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Wireless Automation of Continuous Stirred Tank Reactor Process using Labview and Arduino

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Abstract: - **In many chemical process industries continuous stirred tank reactor plays a major role to provide the final end product with maintaining temperature, level, flow and pressure at its pre specified set point trajectory. Controlling those physical parameters are difficult because of its nonlinear behavior. The model has heat and volumetric balances, and a very realistic feature is that instrument, actuator and process non-linearity's have been carefully measured, for instance, to take account of the volume occupied by heating coils in the tank. Experimental data from step testing and recordings of real disturbances are presented. The model in Simulink and the experimental data are available electronically and some suggestions are given for their application in education, system identification, fault detection and diagnosis. The performance of the CSTH process has improved and the parameters are maintained at their desired level of the set points with minimum Integral Square Error (ISE), minimum rise time, minimum peak overshoot and minimum settling time. The real time plant is interfaced with LabVIEW with NI data acquisition card, Zigbee based wireless data transmission and the experimental results are discussed in this proposed work.**

Key words: - **Disturbance; Experimental validation; First-principles model; Hybrid model; Lab VIEW; Performance analysis; System identification; Zigbee.**

I. INTRODUCTION

The continuous stirred tank heater (CSTH) is a source for the study and control. Control of its considerations is a very essential task. It is necessary to keep the volume, temperature and density of the mixed of cold water in the desired limits. The distinction may lead to many terrible things causing injury to the people and surroundings. A CSTH is a well stirred tank into which the flows continuously and then the product passed out. It can be clear to have a reacting tank and that rotates continuously when the process carried out. Due to easy implementation and benefit of PID controller, it is executed in the design of CSTH process to progress the system's transient response for zero steady state error in addition to minimizing the settling time and the peak undershoot and overshoot.

II. FIRST PRINCIPLE MODELS

The equations of the process reactions are heavily non-linear because which includes bilinear multiplies of temperature, Composition and flow rates (cold water, hot water). Other experts have some other contributions towards dynamics of a reactor with a cooling jacket

2.1 LINEAR DYNAMI MODEL

Mass & Energy balance of the process dynamics are given by the following equations

$$\frac{dv(l)}{dt} = fwc + fwh - fo(l)$$

$$\frac{dy}{dt} = Wst + hwh + lwhfwh + hwc\ lwcfwc - houtloutfo$$

Where,

l -	Denotes level
V -	Volumes of water
fwh	-Hot water flow
fwc	-Cold water flow
fo -	outflow
H -	Heat rate (total enthalpy)
hwh	-Specific enthalpy of hot water
hout	-Specific enthalpy of outlet water
lwc	-Cold water density
lwh	-Hot water density

The temperature of cold and hot water set to 25 and 55 respectively.

2.1.1 THERMODYNAMICS PROPERTIES

The flow rate at steady state operating point is 450

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LPH; temperature of the cold water inflow is 25 with specific enthalpy of 110.1KJKg-1 and density of cold water is 1000.2 Kg/m3.
Wst = hout lout fo – hwc lwc fwc … (2)

Where, fwc = fo is in steady state

2.1.1.1 Assumptions for under non-steady state

(i) The temperature of the outflow from the tank is equal to temperature of the water inside the tank because the tank is well mixed using stirrer.

(ii) Heat transfer rate is not depends on water temperature inside the tank.

(iii) Steam condenses of that particular circumstance do not arise when steady gas to waste.

2.1.2 ZIGBEE BASED WIRELESSTRANSMISSION

The wireless transmission in the CSTH, controlling the level and temperature consist of two modules. Module-1 consists of the field process station along with the Zigbee router. Module-2 consists of PID controller with zigbee coordinator. The field values of level and temperature from the process station is transmitted wirelessly to the PID controller by means of Zigbee. The Zigbee router and coordinator are interfaced in such a way that those two modules can only transmit and receive data's in full duplex manner. The level and temperature value from the field is transmitted to zigbee router then to Zigbee coordinator to PID controller. The PID controller then correlates and adjusts the level and temperature value to the pre-defined set point using kp, ki & kd. The corrected value from the PID controller is transmitted to the process station via Zigbee.

III. CONTROLLER DESIGN

Gain scheduling is a method to control the controllers, which provides satisfactory control for different types of operating point of the system. The standard conventional form of PI controller is,

