop responses of figure 3 show no surprise :

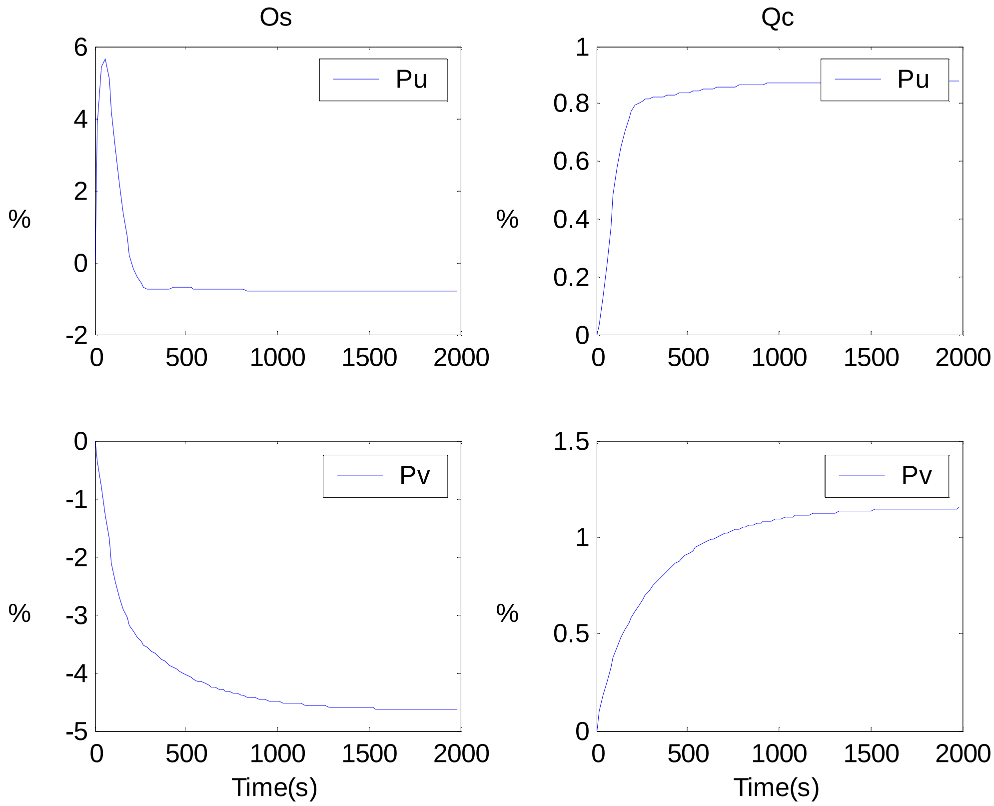

Fig. 3. Open loop step responses

An inlet valve positive variation causes a transitional increase of power, only transitional since the output of the fuel is constantly maintained.
It causes an instant fall in pressure due to the loss of charge in the valve, followed by a second fall generated by the increase of the steam pressure.

A fuel output variation generates variations of equal ways on the pressure and on the power. The slow transitions are due to response time of coal supplying.

2 Current control

The pressure is controlled by the inlet valve command, and the power by the fuel output. The regulators used are of PID type without feedforward. Their equations and coefficients are given hereunder.

$$PID = K_p + \frac{K_i}{s} + \frac{K_d s}{\frac{1}{N} s + 1} \qquad \text{where } s \text{ is the variable of Laplace} \qquad (2)$$

Pu Control	
K_p	0.1
K_i	0.05
K_d	0.1
N	10
Pv Control	
K_p	5
K_i	0.05
K_d	0.2
N	10

Table 1. Curent control coefficient

We can notice on figure 4 that the close loop responses, when following the instructions, highly exceed which is a disadvantage for the plant operation : risk of alarm release, reaction of the operators, excessive prompting the drivers …

