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Automation of Argon unit using Neural Network Predictive Control

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Abstract: This paper presents a method of realization of a real time non linear multi input and multi output systems using mathematical modelling and generalise over a wide range of similar systems for pre-process, controlling and to achieve optimum productivity as per the supply and demands in the industry. In the present work real time input / output data of a large chemical process of Distillation Column of Argon unit in Air Separation Unit (ASU) is taken as sample space and through this data the plant is modelled and simulated over a wide range of real time data. Further to verify the accuracy of the non linear system which is mathematically modelled using State Variable Approach.

I. INTRODUCTION

Argon of 99.99% purity is required for welding in the repair shops and for in-site repairs in other areas. Argon is also required for stirring of liquid steel in the teeming ladles. The only general procedure widely used on industrial scales consists of extracting oxygen, Nitrogen and Argon components of air from air by liquefaction and distillation at cryogenic temperatures. Argon is extracted from ASU.

II. AIR SEPARATION UNIT (ASU)

The general Overview of ASU is shown in Fig 2.1. The Main Process in ASU is Air Compressing Process, Pre Cooling Process, Air Drying Process and Air Drying and Distillation Process in extracting Oxygen, Nitrogen and Crude Argon from the Distillation Column K01, K02 and K03 shown in the Fig 2.1.

The crude Argon gas i.e., is extracted from the distillation column in 2 to 3% of pure only and this gas contains impurities of Oxygen, Nitrogen, and Argon. During the process of distillation, the boiling points of oxygen as well as argon falls very nearer to each other, hence some amount of oxygen is also present in Argon gas. This small amount of oxygen is removed from the Argon gas using a separate Argon compressor plant and during this process Hydrogen is supplied into the plant in proportions such that in the presence of palladium catalyst it forms water and is easily extracted out of the plant.

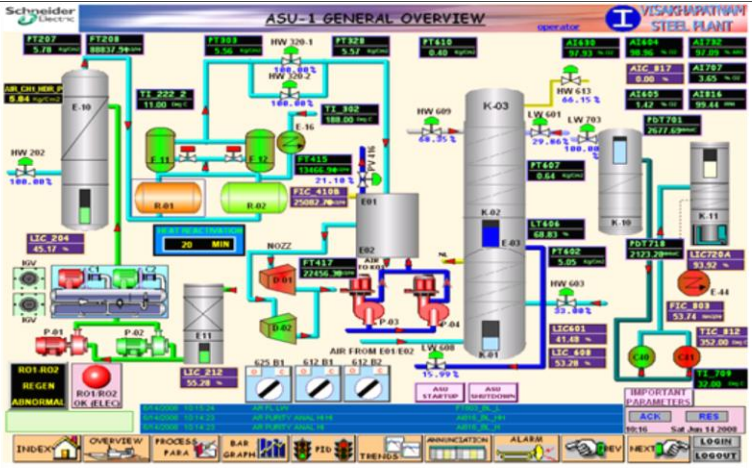

Fig: 2.1. General Overview of ASU

III. PROCESS OF EXTRACTING ARGON

Crude argon i.e., extracted is then send to Distillation Column K10 and to Distillation Column K11 shown in fig 2.1 to obtain pure form of Argon. The crude Argon undergoes the process of Vaporization and then is passed through Driers, Catalytic Reactor, Water coolers, Refrigeration unit, Expander, Compressor and finally the pure liquid argon boiling at the bottom of the column K11 is drawn.

The block diagram of ARGON UNIT is shown in Fig 3.1. The argon compressor plant consists of a compressor which will cool the argon and liquefy it, then it is further processed and it is mixed with Hydrogen gas in large quantity, the mixture of argon gas and hydrogen is combined in the presence of Palladium catalyst to form water. The excess water vapour is condensed and removed. The obtained mixture of pure argon, little amount of water vapour and hydrogen is allowed to pass through aluminum oxide (Al_2O_3), hence the water vapour present in the mixture is completely removed and we are left with only argon gas and hydrogen where the hydrogen gas is left in air freely and pure argon gas is extracted.

