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Wireless Monitoring and Control in Continuous Stirred Tank Reactor for Liming Process in Sugar Industry.

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ABSTRACT

A continuous stirred tank reactor (CSTR) is a closed vessel used in various process industries like Sugar, paint, pharmaceutical, beverages etc., for producing different chemicals. The chemicals in CSTR are heated and stirred continuously for better chemical reaction. In this work, a working model of a CSTR is designed for mixing lime water with sugar cane juice for the liming process in the sugar industries. In this system two crucial and important parameters like temperature and level is measured, controlled and monitored. The working model consists of heating element at the bottom of the CSTR and Resistance Temperature Detector to measure the temperature. The level is measured by using the resistive type level sensor. These measured values will be displayed continuously in the local display unit. The measured value is transmitted using RF module CC2500 to the control room, where the data is monitored in the LabVIEW. If the temperature value exceeds the set point the relay control unit switches ON/OFF the heating element. The level is controlled by the solenoid valve at input side of the CSTR. Both these parameters are controlled by the PIC microcontroller 16F877A which acts as a local control unit.

Keywords: LabVIEW, PIC Microcontroller, CSTR, Liming Process, Wireless Communication

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INTRODUCTION

In sugar industries, the sugar juice extracted from sugar cane is in dark green colour and acidic nature (pH around 5). To remove the soluble, insoluble impurities and to avoid sucrose and fructose separation in the sugar juice. For this purpose lime is mixed with sugar juice to neutralize the acidic nature along with heating (Liming Process). The mixture of lime and sugar juice is heated around 100ºC and passed to other process like crystallization and centrifugaling process. This liming process is taken place in the CSTR.

CSTR is a vessel in which two different chemicals are mixed in specific proportion and heated continuously to produce a new solution. In this arrangement stirrer is mounted at the top of CSTR to avoid the chemical deposition at bottom and for even heat distribution in the reactor. In CSTR various parameters like temperature, level, pressure, flow etc can be measured, among these parameters level and temperature are crucial parameters to monitor and control. If the level of fluid in the CSTR drops below the threshold level it leads to damage in heating coil and the temperature is important parameter to achieve better efficiency in CSTR. Many different types of control strategies were available to control the temperature of CSTR, in the work [6] fuzzy logic based control strategy is implemented which has higher accuracy and faster response. Whereas in lime process the temperature should be maintained around 100ºC, its not a specific value. So in this proposed work simple ON/OFF control strategy is implemented.

To monitor these parameters PLC or MATLAB based control system is being used. These data's are transmitted to the control room through wired medium. Now-a-days the Homes [1], Construction Sites [2] and industries [3] are slowly replacing the conventional sensors and controllers with smart devices for better performance. So in the proposed work the data's are transmitted on wireless medium. To monitor the data in control room SCADA, LabVIEW [4], [5] etc based Human Machine Interfaces (HMI) are used. Here the HMI is developed using LabVIEW for user friendly purpose. To measure, transmit and control the parameters PIC microcontroller is used.

Hardware Description

To measure the temperature, RTD (Resistance Temperature Detector) is fitted at the bottom of the CSTR. RTD is preferred before over other temperature detectors because of its linear characteristic and high accuracy. The measuring range of RTD is (-200 to 650) ºC.

The level of CSTR is measured using resistive type sensor which has a range of 20 to 100 Ω. By using suitable signal conditioning circuit the level of CSTR is fixed as 0 to 50 cm. The signal conditioning circuit comprises of Wheatstone bridge and instrumentation amplifier. The Wheatstone bridge has 100Ω resistor in three arms and RTD in another arm. Instrumentation amplifier is designed with gain of 10 to amplify the bridge output to produce voltage in the range of 0 to 5 V.

The 8-bit PIC microcontroller (16F877A) is used in this work to interface the sensors, to display the measured value in LCD, to transmit the measured values to HMI using wireless module and to control the level and temperature values.

The ADC module in the microcontroller converts the analog signals from the sensors to 10bit digital value. The measured value is transmitted from microcontroller to the control room via zigbee module (CC2500).