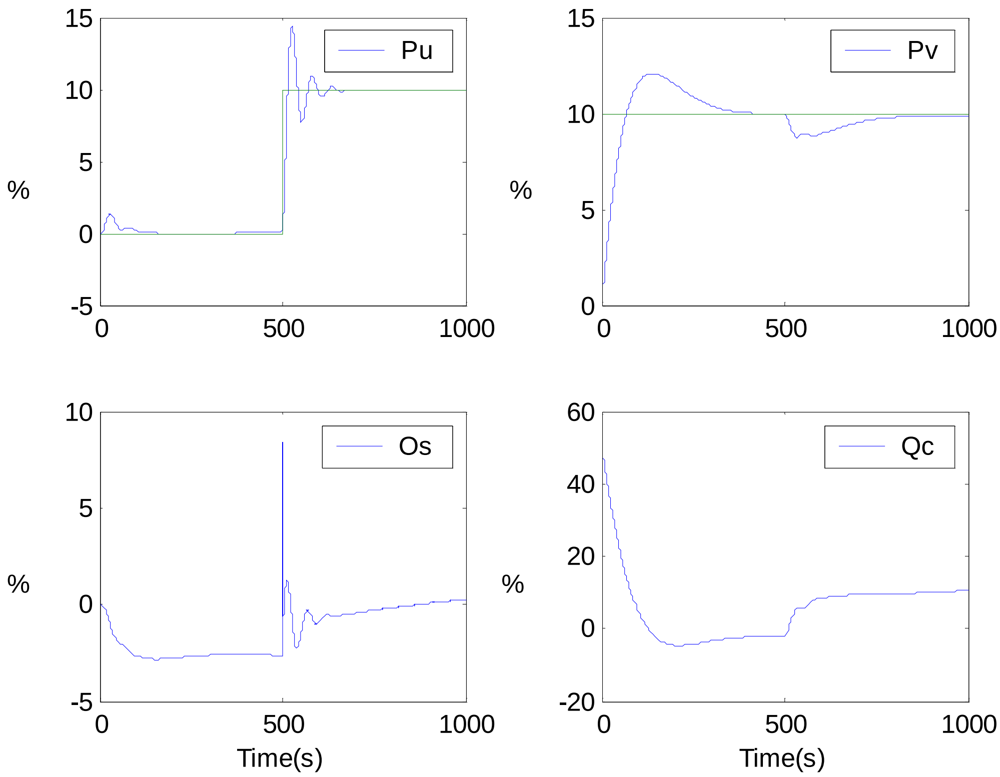

Fig. 4. Close loop responses with current control

The obtained performances through simulation are summarized in table 2 hereunder. In order to quantify the prompting of the drivers, we are calculating accordingly to the energy linked to the time signal on the length of simulation.

Pu Control	
Excess	44 %
Response time	12 s
Pv Control	
Excess	20 %
Response time	51 s
Prompting of the drivers	
Os	1.19 e^4
Qc	6.041 e^5

Table 2. Curent control performance

An optimization of the PID regulation must allow to improve performances, except that it is lacking in a rational methodology. Hence the motivation to use EICASLab to synthesize a new control and to obtain better performances.

3 Multi Control synthesis via EICASLab

Simplified model

According to the EICAS approach for the control system design, a simplified model has been designed : its aim is to focalise on the main aspects of the system : the following has been considered :

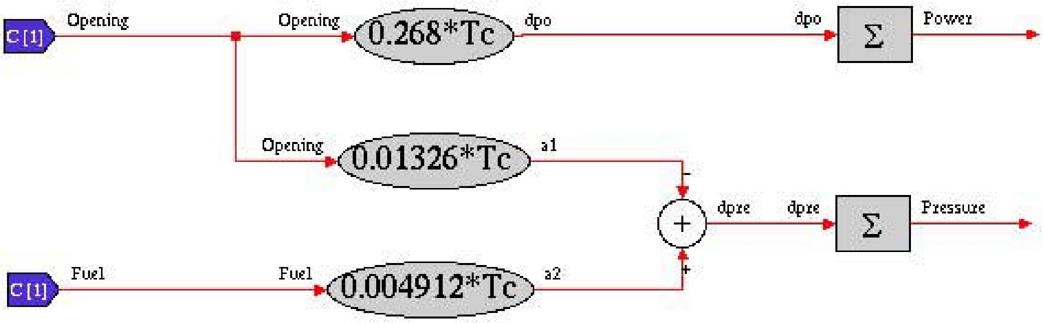

Fig. 14 Simplified model

where Tc is the sampling time of the control, equal to *0.1 s*; the other, smaller, interactions are considered as disturbances.

The model is then :

$$X(i+1) = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} X(i) + \begin{bmatrix} 0.0268 & 0 \\ -0.001326 & 0.0004912 \end{bmatrix} u(i)$$

$$Y(i) = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} X(i)$$

Implementation in EICASLAB

The control has been implemented using the *AAG* (Automated Algorithm Generation) feature of *EICASLAB*: the selected version of *AAG* has been the ‘*Package 2*’ (which implements a control scheme with an automatic model for the commands and the disturbances), and the selected sub-version has been the ‘*A*’ (which implements a complete control scheme, composed by a reference generator, an observer and a control).

