Design And Implementation Of Model Predictive Controller For MIMO System

P.Vaishnavi, K.Sneha, K.M.Nandhini

Abstract-The evaporator is a Multi Input Multi Output (MIMO) system. The controlling of MIMO system is little difficult when compared with SISO (Single Input and Single Output) system. The flow rate of feed and vapor were considered as an input, then the dry matter content and flow rate of product were considered as an output. For superior controlling of the evaporator the model has to be developed accurately. For better accuracy more number of data has to been taken, and then the system identification was done by using MATLAB toolbox. Different controllers were available to control the process. In this work advanced controller like Model Predictive Controller and the conventional controller like PID controller were designed. By giving the different step input and disturbance to the system at various instance, the output of both controllers were evaluated using an error performance criteria. The simulation result shows how MPC give better result than the PID controller by comparing the time response of the system like rise time, settling time and overshoot.

Index Terms— Evaporator, System identification, Proportional Integral Derivative (PID), Model Predictive Controller (MPC), Integral Time Absolute Error (ITAE), Integral Square Error (ISE), Integral Absolute Error (IAE).

1 INTRODUCTION

In many industries the optimal control of parameters like temperature, level, concentration is still a difficult task. Even though different tuning methods of PID controllers were available. In this paper the advance controller MPC was designed. A unique approach to control multiple inputs, multiple outputs is MPC. This controller is an advanced controller has capability to handle multivariable interactions and operating constraints in efficient manner. The proposed controller will use the convolution model to determine the optimal progression of input moves.

The stability condition of the MPC was driven with hard and soft constraint in input and output. The MPC give stable response for both feedback state and output. The online optimization problem was also discussed [1]. The bench example of Permanent-Magnet Synchronous Motor drive was taken as a system. The fundamentals, features and characteristics of MPC were detailed and the designing procedure was also discussed briefly. The current and speed are the parameters were controlled using MPC instead of conventional cascade method. Then the improvement in design of controllers was also suggested [2]. The robust controller was designed using adaptive neural network model predictive controller. In case of change in parameters of the system or any other uncertainties occur, how well the designed controller gave desired output was shown [3].The benefits and drawbacks of tube based MPC was described for both change in trajectory and disturbance occurrence [4].The level of the conical tank was controlled by using the conventional controller like DTPID and an innovative controller like MPC. The linearity portion of the conical tank was taken as a system model. By using the simulation graph the response of the two implemented controllers were evaluated [5]. The bubble cap distillation column was taken and the composition of the substance was controlled using both MPC and PID. The PID was tuned using Sundaresan-Krishnaswamy method. And conclude that the MPC gave more optimized result than the conventional controller by using an integral error comparison [6]. The MPC history and some current improvement were focused [7]. The challenges and solution of using MPC in industries were detailed. It deals with how to install MPC, how to maintain and monitor the continuous task for long time and also discussed the advanced tools available for automatic maintenance and commissioning [8].The level process station was taken as a linearized model. For controlling the level two controllers were designed namely PID and MPC. After designing the controller the time response of the system like rise time, settling time, peak time steady state error were compared to identify which controller is best [9].

The paper is discussed in the below manner: Section 2 deliberates the Evaporator model. Section 3 deals with system identification. Section 4 discusses the Model Predictive Controller. Section 5 shows the simulation results of MPC and PID, and the performance criteria were compared. Finally Section 6 completes how the MPC is better than PID.

2 MODEL DESCRIPTION

The evaporator is necessary in many manufacturing industries for different purpose. In food industries the evaporation process is done for increasing the shelf life and reduces the volume. In chemical industries it is used to separate the valuable compounds. It is also used to segregate drinking water from sea water.

The falling type evaporator is taken as a system. It consists of four sections namely heating section, separation section, condensing section and ejecting section. The heating section contains cylinder in which more vertical tubes are placed. The feed is given to the cylinder and

- *P.Vaishnavi, K.Sneha, K.M.Nandhini*
- *Assistant Professor, Department of Electronics and Instrumentation Engineering, Bannari Amman Institute of Technology.*

steam is flow in a vertical tube to evaporate the water present in a feed. In separation section the vapor and the product has been separated. In condensation section the vapor is cooled to convert it as a water. And in ejection section the vapor is taken away from the evaporator and it create a vacuum. The vacuum is used for reducing the required temperature to evaporate the water content in the feed. The cross section of an evaporator is given in the figure 2.1.