CC2500 wireless module transmits the data's either in broadcasting or point to point modes. The data will be transmitted / received at the baud rate of 9600 per second in the default mode. It covers the distance of 10m for communication.

In the control room the data is monitored in the LabVIEW software which acts as a HMI. In the receiver end the CC2500 is interfaced at the COM port of the CPU. To read and write the data from the user VISA (Virtual Instrumentation Software Architecture) tool is to be configured in the LabVIEW.

If the microcontroller detects any abnormal behavior in the parameter it performs the control action over the particular parameters. Level of CSTR is maintained by controlling the outlet flow of the CSTR, the

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algorithm for level control is discussed below. For controlling the outlet flow Normally Closed type Solenoid valve is implemented in this work.

Level Control Algorithm:

Step 1: Read the level value periodically
Step 2: Compare the level value with reference value
Step 3: If Level < reference
    Close the Outlet Solenoid valve of CSTR
Step 4: Else
    Open the Outlet Solenoid valve of CSTR
Step 5: Goto Step 1

Similarly the temperature of the CSTR is controlled by turning ON/OFF of the heating coil.

Temperature Control Algorithm:

Step 1: Read the temperature value periodically
Step 2: Compare the value with reference
Step 3: If Temperature < reference
Switch ON the Heating Coil
Step 4: Else
    Switch OFF the Heating Coil
Step 5: Goto Step 1

The figure 1 indicates the different circuit blocks available in the proposed system.

RESULTS AND DISCUSSION

The figure 2 shows the simulation output of the proposed system in the Proteus software. Since the LabVIEW software is used as HMI the front panel and block diagram panel is shown in the figure 3 and figure 4. In this work, the CSTR is developed with the necessary accessories to monitor and control the process. The figure 5, figure 6 and figure 7 shows the hardware arrangement of the system. The figure 8 and 9 shows the comparison graph between theoretical and practical value of the designed system.

