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Design and Comparison of MPC Responses for a Centrifuge Separator

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Abstract

The paper deals with design model of centrifuge for different inputs to attain effective output. Input parameters affect the centrifuge separator working. The MPC responses are analyzed for various disturbance inputs and comparison of outputs is done between single MPC and switched multiple MPC block set. Various disturbance models are introduced along with constraints and weights that represent cost function.

Keywords– *Centrifuge separator, Model Predictive Control (MPC),disturbance.*

1. INTRODUCTION

Centrifuge separation is contingent on separation of materials (samples)according to their size, shape, density, viscosity, rotor speed and also on gravitational force [2]. Sedimentation rate of suspended particles are enhanced by centrifugation technique. Centrifugation is hinged on density difference separation technique[6]. Presently in the COVID-19 patient testing labs, centrifuge plays an important role in analysis where centrifugation of specimens should be performed solicitously using centrifuge rotors or sample cups. The rotors or sample possessing cups should be ladened or unladened in biological safety cabinets of clinical labs. Utmost ministration has to be taken in repertoire of centrifuges as well as samples. Samples are stratified as liquid-liquid, solid-liquid or solid-solid. Customarily liquid-liquid type is being analyzed in labs for this pandemic outbreak.

2. SYSTEM MODEL

In this paper, the feed flow rate is considered as output of centrifuge plant model which is related to sedimentation velocity and residence time [8]. Angular velocity is an internal parameter in the process of derivation.

$$q = \left\{ w^2 (P_p - P) D_p^2 \Big/ 18\mu \ln\left(\frac{r_2}{r_1}\right) \right\} * V$$

$$q = \left\{ w^2 (P_p - P) D_p^2 \Big/ 18\mu \ln\left(\frac{r_2}{r_1}\right) \right\} * \left(\pi b (r_2^2 - r_1^2)\right)$$

- The volume of liquid V(m^3) in the bowlis given by :

$$V = \left(\pi b (r_2^2 - r_1^2)\right)$$

3. Modelling using MPC and multiple MPC switching

Simulation is effectuated using Model Predictive Control toolbox in Simulink. In MPC different parameters are needed for attaining results. Exteriorv ariables like reference input, measured output, manipulated variable, measured disturbance and interior parameters like constraints, weights, noise, unmeasured disturbances, unmeasured output affects the plant response.

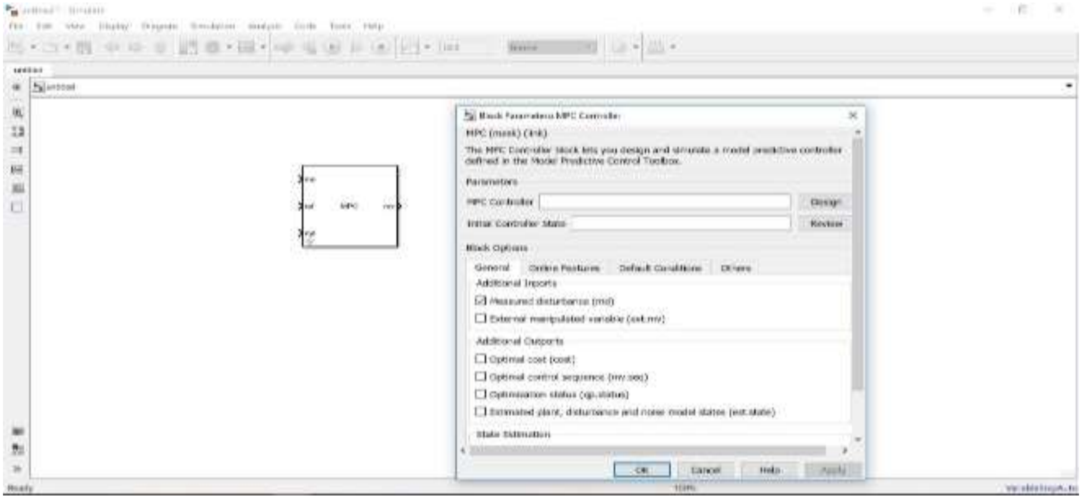

Fig.1. MPC block diagram in Simulink model.

In this paper a centrifuge plant model is designed according to the equation of feed flow rate. The inputs to the plant are acceleration, liquid density, particle density and diameter of the rotor which are given w.r.t standard waveforms. In MPC the output of plant model is connected to mo i.e., measured output of MPC block.

