ID3
ARX Identification

3.21 EXAMPLE 3 . 3 – IDENTIFICATION OF A POWER PLANT

This application of multivariable ARX identification procedures concerns the 120 MW gas power plant of Pont–sur–Sambre (France). The data have been collected by J.E.N. Richalet and refer to the following inputs:

1) Gas flow (Figure 3.21.1)
2) Turbine valves opening (Figure 3.21.2)
3) Super heater spray flow (Figure 3.21.3)
4) Gas dampers (Figure 3.21.4)
5) Air flow (Figure 3.21.5)

The outputs refer to:

1) Steam pressure (Figure 3.21.6)
2) Main steam temperature (Figure 3.21.7)
3) Reheat steam temperature (Figure 3.21.8)

The original data consist in 2202 samples; the sampling time is $\Delta t = 10.24$ s. Because of the small sampling time with respect to the process time constants, every set of 6 consecutive samples has been substituted with their mean value obtaining thus an equivalent sampling time of approximately 1 minute (61.44 s).

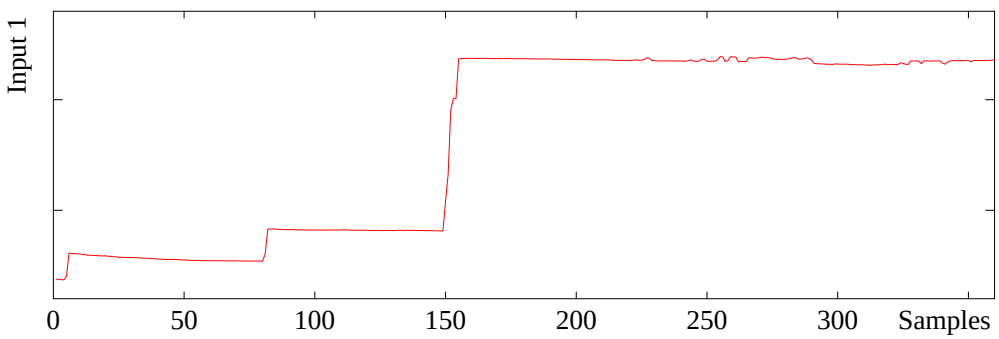

Figure 3.21.1 – Pont-sur-Sambre – Gas flow

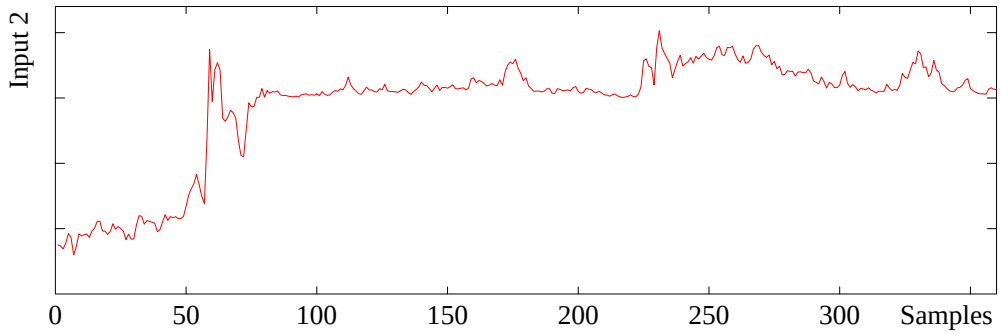

Figure 3.21.2 – Pont-sur-Sambre – Turbine valves opening

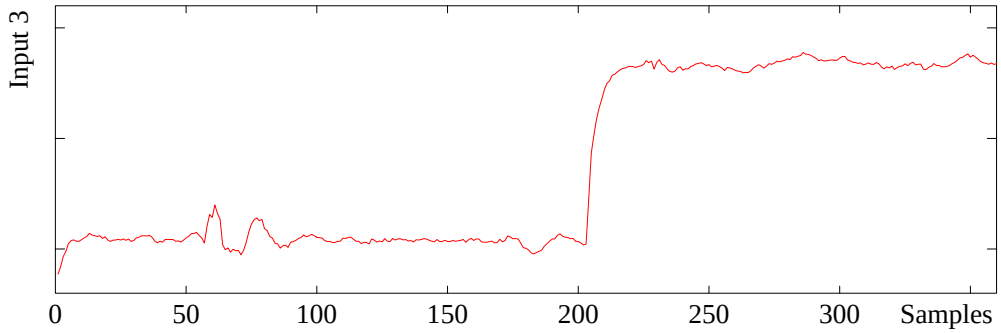

Figure 3.21.3 – Pont-sur-Sambre – Super heater spray flow

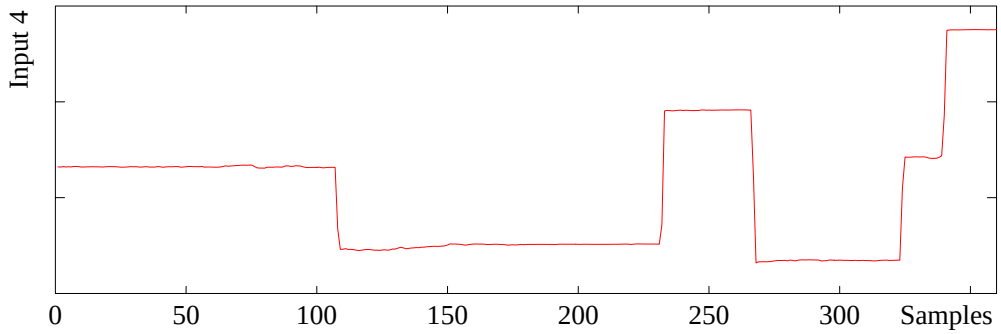

Figure 3.21.4 – Pont-sur-Sambre – Gas dampers

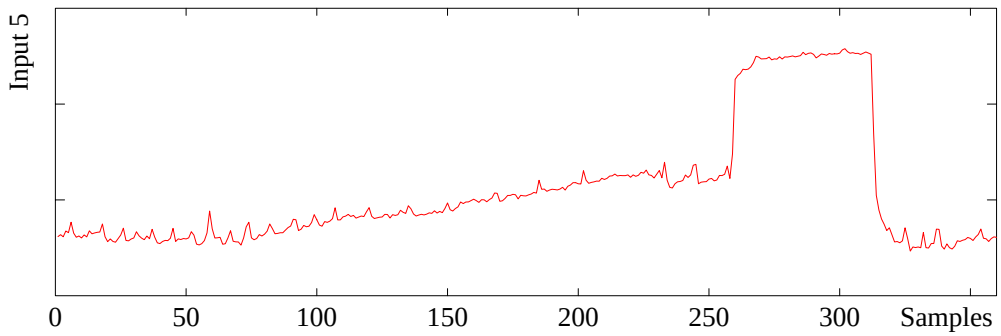

Figure 3.21.5 – Pont-sur-Sambre – Air flow

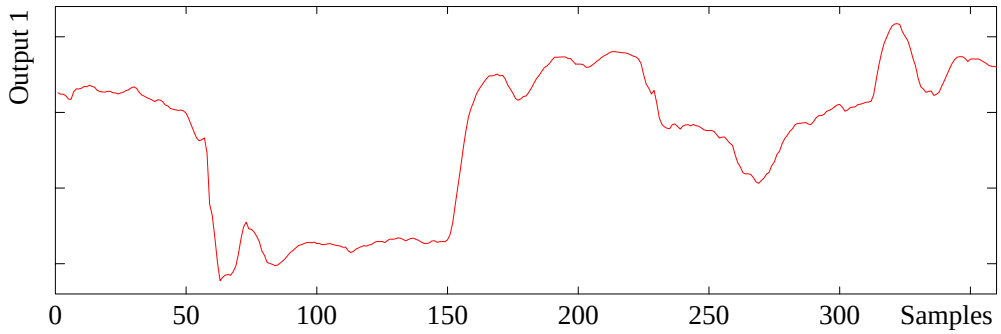

Figure 3.21.6 – Pont-sur-Sambre – Steam pressure

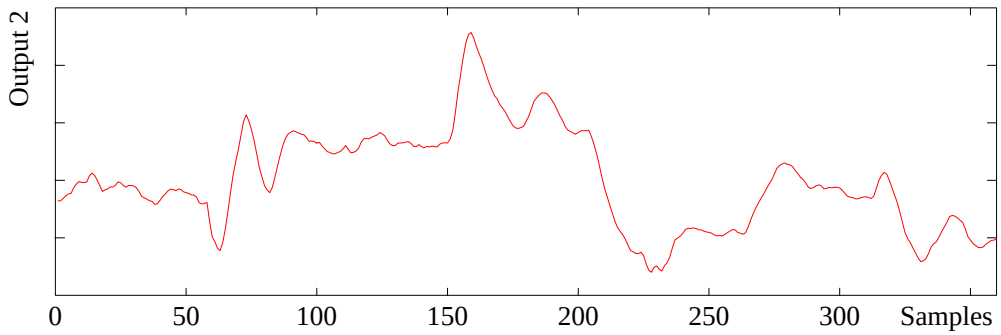

Figure 3.21.7 – Pont-sur-Sambre – Main steam temperature

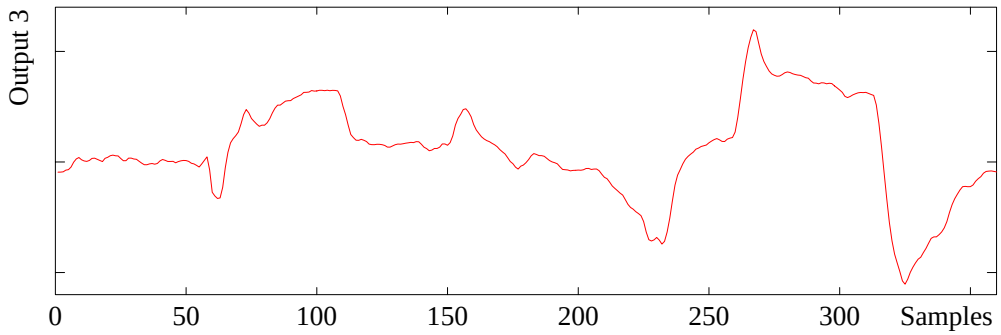

Figure 3.21.8 – Pont-sur-Sambre – Reheat steam temperature

Structural identification – The parameters of models with structures increased according to (3.20.1) have been estimated by means of (3.18.4); the corresponding previsions of predictor (3.17.11) have then been used to compute cost function (3.18.14). Using the FPE criterion we then obtain the following values:

$$FPE\,(1,\,1,\,1) = 1233$$
$$FPE\,(2,\,1,\,1) = 1220$$
$$FPE\,(2,\,2,\,1) = 1108$$
$$FPE\,(2,\,2,\,2) = \;\; 755$$

$$FPE\,(3,\,2,\,2) = \quad 628$$
$$FPE\,(3,\,3,\,2) = \quad 651.$$

As is shown also in Figure 3.21.9, the last structure leads to an increase in the value of the criterion. We must thus reduce by one the last structural index that has been increased (ν_2) and continue the procedure increasing only remaining indexes. This step establishes that $\nu_2 = 2$. We must now restart from structure (3,2,2) increasing the last index; we obtain the values which follow:

$$FPE\,(3,\,2,\,2) = \quad 628$$
$$FPE\,(3,\,2,\,3) = \quad 642$$

that show an increase in the criterion also for structure (3,2,3) (Figure 3.21.10). This step has established that $\nu_3 = 2$.

