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Comparison between ARMA and Sub-Space Identification Method for Modelling of Air Separation Unit

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Abstract—In the present work two popular methods for modelling a system are compared using modelling of Air Separation Unit (ASU). To Model any MIMO system in general both ARMA and Subspace Identification methods can be used, and the optimum results can be achieved only after thorough investigation in the actual process of the system and the methodology by which the modelling can be done so as to suit our requirements. A higher order system can be modelled improving its overall stability, as well as a system with lower order can be modelled with less complexity.

Keywords—MIMO, ASU, System identification, ARMA, N4SID.

I. INTRODUCTION

In industries where large machinery is used, engineers have found it very difficult to analyse the problems associated with the working of systems generally considering a MIMO system which are nonlinear in nature. Huge time lags in the process and nonlinearity makes it difficult to analyse the system controllability as well as stability. Adapting a new controlling technique is difficult and there is always an ambiguity that wether the system will work properly to the demands or not. We have in general two efficient methods for modelling of ASU, ARMA modelling method and subspace identification method. Both these methods have their own importance for achieving optimum results. In this work both ARMA and Subspace Identification methods are discussed in brief and compared for designing of ASU.

II. METHODOLOGY

There is feasibility to model any non linear system with the knowledge of input output vectors and initial conditions. Consider a system governed by the set of first order differential equation:

Where x(t) is an n x 1 state vector.
A is an n x n matrix.
u(t) is an r x 1 input vector. B is an n x r input matrix.

The fundamental assumption imposed on the system is that of system controllability; i.e. it is assumed that of system controllability matrix

$$\gamma = [B, AB, A^2B\ldots A^{n-1}B]$$

has rank n. In addition, it is generally assumed in this short paper that the r columns B are linearly independent. For the present purpose only the observability form will be discussed. Beginning with an assumed discrete space model. The general approach for modelling leads to state variable approach. In state space analysis

$$x(k-1) = Ax(k) + Bu(k),\ x(0)$$
$$y(k) = Cx(k) + Du(k)$$

The values of A, B, C & D are estimated using subspace method for identification of linear systems. This method [3] performs a deterministic D-T system identification by calculating an observable form state space model

$$R_0 = \{A, B, C, D\}$$

From a set of inputs and corresponding output data, certain restrictions are placed on the input signals to ensure that the system excitation is "sufficiently rich".

2.1 ARMA Approach

The ARMAX model structure is based on auto Regressive moving averages method for relating the output with previous, present and error inputs, the block diagram is shown in fig 4.1 where the values A,B,C & D are found by repetitive iterations.

$$\begin{aligned} y(t) + a_1 y(t-1) + \ldots + a_{n_a} y(t-n_a) = \\ b_1 u(t-n_k) + \ldots + b_{n_b} u(t-n_k-n_b+1) + \\ c_1 e(t-1) + \ldots + c_{n_c} e(t-n_c) + e(t) \end{aligned}$$

A more compact way to write the difference equation is

$$A(q)y(t) = B(q)u(t-n_k) + C(q)e(t)$$

$$\begin{aligned} A(q) &= 1 + a_1 q^{-1} + \cdots + a_{n_a} q^{-n_a} \\ B(q) &= b_1 + b_2 q^{-1} + \cdots + b_{n_b} q^{-n_b+1} \\ C(q) &= 1 + c_1 q^{-1} + \cdots a_{n_c} q^{-n_c} \end{aligned}$$

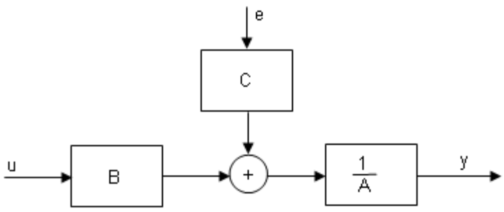

Fig 2.1 Modelling using ARMA

2.2 Subspace Approach

System identification aims at constructing state space models from input-output data. The left hand side shows the subspace identification approach: first the (Kalman filter) states are estimated directly from input-output data, and then the system matrices can be obtained. The right hand side is the classical approach: first obtain the system matrices, and then estimate the states.