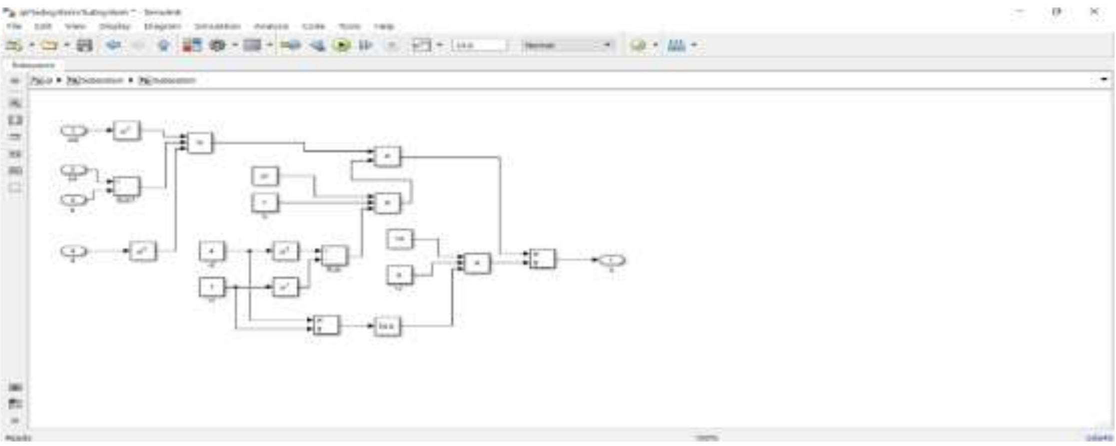

Fig.2. Simulink model for Feedflow rate equation.

The disturbance codes are written in mpcobj design section of command window which is specified in MPC controller of Simulink window.

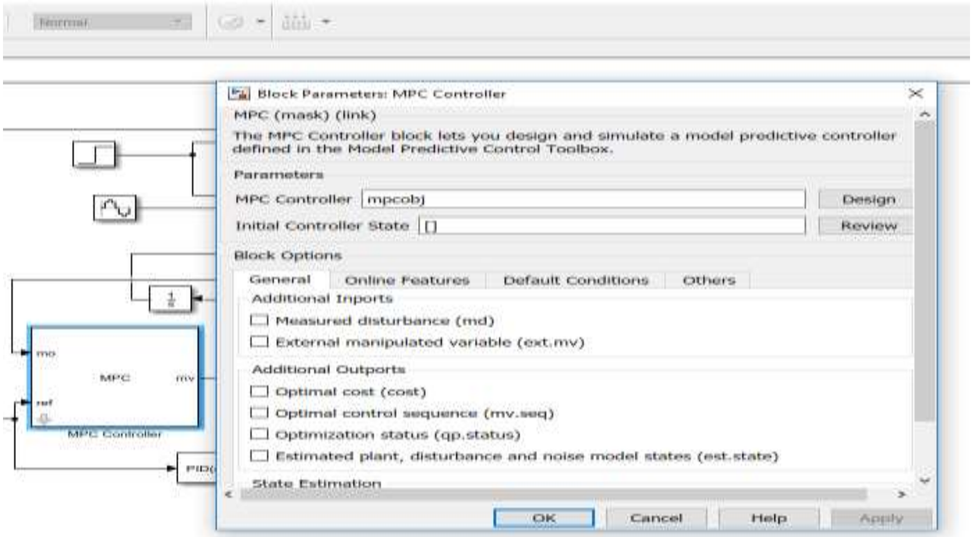

Fig.3. Design option in MPC controller.

Two types of disturbance models are taken and analyzed their responses for the existing plant. The cases are written as follows:
case-1: plant=rss(3,2,3);
case-2:plant=rss(3,2,4);

rss indicates random continuous test model. The variables for both cases are mentioned as states, outputs and inputs.