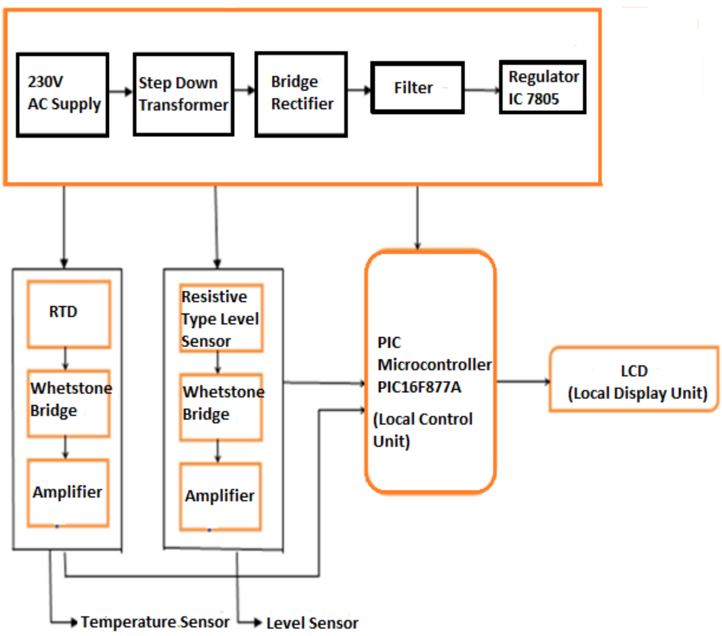

Figure 1: Circuit Block Diagram of the Circuits

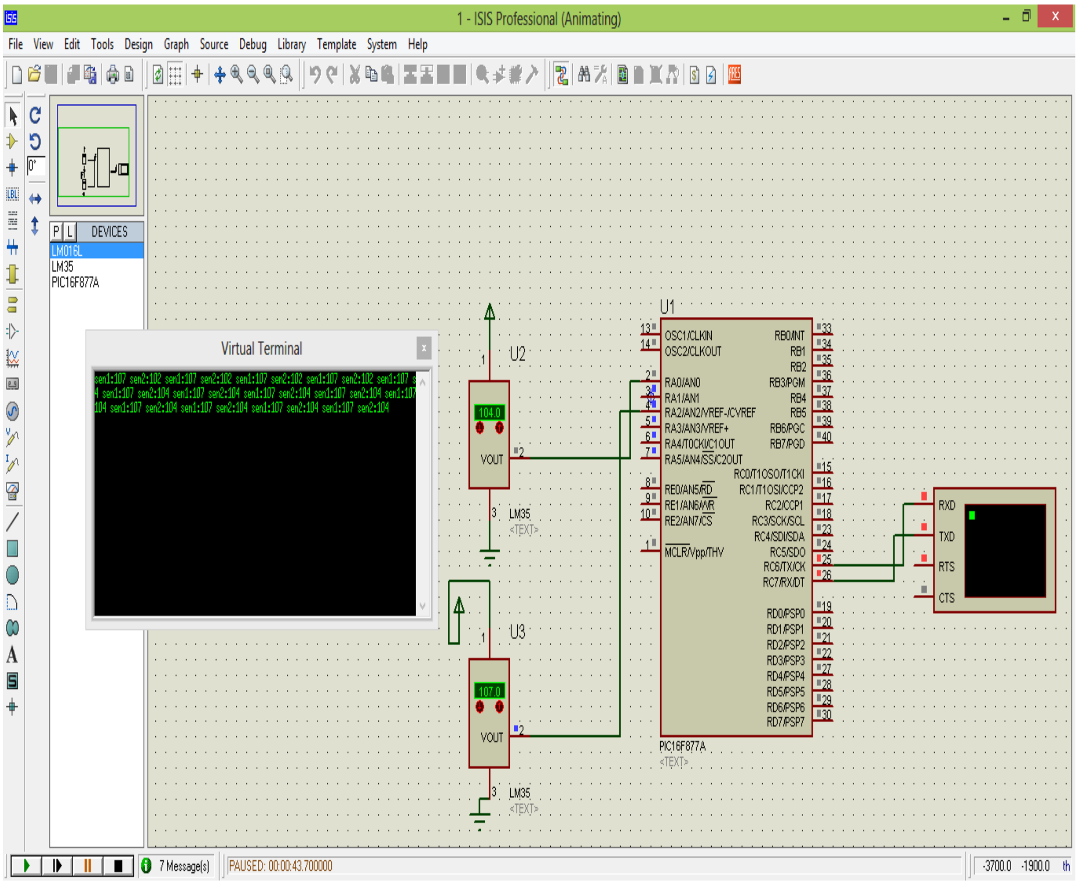

Figure 2: Simulation output of the proposed system