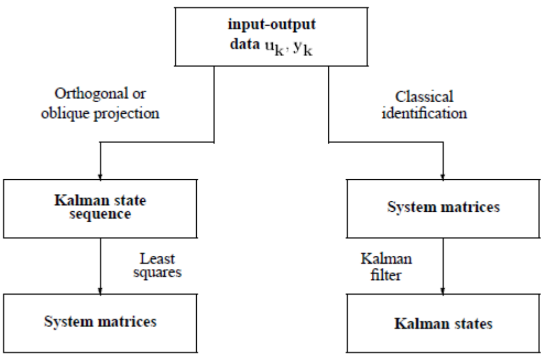

Fig 2.2: Subspace Identification Method

III. DISCUSSION ON RESULTS

Using both ARMA and Subspace identification methods modelling of nonlinear MIMO system is achieved and results of modelling and stability are compared as follows.

Table 3.1: Comparison between ARMA and Subspace Identification method for different cases of model orders

S.No	Model Order	Subspace Identification	ARMA
1	I	91.14	96.82
2	II	95.81	96.82
3	III	96.14	96.82
4	IV	96.65	97.03
5	V	96.65	96.98
6	VI	96.70	97.05
7	VII	96.64	97.09
8	VIII	96.65	97.09
9	IX	96.65	97.08
10	X	96.65	97.08

Kalman filter states can be obtained directly from input-output data using linear algebra tools (QR and singular value decomposition) without knowing the mathematical model.

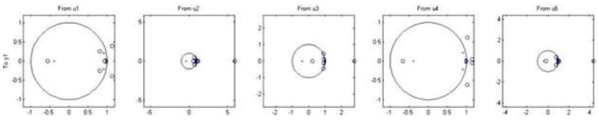

Fig 3.2(a): Poole-Zero plots for model obtained with Subspace method

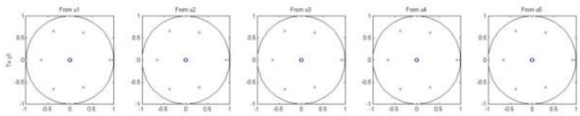

Fig 3.2(b): Poole-Zero plots for model obtained withARMA method

Comparing the stability of the modelled system then using ARMA method of modelling it is found that the system is far stable compared to that of model modelled using Subspace identification method, as it is seen from Fig 3.2(a) that the poles appear on the unit circle which resembles that the system is marginally stable.

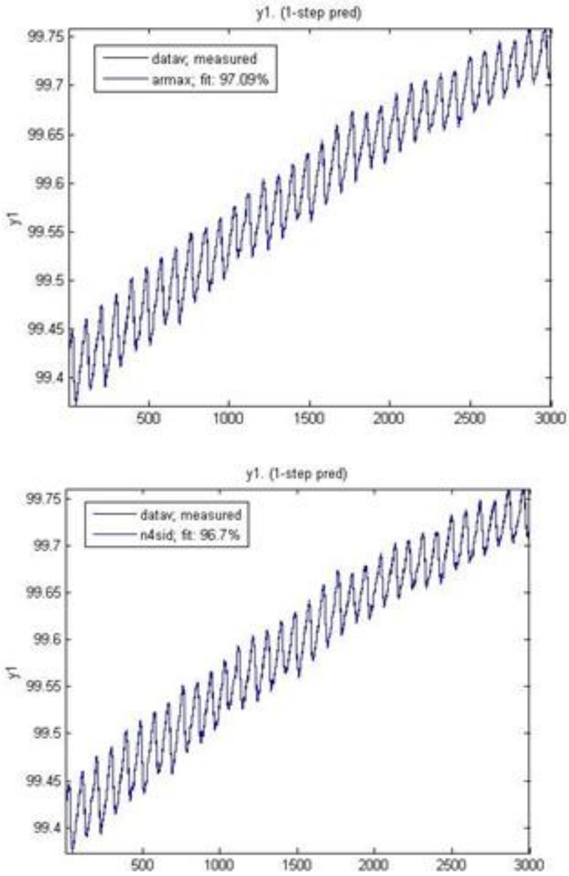

Fig 3.1: Model approximation by comparing the identified model with original data.