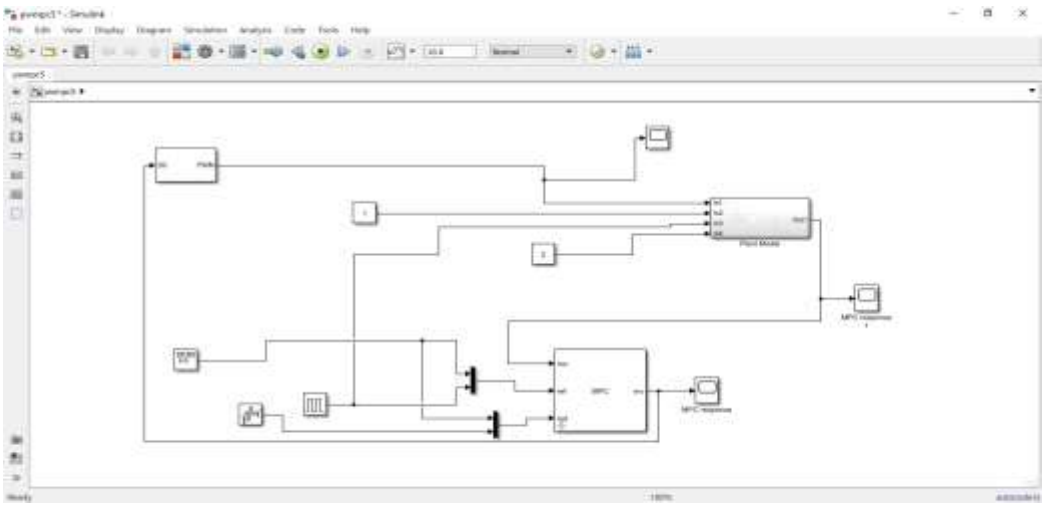

Fig.4. Feedflow model with external measured disturbance for single MPC block.

As shown in figure-4 standard input signals are assigned from source section of Simulink to MPC block w.r.tmo, ref and md parameters. mo represents measured output, ref denotes reference input and md indicates external known measured disturbance. Similarly the plant model is also provided with values for In2 & In4, In3 is connected to reference signal. The mv port of MPC that indicates manipulated variablewhoseoutput is fed to DC-PWM block that converts into pulsed signal which is again fed to In1 of plant model. As density changes in centrifugation process and In1 represents density so mv output is allotted to this input of plant that influences the response of the plant w.r.t MPC mechanism.

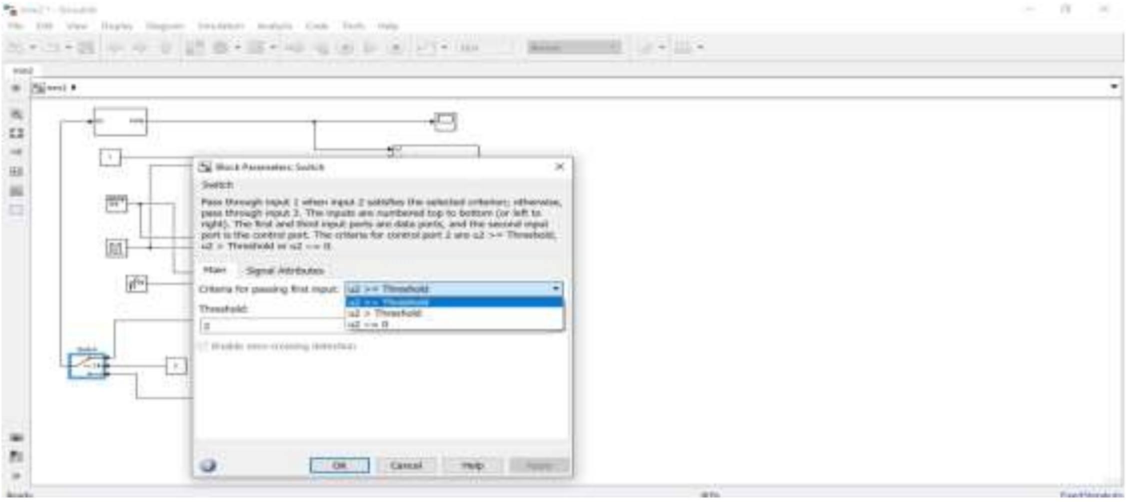

Fig.5. switch block in multiple MPC model.

Switch plays an important role in design of multiple MPC models because based on the mv outputs of MPC-1 and MPC-2 block outputs and predefined threshold value the response from switch is transferred to DC-PWM block. It is clearly represented in figure-5. U2 represents control port that switches accordingly which effects the overall response.