The poles have been tuned considering the desired settling time and the allowed values of the commands.

The following table 3 describes the data inserted in the *AAG* :

Reference generator poles
0.98 ; 0.98 ; 0.99 ; 0.99
Observer poles
0.9 ; 0.9 ; 0.9 ; 0.9 ; 0.9
Control poles
0.9 ; 0.9
Weight for identification – Observor error
1 ; 0
Weight for optimisation – Observor error
1 ; 0
Weight for optimisation – Control error
1 ; 0
Model
$X(i+1) = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} X(i) + \begin{bmatrix} 0.0268 & 0 \\ -0.001326 & 0.0004912 \end{bmatrix} [U(i) + D(i) + W(i)]$ $Y(i) = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} X(i)$

Table 3. Control advanced parameters

The figure 5 gives the results obtained through simulation.

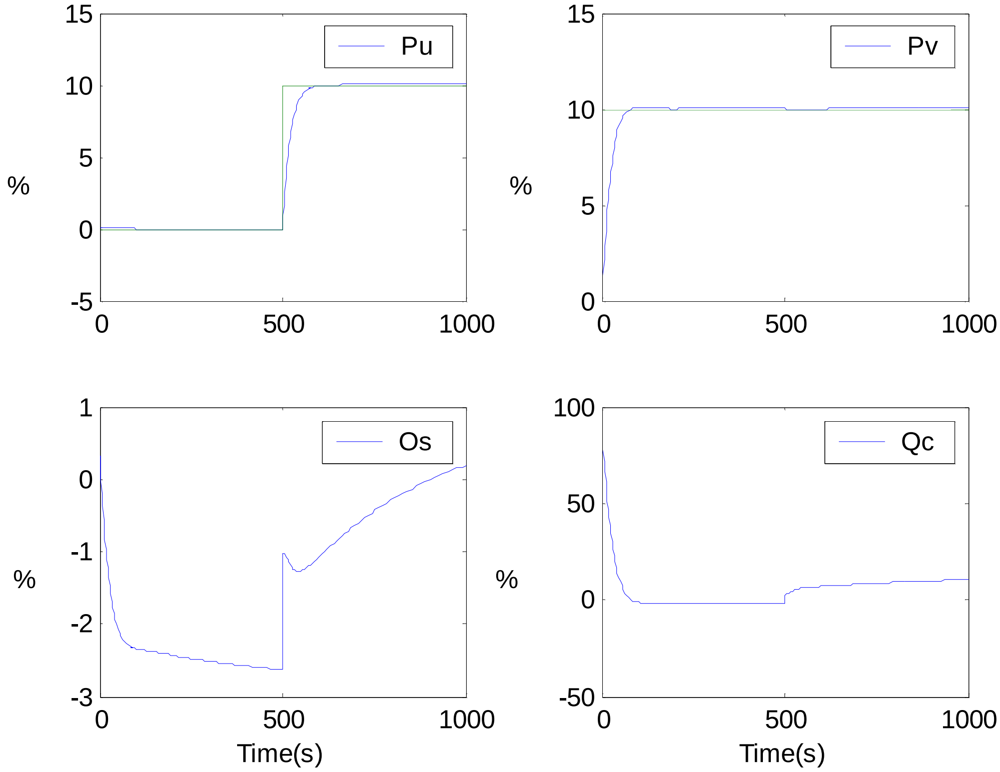

Fig. 5. Close loop responses with advanced control

The table 4 sums up the obtained performances.

Pu Control	
Excess	0 %
Response time	39 s
Pv Control	
Excess	0 %
Response time	39 s
Prompting of the drivers	
Os	4.85 e^2
Qc	6.16 e^4

Table 4. Advanced control performance

The expected aims are reached with the advanced control : excesses when following the instructions are void and the prompting of the drivers have decreased. We can also notice a better reject of perturbations due to a multivariable control which takes into account the natural coupling of the process.

4 Conclusions and perspectives

The synthesis of a multivariable control has allowed to increase in a significant way the process performances. The supply of more complex structures put forward by the tool should be studied now.

In order to implement the real process, two main points are to be studied. Firstly, simulating the system on more complex transitions including the non-linearities of the drivers : typically, saturation in position and speed. Secondly, integrating into the system a commutation device between the manual and automatic way of piloting, in order to guarantee a smooth commutation.

Acknowledgements

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References

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