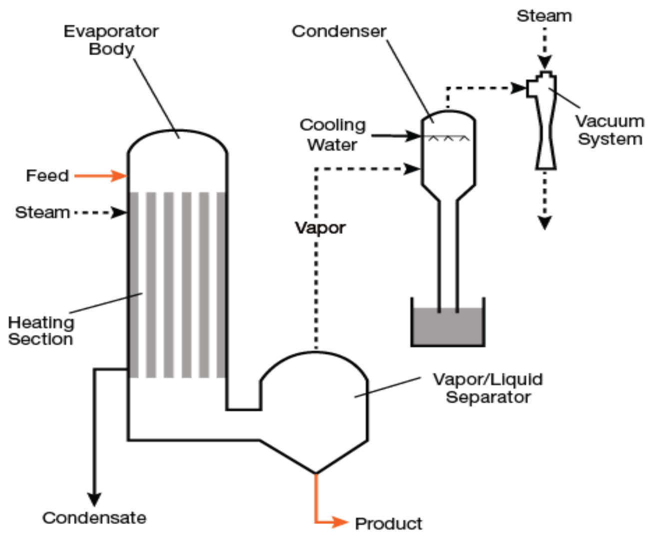

Fig. 2.1 Cross sectional diagram of an evaporator

The evaporator mass balance equation is given

$M_F = M_P + M_V$ (1)

$M_S = M_C$ (2)

where

M_F = Mass flow rates for feed

M_P = Mass flow rates for product

M_V = Mass flow rates for vapor

M_S = Mass flow rates for steam

M_C = Mass flow rates for condensate

The energy balance of the evaporator

$M_F h_F + M_S h_S = M_P h_P + M_V h_V + M_C h_C$ (3)

where

h = Enthalpy

3 System Identification

To design a controller for a plant, the plant model is necessary. The model of a plant was identified using system identification toolbox. By using the statistical method, system identification form a mathematical model from the measured data. The main objective is to predict a model from measured input-output data. The model is a mathematical relationship between input (cause) and output (effect) of a plant measured data. In other words model is a mathematical mapping of input and output observed data. The developed model must be more accurate. So only it acts a good substitute for a plant. In this work the state space model was identified and used. The block diagram of system identification is given in the figure 3.1.

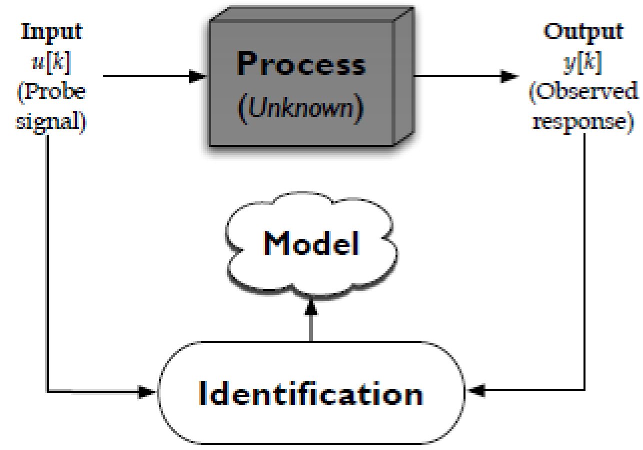

Fig.3.1Block diagram of System Identification

4 Model Predictive Controller

MPC mainly contains plant model and optimizer. The model is used to predict the future output of the process and optimizer is used to ensure that whether the predicted output should track the desired reference or not. The aim is to achieve the reference trajectory by the predicted output. In case of MIMO system more PID controllers were used and it works independent of each other. But MPC consider all the inputs and outputs and works based on that. MPC can handle both hard and soft constraints. Like the feedforward control, MPC can also have a preview capability. MPC wants to predict the best path for reference tracking which means decrease the error between desired and predicted output. The manipulated variables are calculated in order to reduce the cost function. The MPC cost function is given below

$$J = \sum_{i=1}^{N} w_{x_i} (r_i - x_i)^2 + \sum_{i=1}^{N} w_{u_i} \Delta u_i^{\,2} \quad (4)$$