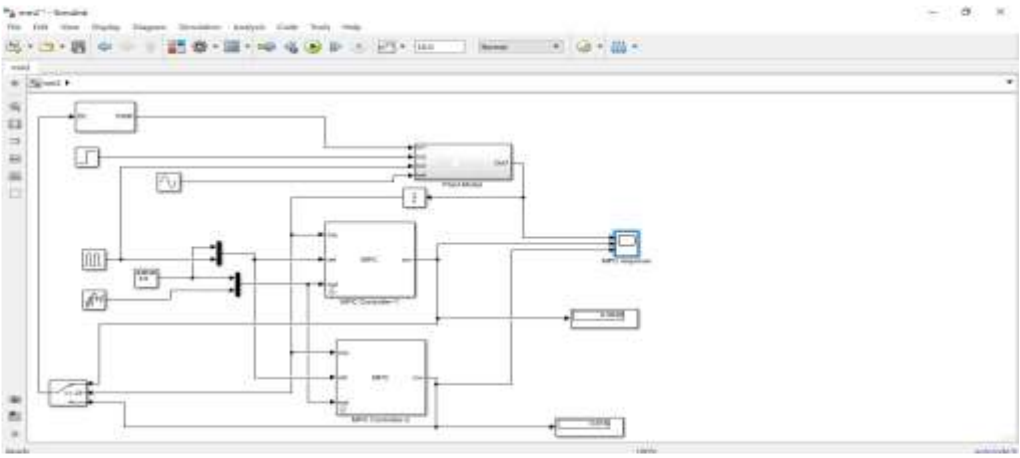

Fig.6. switch block in multiple MPC model for u2> = Threshold.

Figures 6 and 7 represent MPC models for different switch conditions: u2 > = Threshold and u2~ = 0. Model for u2 > Threshold is not kept because it shows similar values as u2 > = Threshold. The input to threshold is taken from plant output in both cases so that it automatically gets altered.

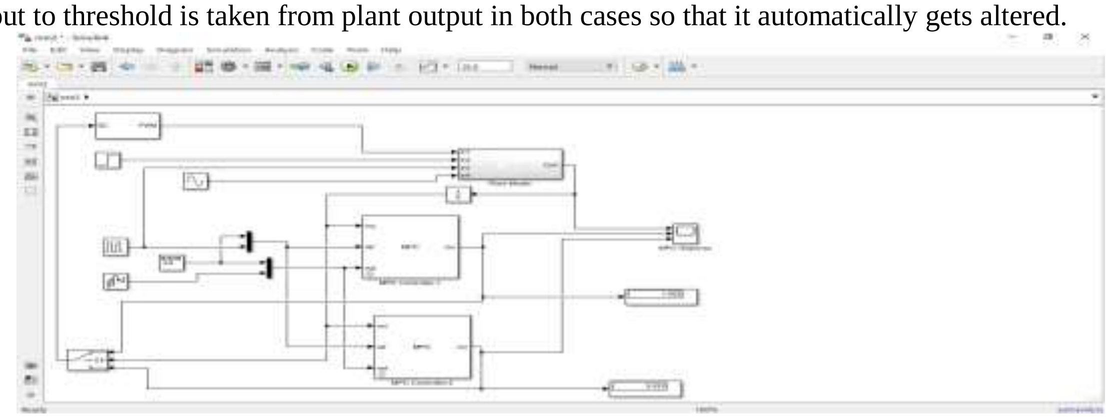

Fig.7. switch block in multiple MPC model for u2~ = 0.

4. RESULTS

4.1 <u>Responses of single MPC block</u>
for plant=rss(3,2,3)