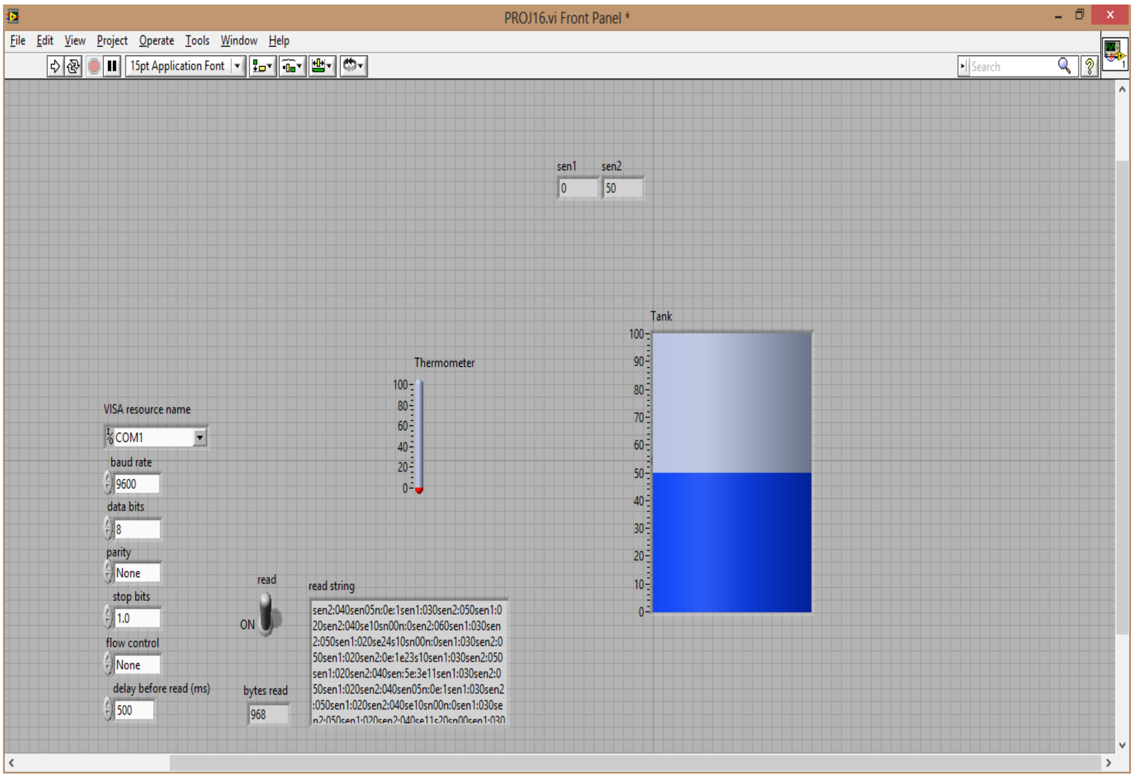

Figure 3: Frontpanel window of the LabVIEW

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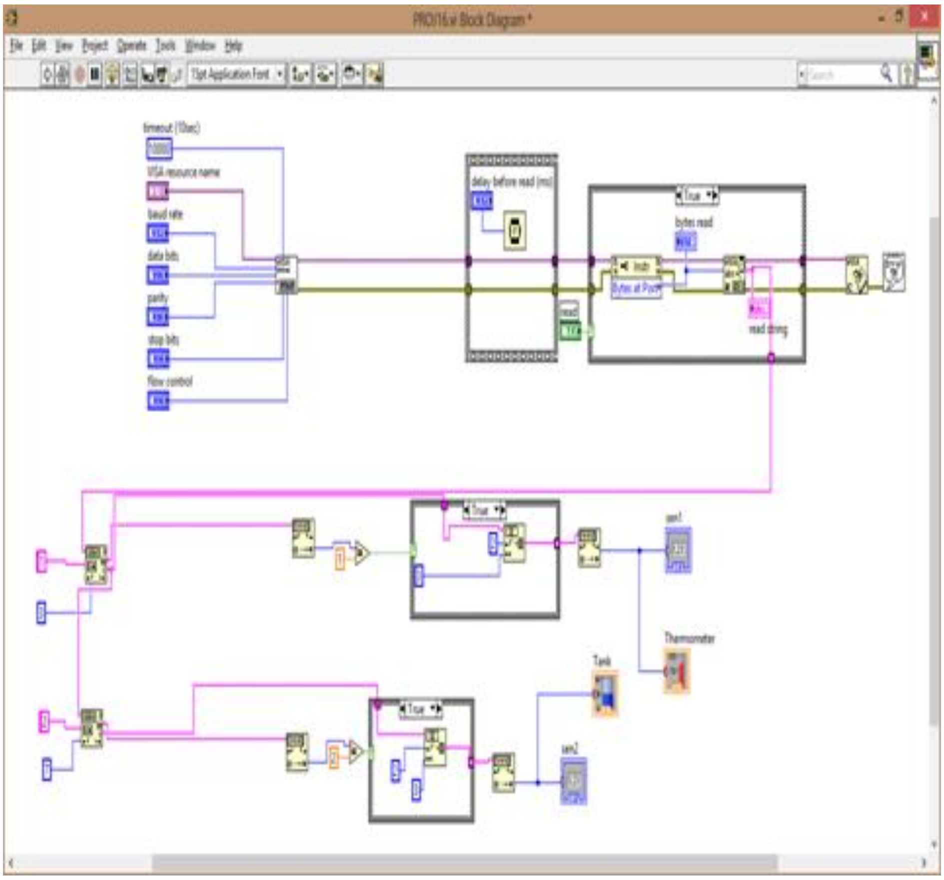