Where,

J – Cost function

x_i – i^{th} control variable

r_i – i^{th} reference variable

u_i – i^{th} manipulated variable

W_{xi}, W_{ui} – weight coefficient

The main parameters of MPC are sample time, prediction horizon, control horizon, constraint and weights. The sample determines the control algorithm execution rate. The prediction horizon can be represented using P which means how far the MPC predict the output and how far the control action can take is called control horizon and it is represented by C. Practically all the system has some constraints based on the application the constraint type is chosen whether it is hard or even. Assigning weight to the outputs is more important for set point tracking. The MPC is designed by finding and applied all the above mentioned parameters. The basic concepts of MPC is shown in the figure 4.1

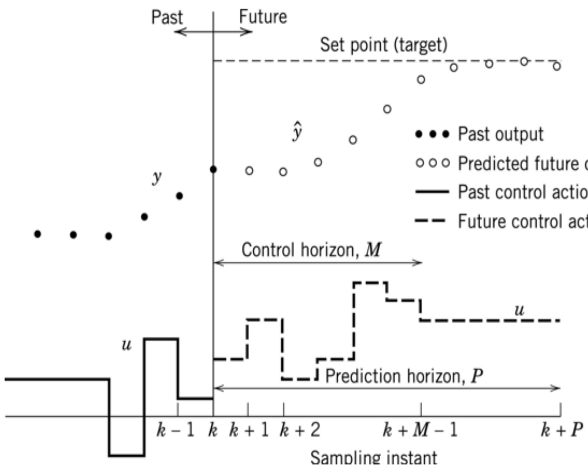

Fig. 4.1Basic concept for MPC

From the above figure u represent manipulated variable. For reducing an error, at kth instant the control action {u(k),u(k+1)…u(k+M-1)} can be calculated over M instant. By using the calculated control action the output of the model was predicted over P sampling time and check whether it satisfied the cost function and constraint. After implemented the control action u(k). The same steps would be followed for the next sampling instant k+1.

5 Results And Discussion

By using the feed flow rate and vapor flow rate and output like concentrated valueand flow rate of product were collected from the evaporator. From the collected data system identification was done. The MPC was designed and analyzedfor the linear MIMO system. The MPC output is compared with the conventional PID controller using performance criteria.

5.1 Simulation results of dry matter content

The figure 5.1 shows the dry matter content response of a taken MIMO system when the step input is given to the feed flow and the vapor flow. The step input of -1 is given to the feed flow at the sample instant of 10, the PID controller give maximum undershoot and error than the MPC to reach the set point. Next the step input of 2 is given to the vapor flow at sample instant of 60. The PID controller takes more time for overcoming the disturbance than MPC but there is no oscillation.

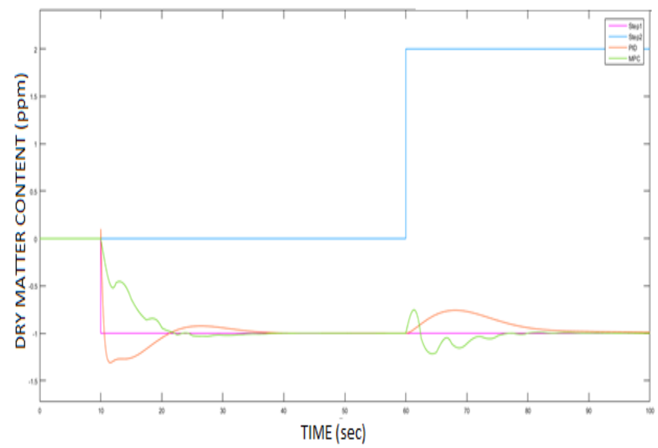

Fig. 5.1 Simulation result for dry matter content response

5.2 Performance comparison for dry matter content response

TABLE 1
PERFORMANCE COMPARISON FOR DRY MATTER CONTENT RESPONSE

CONTROLLER	MPC	PID
ITAE	176.8	308.2
ISE	2.169	1.279
IAE	5.84	6.583

The performance criteria like ITAE, ISE and IAE is given in the Table I for both controllers PID and MPC. The above comparison shows that MPC gives minimum error than PID controller.