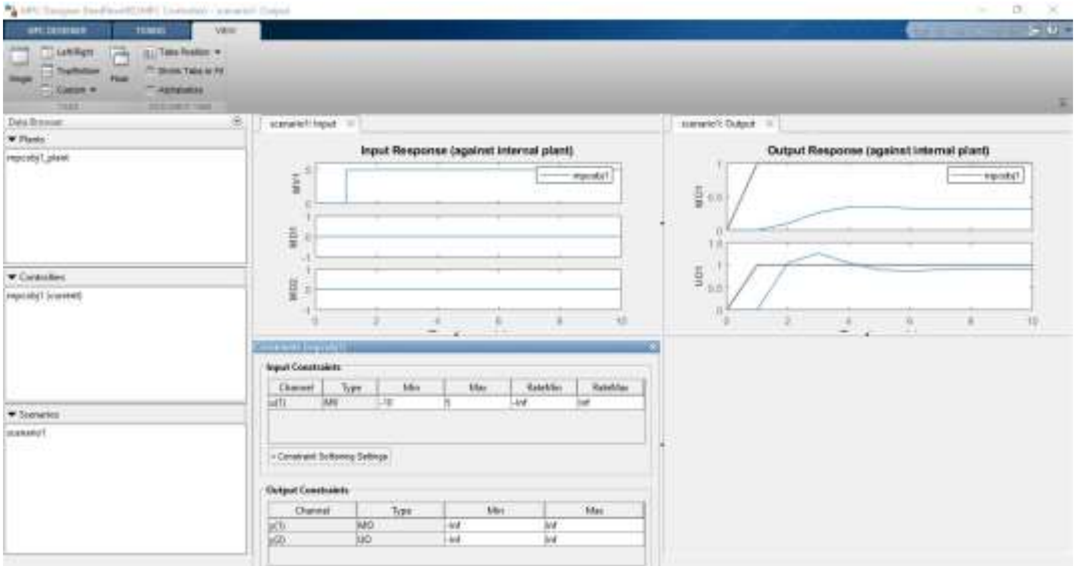

Fig. 8.Responses of feedflow model with constraint values

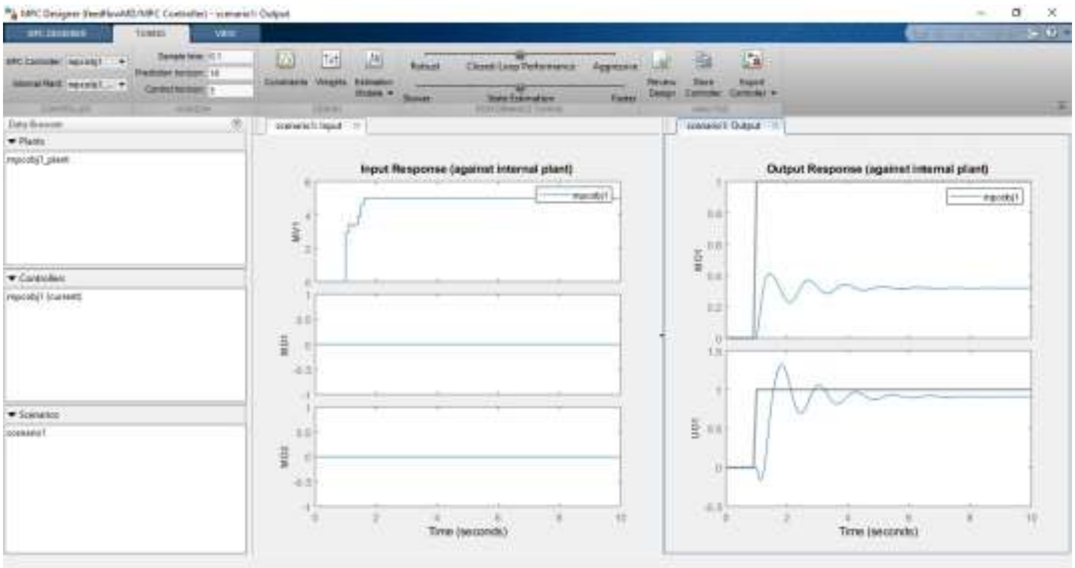

Fig. 9. Responses of feedflow model for sample time Ts=0.1s

Figures 8 & 9 represents mpcdesigner responses for plant=rss(3,2,3) and figure-10 is analogous graphical output.

