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MPC Control of Stirred Tank Heater with Multiple Operating Conditions

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Abstract- **Stirred tank heater is used in many chemical processes. Often tank is heated, either by a coil or a jacket surrounding the tank. The temperature in the tank is maintained by the flow rate of a fluid through the jacket. Here the basically four input but out of four one input act as manipulated variable (jacket flow rate), others are taken as unmeasured disturbances. And there are two outputs, out of which tank temperature is maintained at desired value. Model Predictive Control (MPC) uses the dynamic state of the process and calculates changes in the independent variable. The objective is to calculate Independent variables (1) Develop the nonlinear dynamic model of a perfectly mixed stirred tank heater, (2) develop the LTI model of stirred tank heater, (3) Use MATLAB for simulations and show the dynamic of stirred tank heater at multiple operating condition.**
Keywords: - MPC, Stirred Tank Heater, Modelling equations, State Space, LTI

I. INTRODUCTION

The models used in MPC are generally intended to represent the behaviour of complex dynamical systems. The additional complexity of the MPC control algorithm is not generally needed to provide adequate control of simple systems, which are often controlled well by generic PID controllers. Common dynamic characteristics that are difficult for PID controllers include large time delays and high-order dynamics. And MPC also Handel the plant constraint. MPC models predict the change in the dependent variables of the modelled system that will be caused by changes in the independent variables. In chemical process, independent variables that can be adjusted by the controller is often either the set points of regulatory PID controllers. Or the final control element. Independent variables that cannot be adjusted are used as disturbances. Dependent variables in these processes are other measurements that represent either control objectives or process constraints.

MPC uses the current Plant (Stirred Tank Heater) measurements, the current dynamic state of the process, the MPC models, and process variable targets and limits to calculate future changes in the independent variables. Stirred Tank Heater are used in many Chemical Process. This stirred tank heater is heated, either by a jacket surrounding the vessel. The objective is control the temperature of the vessel at desired value at multivariable operating condition. Here use the flow rate of a fluid through the Jacket as manipulated variable which is constrained.

II. DYNAMIC MODELLING OF PLANT

Consider a Stirred Tank Heater where the tank inlet steam is received from another process unit. The objective is to raise the temperature of the inlet steam to a desired value. Before drive the mathematical model, we have some assumptions which are we take for mathematical modelling.

- Consider constant volume with constant liquid density and heat capacity.
- Assumed Perfect Mixing in both Tank and Jacket.

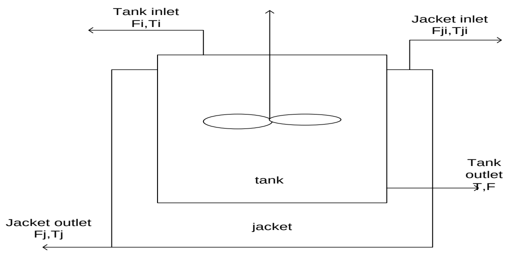

Figure 1: stirred tank heater

III. BASIC MODELLING EQUATIONS

- **Mass Balance Equation.**
- **Energy Balance Equation.**

1. Mass Balance around Tank

$dV\rho/dt = F_i\rho - F\rho$ (1)

$dV_j\rho/dt = F_{ji}\rho - F_j\rho_j$ (2)

2. Energy Balance Around Tank:-

$V\rho C_p\, dT/dt = \rho F C_p\,(T_i - T) + Q$ (3)

$V_j\rho C_{p\,j} dT_j/dt = \rho_j F_j C_{pj}\,(T_{ji} - T) - Q$ (4)

Derived Modeling Equation:-

$dT/dt = F/V(T_i - T) + UA(T_j - T)/VC_p\rho$ (5)

$dT_j/dt=F_j/V_j(T_{ij}-T_j)-UA(T_j-T)/V_jCp_j\rho$ (6)

Where V = Volume of Tank

V_j = Volume of Jacket

ρ = Density of fluid in Tank

ρ_j = Density of fluid in Jacket

F_i = Inlet flow rate of steam through tank

F = Outlet flow rate of steam through tank

F_{ji} = Inlet flow rate of fluid through jacket

F_j = Outlet flow rate of fluid through jacket

T_i = Inlet Temperature of Tank

T_{ji} = inlet Temperature of Jacket

T = Temperature of Tank

T_j = Temperature of Jacket

$Q = UA(T_j-T)$

where U = universal coffecient of heat constant

A = Area of contact

After getting the equation 5 & 6 we make a dynamic model of stirred tank heater which show their input and output variable as shown in Figure 2.