After modelling the output data of the original model is compared with the outputs of the simulated model and it is found that the model obtained by subspace identification method gives 96.7 % approximation whereas the model designed using ARMA method provides 97.09 % approximation. Hence in terms of modelling a non liner MIMO system ARMA method achieves optimum results compared to that of Subspace Identification method the results are described in tabular form Table: 3.1.

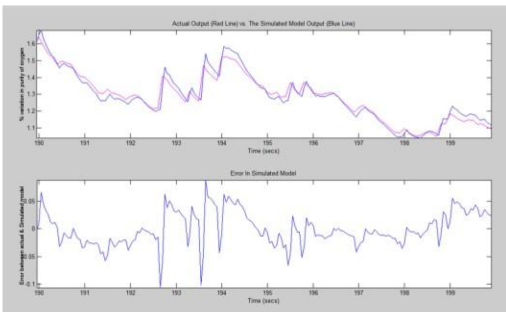

Fig 3.3(a): Comparison between original system and proposed model identified using Subspace identification method.

The response of the system employing neural network predictive controller are compared for the two models modelled with subspace identification method and ARMA respectively as shown in the fig 3.3 (a) and 3.3 (b) and it is found that with ARMA method as it provides a stable system the controlling is achieved with optimum results whereas for model using subspace identification method becomes unstable while achieving controllability. The outputs of the two systems are compared in fig 3.4 (a) and 3.4 (b).

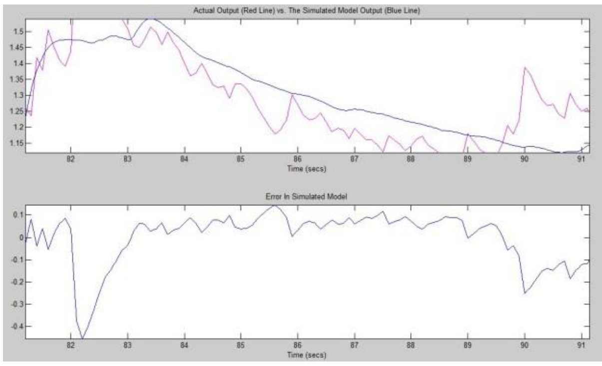

Fig 3.3(b): Comparison between original system and proposed model identified using ARMA method.

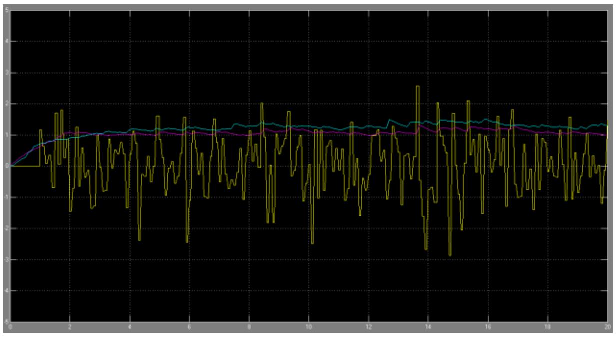

Fig 3.4 (a) Comparing Subspace identified method model and ARMA method model with input.

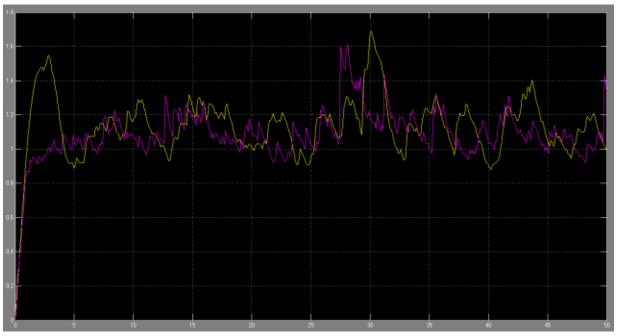

Fig 3.4 (b) Comparing Subspace identified method model and ARMA method model with individual response.

IV. CONCLUSION

In terms of modelling a non-liner MIMO system ARMA method achieves optimum results compared to that of Subspace Identification method also it is found that with ARMA method as it provides a stable system the controlling is achieved with optimum results whereas for model using subspace identification method becomes unstable while achieving controllability. For more optimum results we have to consider a more complex NNPC and large amount of training data for it. By observing the results we conclude that ARMA method can be used for optimum modelling of a nonlinear MIMO System and its far stable reliable for controllability.

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