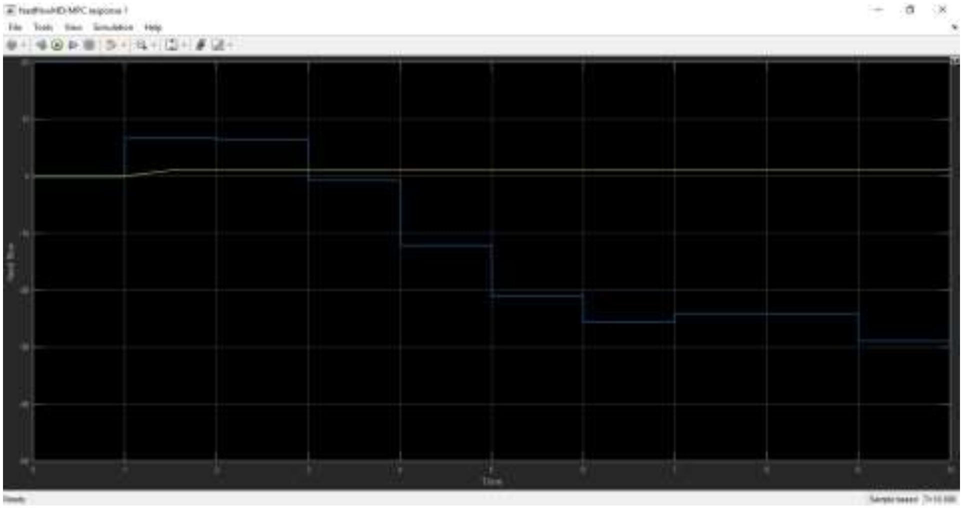

Fig. 10. MPC response of plant for rss(3,2,3)

For plant=rss(3,2,4)

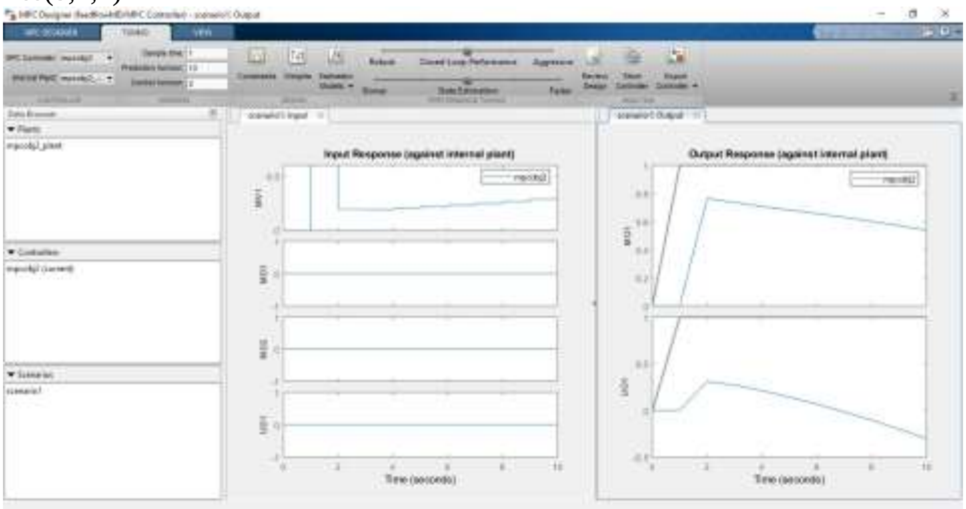

Fig.11. Responses of feedflow model for p=10 and m=5 values

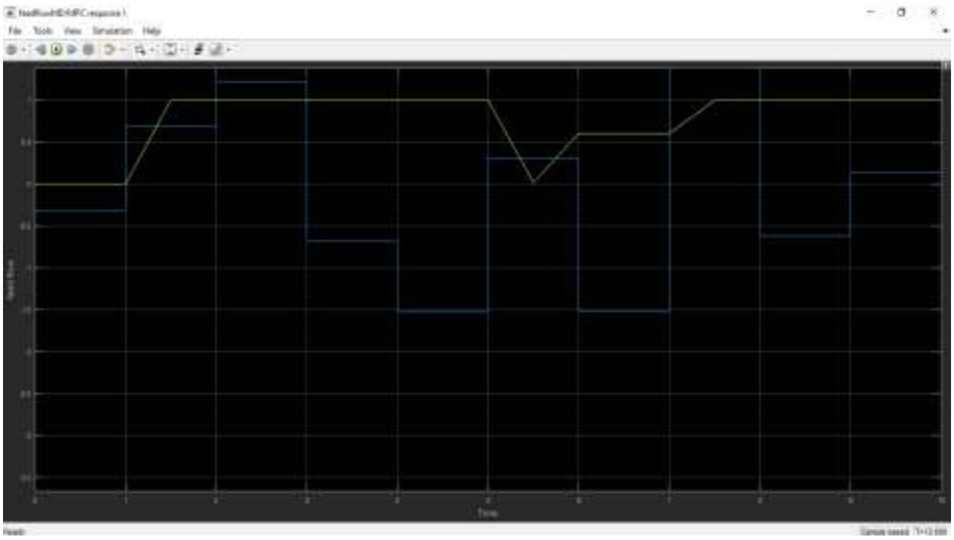

Fig. 12. MPC response of plant for rss(3,2,4)

Figures 11 constitutes mpcdesigner response for plant=rss(3,2,4) and figure-12 is corresponding graphical output.