5.3 Simulation results of product flow

The figure 5.2 displays the product flow response of an assumed MIMO system when the step input is given to the feed flow and the vapor flow. The step input of -1 is given to the feed flow at the sample instant of 10, the PID controller give maximum overshoot, undershoot and error than the MPC to eliminate the disturbance. Next the step input of 2 is given to the vapor flow at sample instant of 60. The PID controller takes more time for settling with less oscillation than MPCto track the reference trajectory.

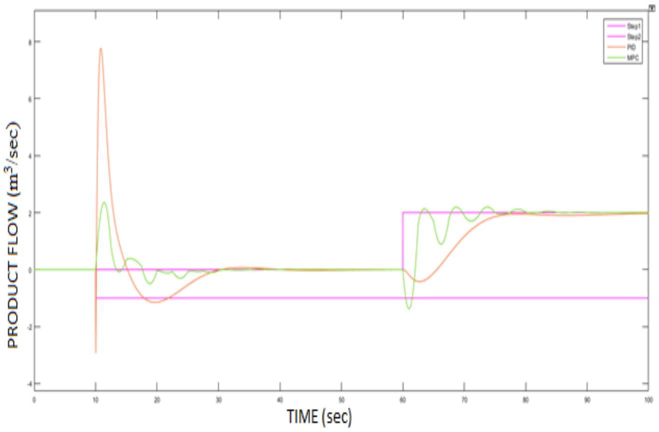

Fig. 5.2 Simulation result for product flow response

5.4 Performance comparison for product flow response

TABLE 2
PERFORMANCE COMPARISON FOR PRODUCT FLOW RESPONSE

CONTROLLER	MPC	PID
ITAE	783.5	1927
ISE	29.36	129.6
IAE	17.93	48.86

The performance criteria like ITAE, ISE and IAE is given in the Table II for both controller PID and MPC. The above comparison shows that MPC gives minimum error than PID controller.

6 CONCLUSION

In this work MIMO evaporator was chosen. The flow rate of feed and vapor data were collected and taken as an inputs and concentrate and flow rate of product data were taken as output. With the above mentioned data, system identification was done. In order to achieve a required amount of ppm and flow rate, Model Predictive controller has been designed. The designed controller compared with the conventional PID controller by using performance criteria like ISE, ITAE and IAE. From the simulation it is clear than that MPC has less overshoot, undershoot and settling time than the PID controller. It reveals that MPC is superior to the PID controller.

REFERENCES

[1] Alex Zheng and Manfred Morari (1995), Stability of Model Predictive Control with Mixed Constraints, IEEE transactions on automatic control, Vol.40, No.10

[2] Saverio Bolognani and Luca Peretti (2009)Design and Implementation of Model Predictive Control for Electrical Motor Drives, IEEE Transactions on Industrial Electronics, Vol. 56, No. 6.

[3] Swati Mohant (2009) ," Artificial neural network based system Identification and model predictive control of a flotation Column. Journal of Process Control 19,pp 991-999

[4] David Q. Mayne, Eric C. Kerrigan, Paola Falugi (2011), Robust model predictive control: advantages and disadvantages of tube-based methods, International Federation of Automatic Control.Vol 22, Issue 12

[5] Sukanya R. Warier, SivanandamVenkatesh (2012), Design of Controllers based on MPC for a Conical Tank System ,IEEE -International Conference On Advances In Engineering, Science And Management.

[6] M.Manimaran et al. (2013),Optimization and composition control of Distillation column using MPC, International Journal of Engineering and Technology (IJET).Vol 5, No 2.

[7] David Q Mayne (2014), Model predictive control : Recent development and future promise, Automatica, Vol 50,Issue 12.

[8] Michael G. Forbes and Rohit S. Patwardhan (2015), Model Predictive Control in Industry: Challenges and OpportunitiesThe International Federation of Automatic Control

[9] B.V.Anarase and B. J. Parvat (2016), Design of Model Predictive Controller for Level Process. IOSR Journal of Computer Engineering,pp. 10-16.