Figure 4: Block diagram window of the LabVIEW

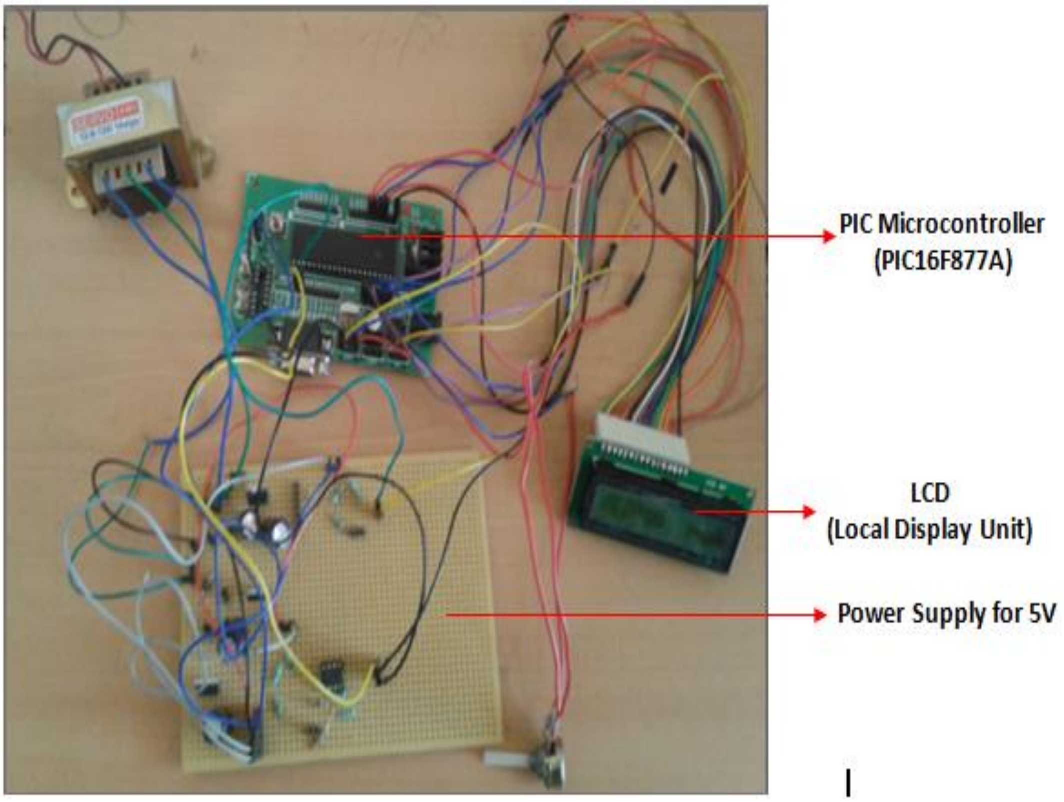

Figure 5: Local control and display unit of the CSTR

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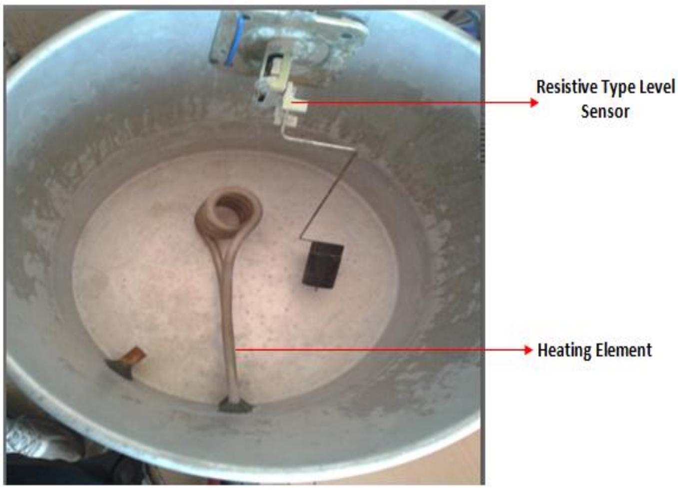