4.2Responses of multiple MPC blocks

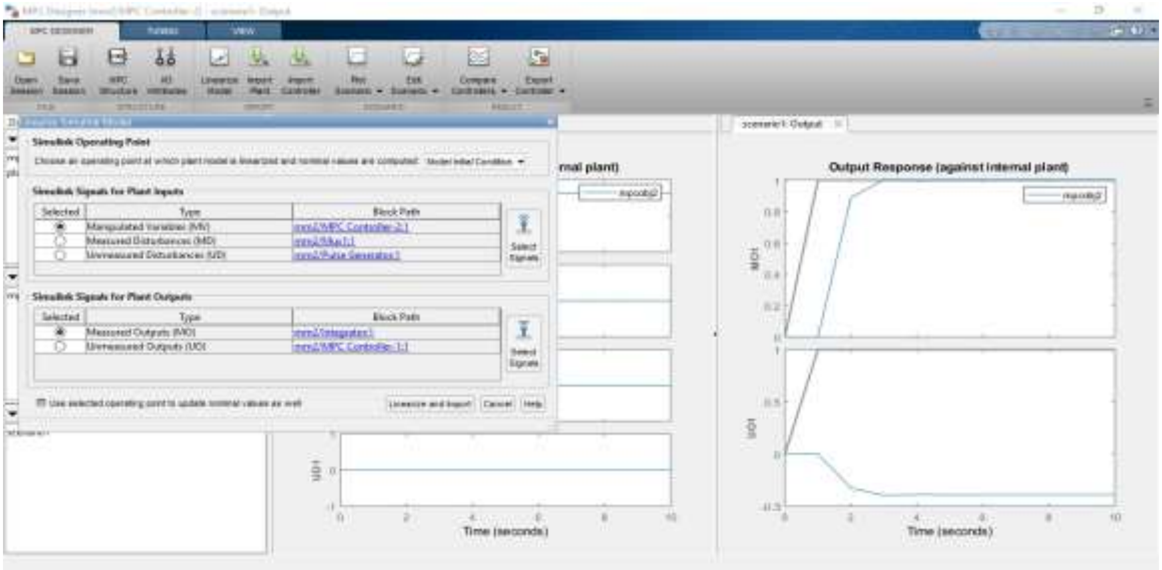

Fig.13mpcdesigner response of multiple MPC model for u2 > = Threshold.

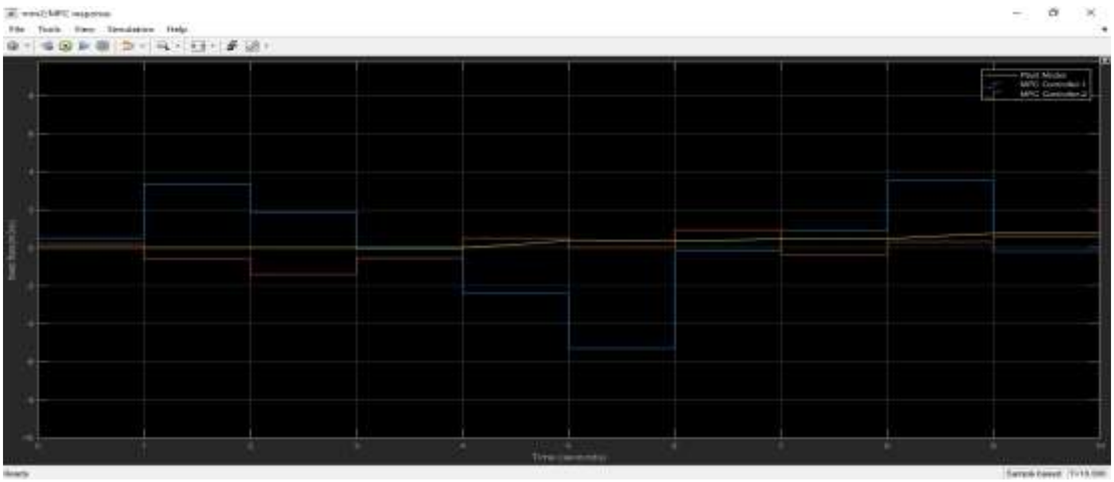

Fig.14. graphical response of multiple MPC model for u2 > = Threshold.