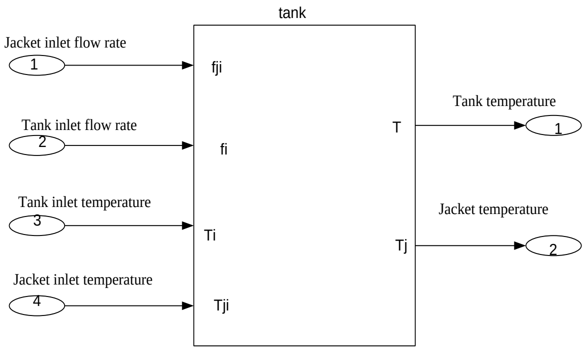

Figure 2: Tank-inout

IV. Develop the LTI model of tank heater

As per concern the the MPC is familiar with the linear model so develop the LTI model by using the linmod command apply on tank_inout model

[a, b, c, d] = linmod('tank_inout', x0, u0);

tank=ss(a,b,c,d);

here the tank is the LTI model of non-linear stirred tank heater which is use in the MPC control.the tank is a state space form of stirred tank heater.

V. MPC control of stirred tank heater

As taking the initial the value of tank temperature And jacket temperature we modeling the model of stirred tank heater. The model has four inputs the one is manipulated variable (flow rate of jacket) and other are unmeasured disturbances. There are two outputs which is tank temperature and other one is jacket temperature. The our objective is to control the tank temperature from initial value to desired value. Here manipulated variable is constrained. Taking the value of the disturbances value:

Tank inlet flow rate = 1 ft^3/min

Tank inlet temperature = 50 °F

Jacket inlet temperature = 200 °F

After taking these values we simulate the stirred tank heater using MPC. As the Simulink diagram as shown in Figure 3.

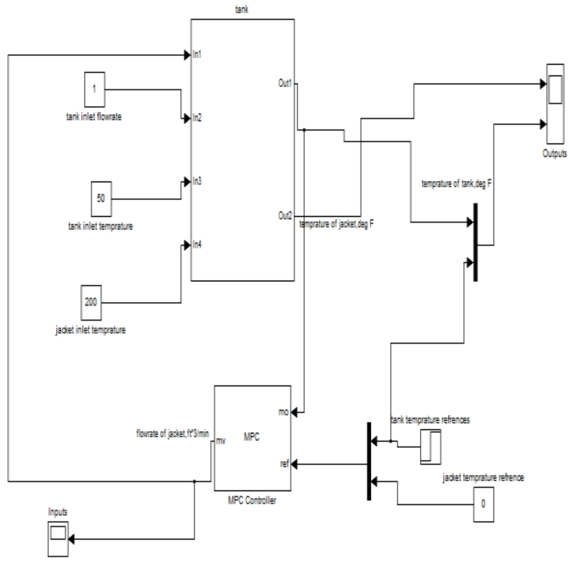

Figure 3: simulation diagram of MPC control

VI. RESULT

After simulation we get output waveform and manipulated variable wave form. Here our initial value of tank temperature is 125 and desired value is 135. Then our result waveform show the dynamic of stirred tank heater