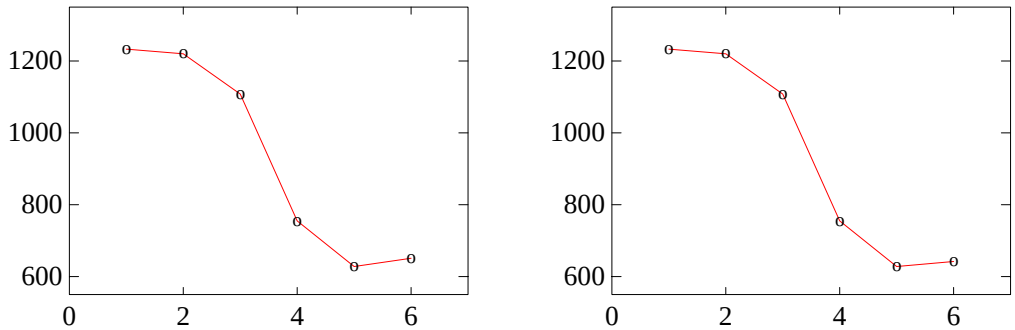

Figure 3.21.9 and 3.21.10 – FPE criterion; evaluation of ν_2 and ν_3

It is now necessary to return once again to structure (3,2,2) increasing the only structural index whose value has not yet been established, i.e. ν_1. We get

$$FPE\,(3,\,2,\,2) = \quad 628$$
$$FPE\,(4,\,2,\,2) = \quad 635.$$

Also structure (4,2,2) leads to an increase in the value of the criterion with respect to (3,2,2) (Figure 3.21.11) and this establishes the value of the last structural index at $\nu_1 = 3$.

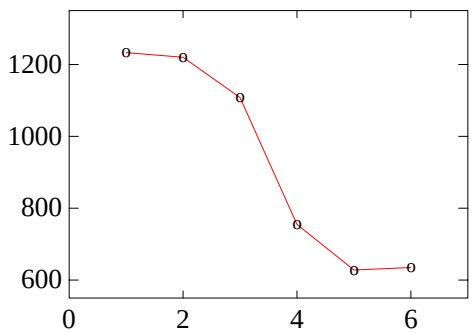

Figure 3.21.11 – FPE criterion; evaluation of ν_1

The application of all other criteria would have led to select the same structure for the model as can be seen in Table 3.21.1 that reports the values assumed by AIC, MDL and PPCRE for models with all previous structures.

Structure		*AIC*	*MDL*	*PPCRE*
(1, 1, 1)	→	2612	2706	5.96%
(2, 1, 1)	→	2608	2733	5.80%
(2, 2, 1)	→	2573	2729	5.41%
(2, 2, 2)	→	2431	2607	4.41%
(3, 2, 2)	→	2364	2582	3.90%
(3, 3, 2)	→	2377	2626	3.88%
(3, 2, 3)	→	2372	2618	3.87%
(4, 2, 2)	→	2367	2609	3.86%

Table 3.21.1 – AIC, MDL and PPCRE criteria for different model structures

The application of the PPCRE criterion to multivariable models can be performed considering the quantity, analogous to (3.14.14),

$$PPCRE(\theta) = 100\sqrt{\frac{N\,J^*(\theta)}{\sum_{i=1}^{m} {y_i^\circ}^T y_i^\circ}} \tag{3.21.1}$$

under the assumption of zero–mean output sequences. If this assumption is not verified, it is necessary to subtract from the entries of y_i° their mean value before computing (3.21.1).

Model validation – A sound validation of the model that has been identified can be performed testing the whiteness of the residuals of the associated predictor (3.17.11). This test could have been applied also in the structural identification step. The values of $\zeta_{367,8}$ for the residuals of the models corresponding to all previous structures are

Structure		$\zeta_{367,8}(y_1)$	$\zeta_{367,8}(y_2)$	$\zeta_{367,8}(y_3)$
(1, 1, 1)	→	73.2	537.7	569.5
(2, 1, 1)	→	26.8	532.2	542.6
(2, 2, 1)	→	26.7	9.6	410.2
(2, 2, 2)	→	25.3	17.6	8.0
(3, 2, 2)	→	13.2	16.7	8.1
(3, 3, 2)	→	13.7	13.7	9.1
(3, 2, 3)	→	10.6	17.2	25.2
(4, 2, 2)	→	5.4	11.7	8.5

Adopting a confidence level of 99% and remembering that $\chi^2_\alpha(8) = 20.1$ we can succesfully validate the model with structure (3,2,2) and also observe that the test on

the whiteness of the residuals leads to select a model with the same structure that has been obtained applying all other criteria.