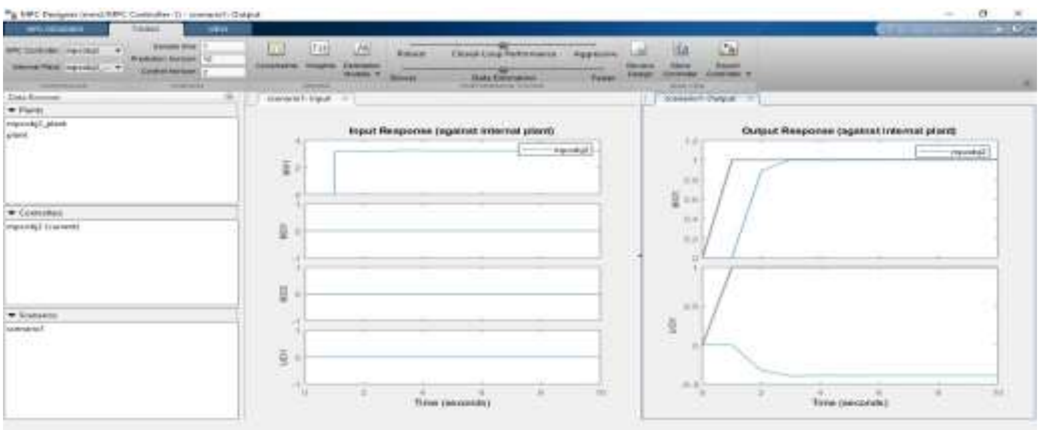

Fig.15. mpcdesigner response of multiple MPC model for u2~ = 0.

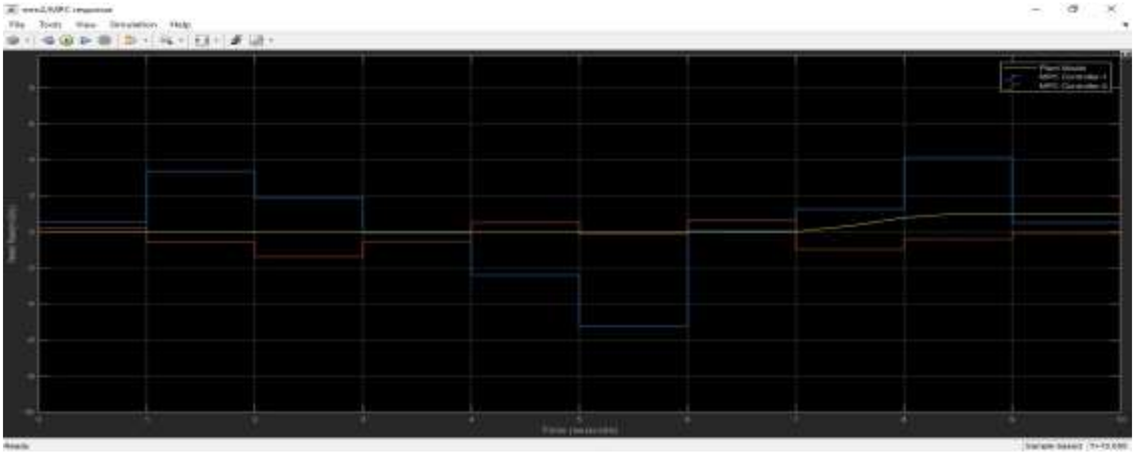

Fig.16.graphical response of multiple MPC model for u2~ = 0.

Figures 14 and 16 relates to graphical display of multiple MPC whereas figures 10 and 12 are denotes graphs of single MPC for contrary plant disturbance conditions. It is clearly observed that settling time of PWM output is different in all four cases that are mainly dependent on variations in MPC structures.

5. CONCLUSION

In this paper the responses of a plant resembling centrifuge separator for single and multiple MPC blocks are observed. Similar inputs are provided for both controllers and plant but the main difference is with multiple MPC modelling that contains switching between two MPC blocks for different plant variables and threshold conditions. This prototype modelling can be implemented for real-time handling of centrifuge separators to obtain desired reactions efficiently and effectively

6. REFERENCES

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