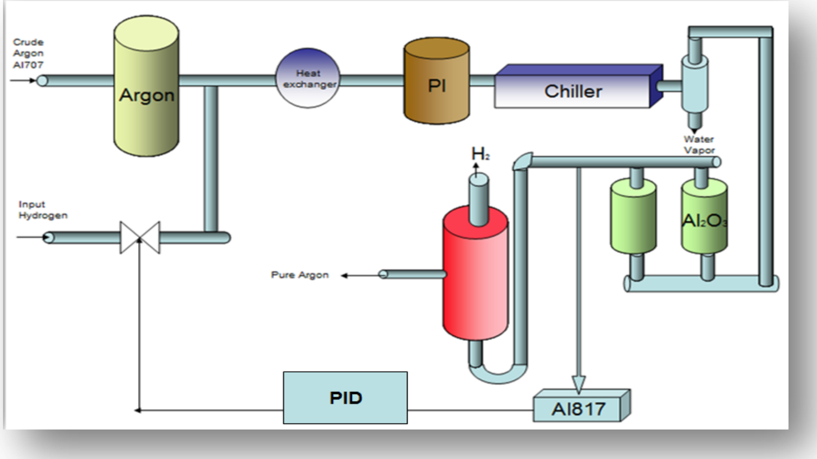

Fig 3.1: Block diagram of ARGON UNIT

PERFORMANCE OF THE PLANT

Liquid Argon:	**Production**	
	per unit	**Total**
N cum per day	2,400	7,200
N cu m per hour	100	300
Purity (min) ,%	99.99%	99.99%
Dew Point, deg. C(-ve)	70 deg.c	70 deg.c

DATA

S.No	Analyser Indicator	Range	Threshold
1	Ai817 : H2 In Argon Analyser	0 – 10%	5%
2	Ai707 : Oxygen In Crude Argon Analyzer	0 - 25%	Nill

IV. MATHEMATICAL MODELING

Consider a system governed by the set of first order differential equation:

$$\dot{x}(t) = Ax(t) + Bu(t)$$

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.

$$x(k-1) = Ax(k) + Bu(k), \qquad x(0)$$

$$y(k) = Cx(k) + Du(k)$$

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

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

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".

V. RESULTS

The Table 1 describes the % correlation between the simulated output of the estimated model with different orders and the original set of real-time outputs. Refer appendix for graphical presentation of the results.

S.No	Order	Model fitting
1.	1	97.29 %
2.	2	96.98 %
3.	**3**	**99.22 %**
4.	4	92.46 %
5.	5	97.41 %
6.	6	94.51 %
7.	7	0.00 %
8.	8	0.00 %
9.	9	0.0003 %
10.	10	.0023 %

Table 1: % Fitness of the estimated model (with different orders) to the real model.

For model order 3 we get highest fitting for simulated and real-time data.

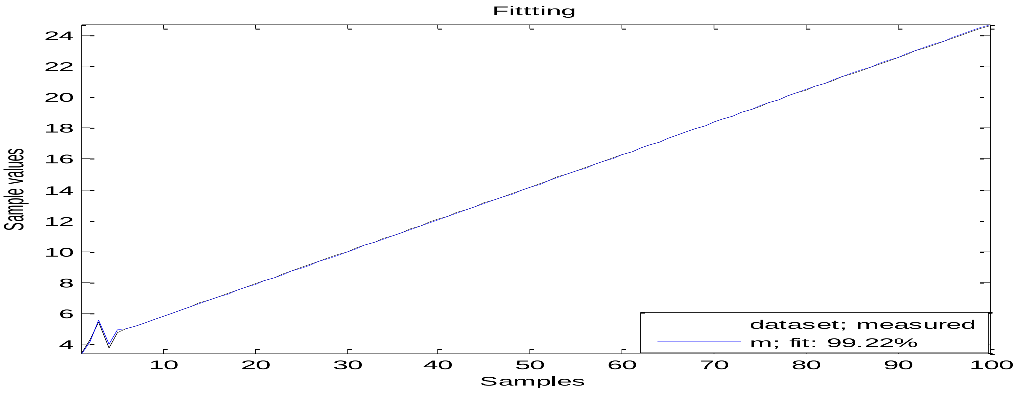

Fig: Compare of estimated model outputs with original set of outputs

The discrete state space model parameters are:

A= **0.7823 -0.22141 0.049896**
-0.133 0.85253 0.0046846
-0.29008 -0.61584 -0.17839

B= **6.1938e+013**
1.3765e+013
-1.0826e+015

C= **[3.0831e-012 -5.2941e-012 1.0749e-013]**

D= **0**

x (0) = **5.2754e+014**
1.2083e+014
-9.1477e+015

The transfer function obtained from the state space model is as follows:

$$H(z)= \frac{0.03733\, z^3 - 0.03986\, z^2 + 0.004464\, z + 0.001814}{z^3 - 1.456\, z^2 + 0.3632\, z + 0.09473}$$