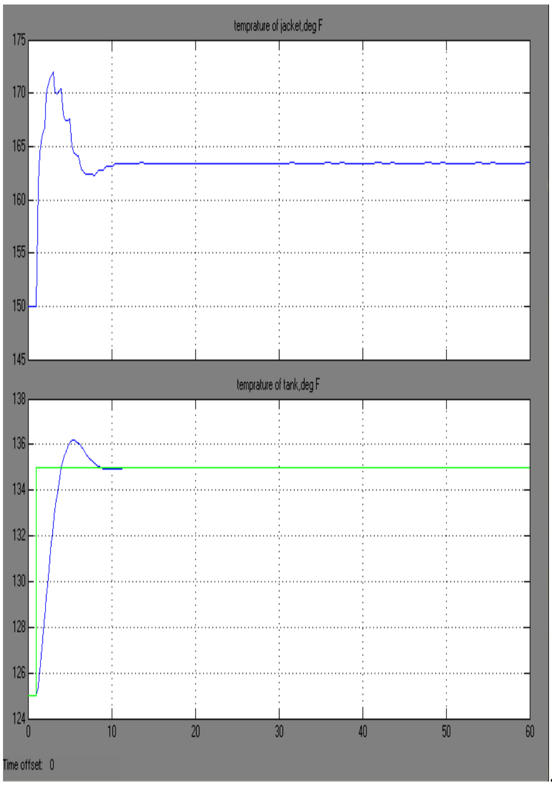

Figure 4 : Output wave form

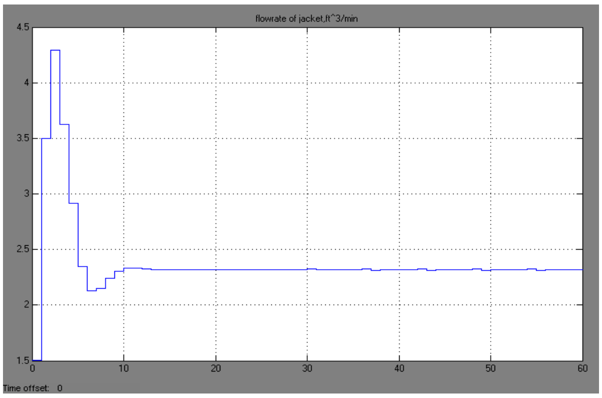

Figure 5: Waveform of manipulated variable

As the plant dynamic is shown in result waveform for the given parameter. As the change in any parameter the change in dynamic is shown in results as shown below:

Change in tank flow rate (1 to 1.2)

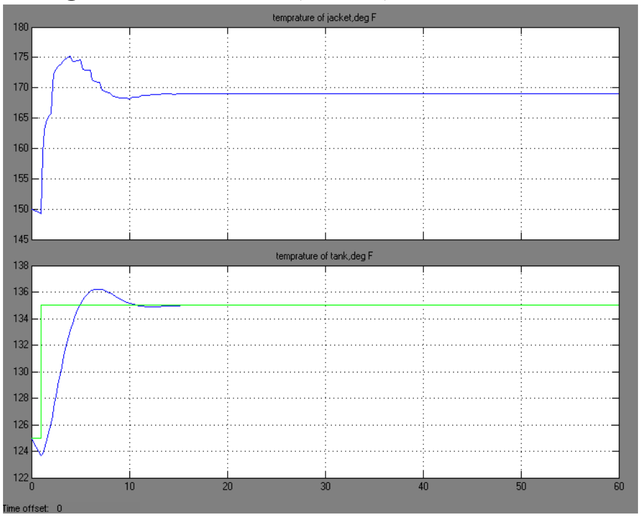

Figure 6: Output waveform after change in tank inlet flowrate

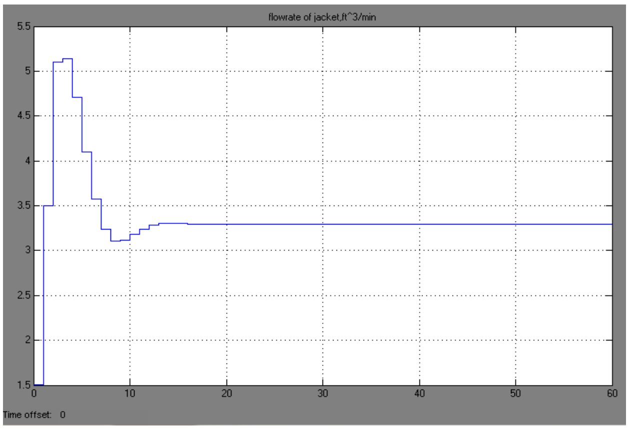

Figure 7: Manipulated waveform after change in tank inlet flowrate

Change in tank inlet temperature (50 to 55)