Figure 6: Designed CSTR with heating coil and resistive type level sensor

Figure 7: Overall arrangement of the proposed CSTR

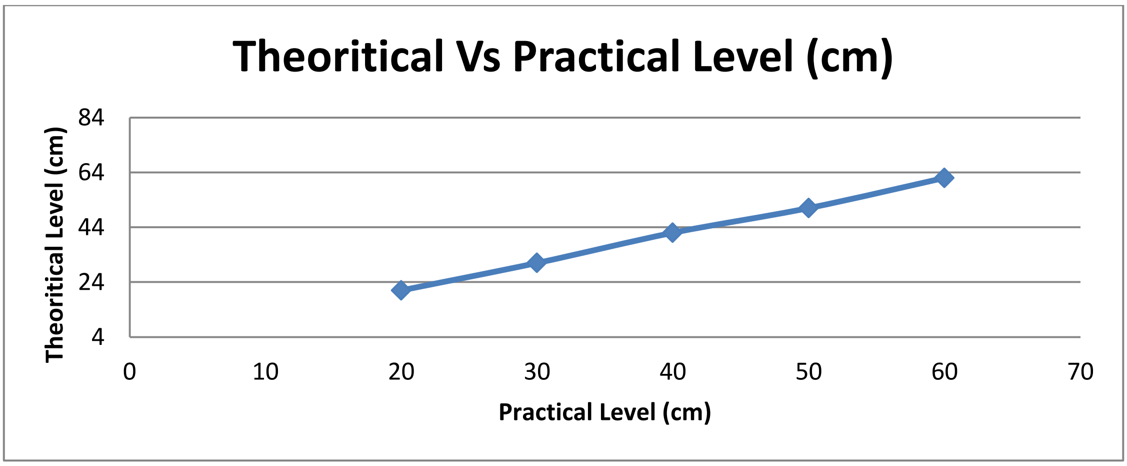

Figure 8: theoretical vs practical level

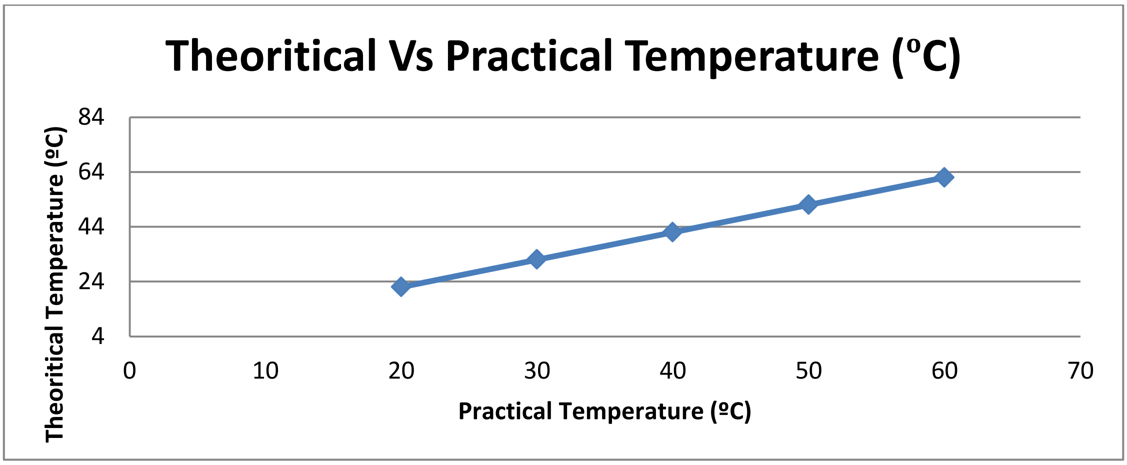

Figure 9: theoretical Vs Practical temperature

CONCLUSION

Prototype model of CSTR is designed using aluminium and two different parameters were measured continuously and displayed on the LCD as a local control unit. The values which are displayed have accuracy in the range of ±1 of actual value. This system developed at low cost and less complexity. The measured parameters of CSTR are transmitted continuously to the HMI through zigbee transceiver. In control room LabVIEW based HMI is developed to monitor the data. If the parameters exceed the set point, microcontroller performs control action over the parameters.

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