The pole – zero plot for the obtained transfer function is as follows:

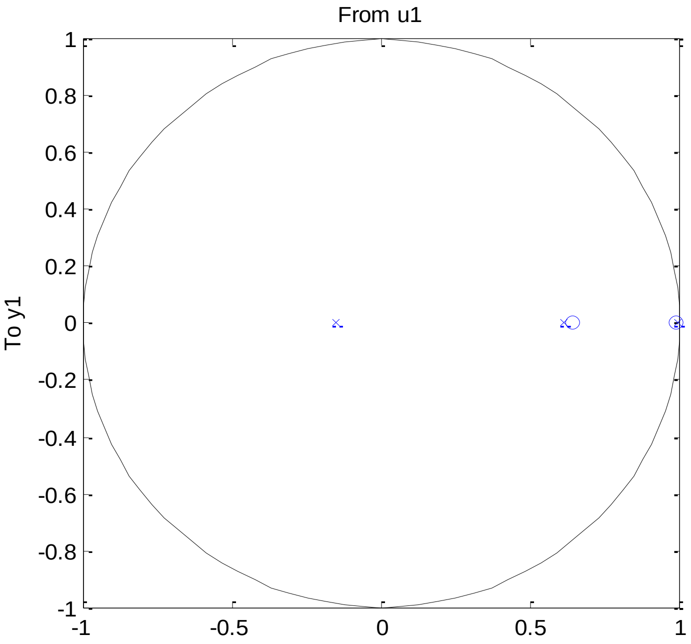

Fig 3: Pole-Zero Plot for the estimated model.

VI. CONCLUSION

The real-time model for argon unit is estimated using state space analysis and from the A,B,C & D parameters the model is described into a discrete time LTI system. From table 1.1 it is observed that the system approaches to nearly real-time system with 99% results matching the desired outputs, from the fig 3 it is observed that the present system is marginally stable.

VII. FUTURE SCOPE

The present modeling technique can be well utilized in understanding for the controllability of the system so as the present real-time system can be mathematically modeled with wide range of feedback paths and then one can comment upon its stability as well as feasibility to develop such a real time system.

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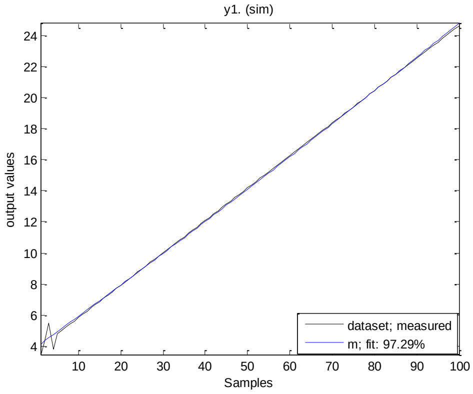
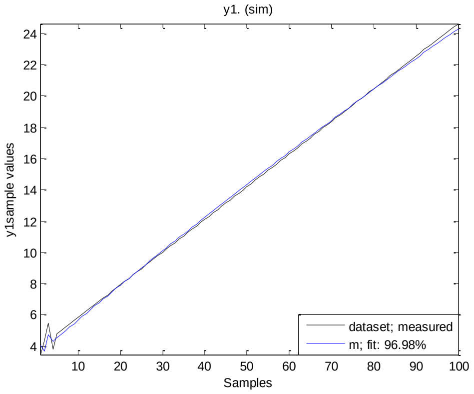
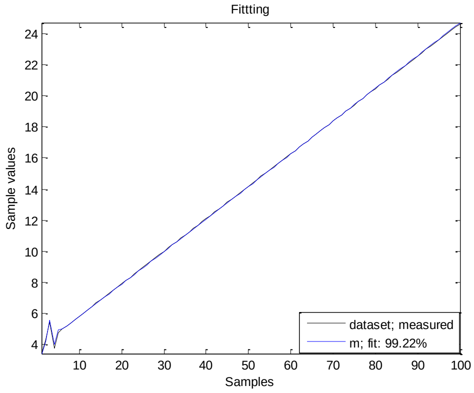
APPENDIX