Model performance – The excellent predictive performance of the model that has been identified can be evaluated observing Figures (3.21.12), (3.21.13) and (3.21.14) where the prediction error has been reported (in the same scale) against the observed outputs. In this case the plot of the predictions against the observed outputs is less informative because these plots are almost undistinguishable.

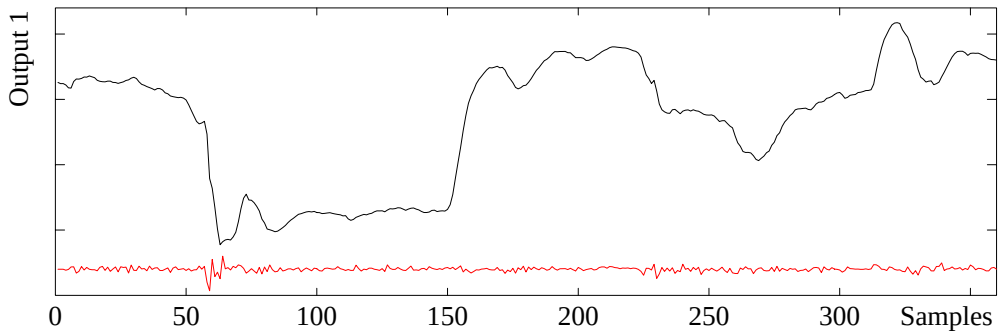

Figure 3.21.12 – Observed output 1 and prediction error

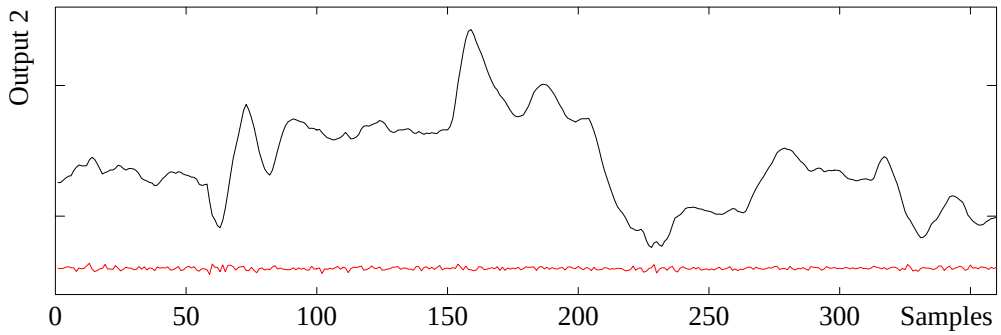

Figure 3.21.13 – Observed output 2 and prediction error

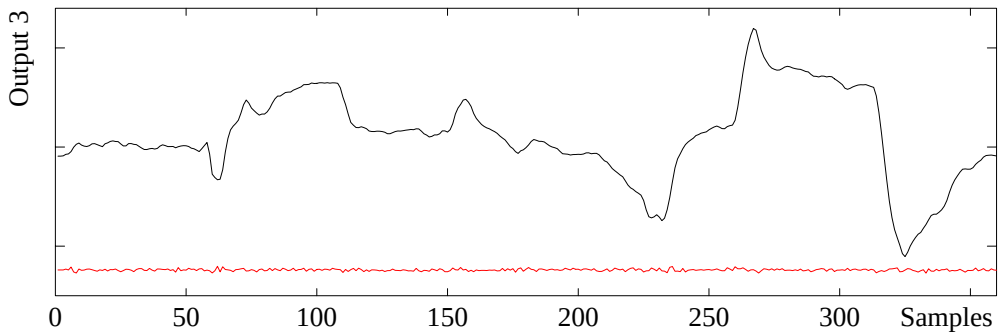

Figure 3.21.14 – Observed output 3 and prediction error