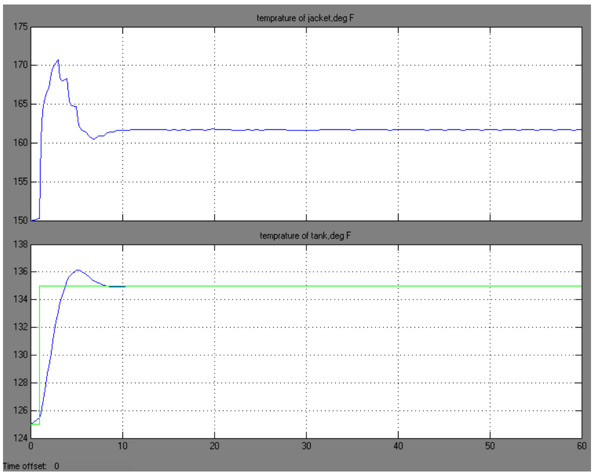

Figure 8: Output waveform after change in tank inlet temperature

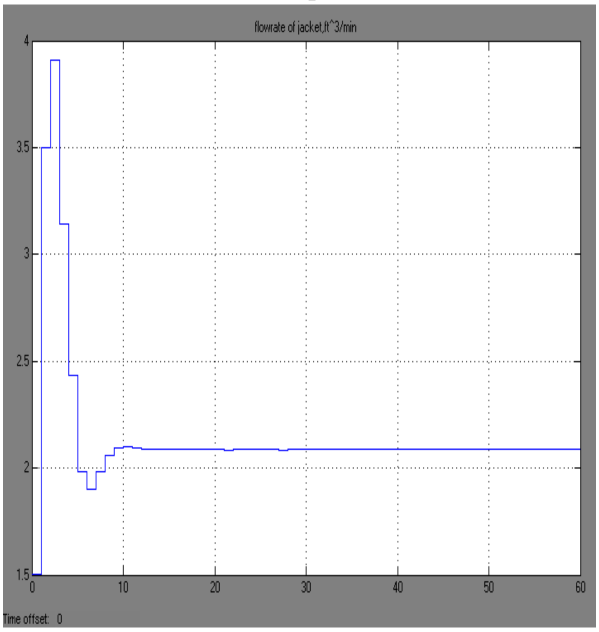

Figure 10: Manipulated waveform after change in tank inlet temerature

Change in jacket inlet temperature (200 to 220)

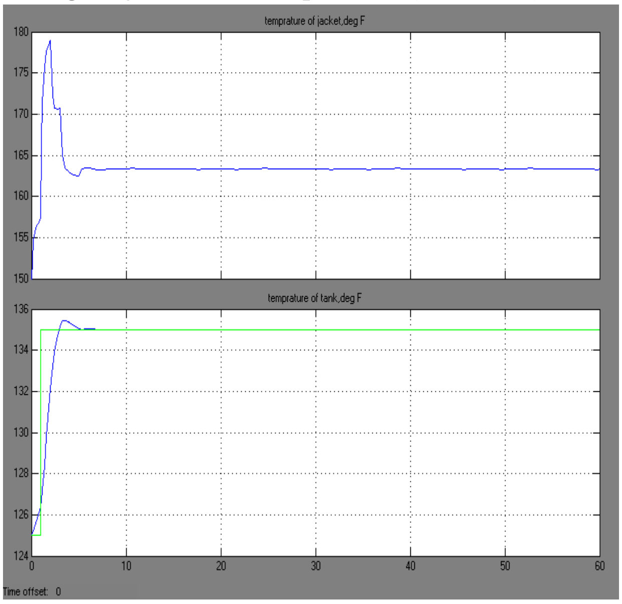

Figure 9: Output waveform after change in jacket inlet temperature

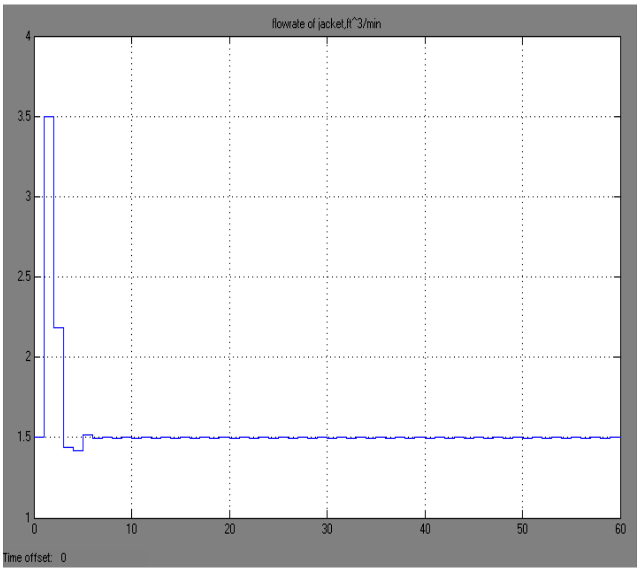

Figure 11: Manipulated waveform after change in jacket inlet temperature

VII. CONCLUSION

The objective of the project to control the temperature of the tank in non-linear stirred tank heater without abolished the plant constraint. Here the manipulated variable is constrained. In the simulation result the plant objective is achieved at various operating condition. As we apply the various operating condition, the plant dynamic is changed but the tank temperature is maintained at the desired value without abolished constraints. After analysis the result we can say that MPC controller can processes with large number of manipulated and controlled variables. Allows constraints to be imposed on both manipulated variable and control variable. Hence we can say that MPC controller Control the output variable of non-linear plant without abolishing the plant constraints.

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