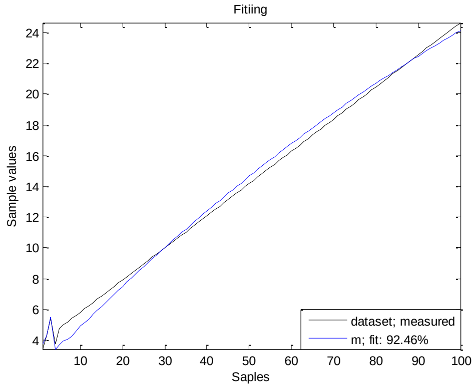
(a)



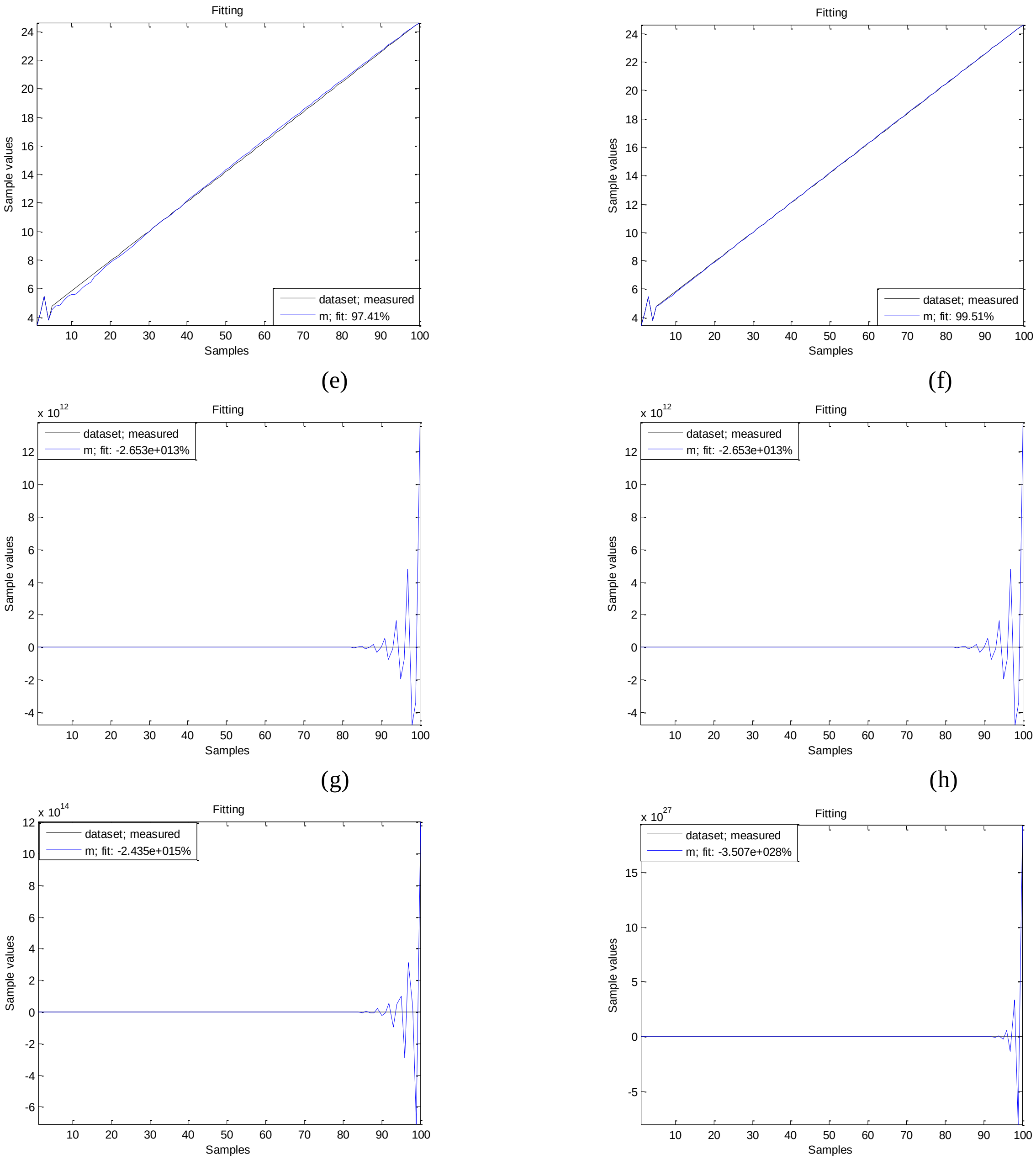
(b)



(c)



(d)



(e) (f)

(g) (h)

(i) (j)

Fig: (a) to (j) represents different model estimates with different order as taken from 1 to 10 and graphs representing the matching between the simulated results and the original outputs of the plant.