$$C(S) = K_C \left(1 + \frac{1}{\tau_{ic}} + \tau_D S\right) \ldots (3)$$

Kc = Propotional gain

i = Integration time

D = Derivative time

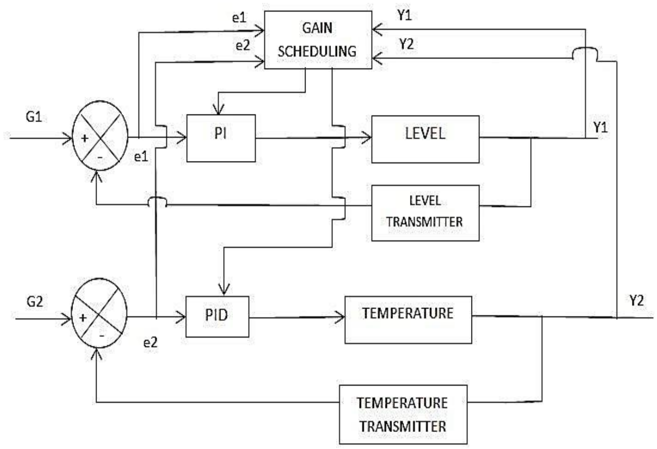

Figure.1 Automatic gain scheduling Controller Design for CSTH Process

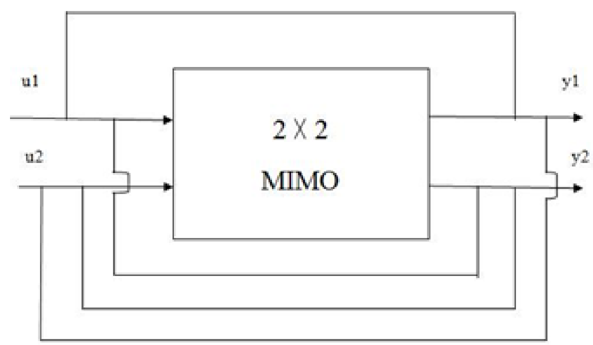

*Figure.2 General structure of 2*2 MIMO System*

I/P Valve movement in (mA)	Temperature of the water inside the tank (°C)	Specific enthalpy h_{out}(kg/m³)	Density of water (l_{out}) (Kg/m³)	Steady state heat transfer (W_{st}) (KJ/S)
4	25	110.1	1000.2	0
6	31.2	137.3	998.1	2.15
8	37.5	164.6	995.9	4.5
10	43.75	192	993.8	7.2
12	50	219.4	991.6	9.5
16	56.3	246.8	987.4	10.6
18	68.8	301.6	985.3	12.8
20	75	329.1	983.2	14.4

TABLE II PERFORMANCE METRICS WITH RESPECT TO CONTROLLER PARAMETER

Tuning Method	Gain (Kc)	Integral Gain Time (K_i / T_i)	Derivative (K_d)	Integral Square error (ISE)	Rise Time (sec)	Settling time (sec)	Over shoot (%)
Ziegler Nicholas	11.5	1.7	1.1	52.26	5	50	80%
Cohen-coon	10.2	2.5	0.36	93.54	4	60	90%

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IV. RESULTS AND DISCUSSION

For level set point=16mA and the corresponding Control Valve PID output is 13.34mA shown in Fig.3

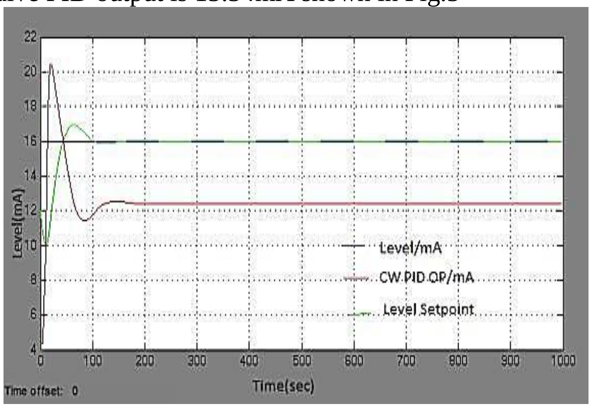

Figure.3 Simulation graph for Level control

For Temperature set point=12mA and the corresponding Steam Valve PID output is 13.72mA shown in Fig.4

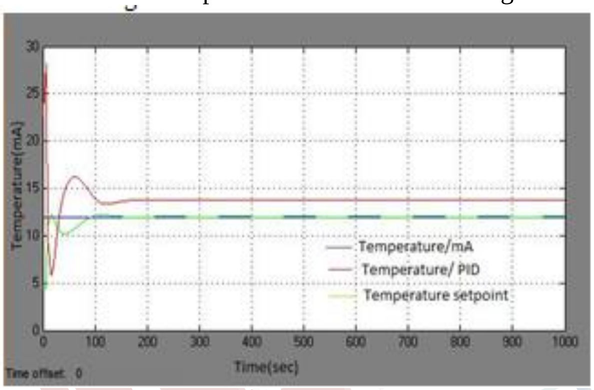

Figure.4 Simulation graph for Temperature control

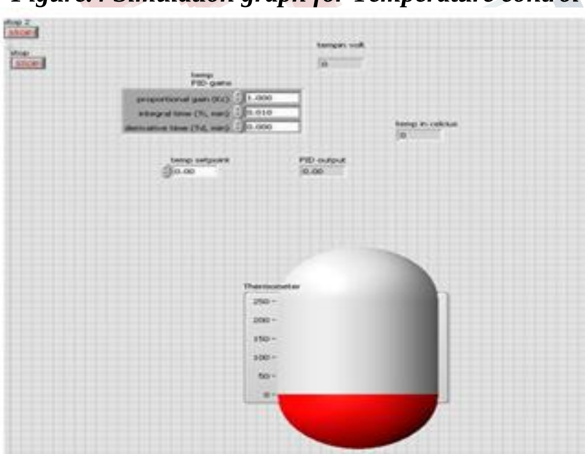

Figure.5 Simulation graph for Temperature control Front panel diagram of LabVIEW for continuous stirred tank reactor.

Figure5 shows the front panel structure of LabVIEW program for controlling temperature in CSTH process

Figure.6 Zigbee Implementation

Figure.7 Experimental setup of CSTH Process

V. CONCLUSION

The experimental results show that the proposed controller is having better set point tracking capability rather than the conventional controller. The performance of the CSTH process has improved and the parameters are maintained at their desired level of set points with minimum Integral Square Error (ISE), rise time, peak over shoot & settling time. From the experimental data it is clearly shows that, by using this proposed algorithm the overall feedback cost function of the process are reduced and the quality of end product the process has been increased.

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