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Automation of Level and Temperature Control in Food Industries using PLC and SCADA

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***Abstract*: Automation refers to the controlling of manufacturing processes by the use of automatic equipments and thus introducing minimum human intervention. As a result the product quality and the system accuracy is improved. Saving of energy, material and labor is also achieved. The present paper focuses on the role of engineering in food industries. It exhibits automatic control of level and temperature of a tea powder manufacturing process using PLC. The automation is further enhanced by the interfacing of PLC with the SCADA (Supervisory Control and Data Acquisition) for continuous monitoring. The PLC and the SCADA control technique controls the process parameters quite accurately, and satisfactory results are found. This is a simple example of process automation, which can be applied at industry level as well.**

Keywords: **Automation, PLC, SCADA, SoMachine Basic EL software.**

I. INTRODUCTION

A manufacturing plant requires continuous monitoring and observation at regular intervals. When it is controlled manually, it increases possibilities of errors at measuring level of a process. To overcome such problems concept of automation came into play.

The **SCADA** (Supervisory Control and Data Acquisition) is used to automate a plant and reduces manual labour. The **SCADA** monitors the system and automatically acquires data from field inputs and outputs through PLCs, RTUs (Remote Terminal Inputs) etc. and stores it into its database. These data are further used to analyze the system (Figure 1). **Programmable Logic Controller (PLC)** is a special type of computer used to control machines and processes. It has CPU, memory, IO module like PC. These are designed to sustain in harsh industrial environment and are flexible to interface with the real world inputs and outputs. **PLC** acts as I/O device, through which the SCADA communicates with process inputs and outputs. The CPU of a PLC accepts program logic (sequencing, timing, counting and arithmetic) downloaded from PC, then reads the inputs, executes the program and updates the output (Figure 2).

There are many methods adopted for the process control and monitoring in manufacturing and power plants. Zhao (2011) [2] in his survey on Wireless Sensor Network (WSN) in industrial process control and monitoring, has shown a number of advantages as well as drawbacks of WSN. Benefits are e.g. reduced cost, better performance and easy maintenance etc. and there is no constraint in wiring. But WSN technology is not considered as mature approach in the process monitoring and control due to some limitations. Limitations are with the memory, bandwidth, processing power and constrain in energy capacity etc.

M Usha Rani et al. (2013) [4] has used web based technology for water flow and level monitoring. Sharma et al. (2015) [3] have used GSM technology and SMS service in his project on automation using 8051 microcontroller. Several advantages of this method are: the range of device is very high, operation is simple and easy to use etc. For this approach limitations are such as, sufficient balance or message pack is required and network access is necessary.

Rajaraman et al. (2014) [5] have shown the control and monitoring of process variables using LabVIEW. LabVIEW is not suitable for industry processes, since it has communication handling problem with controllers like **PLC**s etc., issues like data sorting/retrieving from database, alarm handling are among the other problems. Implementation of the **SCADA** using LabVIEW is a cumbersome job.

Kore et al. (2015) [1] have discussed about a microcontroller based wireless monitoring and control of industrial system. ZigBee communication protocol has been used for the communication. ZigBee communication has several advantages like lower power consumption, longer battery life etc. Microcontroller has been used as the main controller, which is of low cost. Still Microcontrollers are not preferred for rugged and rough industrial environment. A microcontroller cannot withstand dusty environment like in cement industry. It cannot work in offshore environment where humidity, corrosion, vibrations etc. are at high levels. Individual ZigBee modules are required to connect with each sensor under study, which involves extra cost.

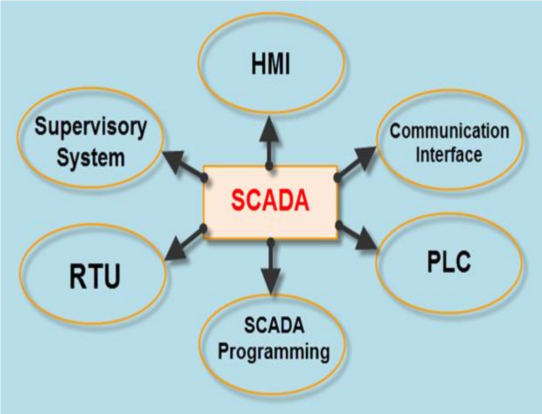


Figure 1: The SCADA basic block diagram [7]

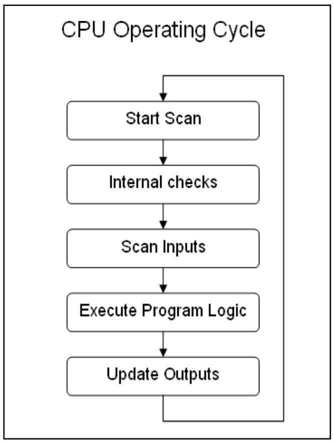


Figure 2: CPU operating cycle of PLC [6]

In the present paper we have considered a tea powder making process. It consists of several stages. Here the prototype of a part of the first sequence, the **Extraction** process has been implemented. For this stage we are controlling two parameters: level and temperature using Schneider Electric M200 PLC and Vijeo Citect SCADA. We are using thermocouple and Ultrasonic sensor to measure the temperature and the level respectively.

II. PROPOSED SYSTEM SET-UP

Figure 3 shows the proposed hardware set-up. The process under consideration is a part of an instant tea powder making process. The system consists of three sensors for level, temperature and flow rate measurement and a heater, conveyor, agitator, solenoid valve, two tanks etc.

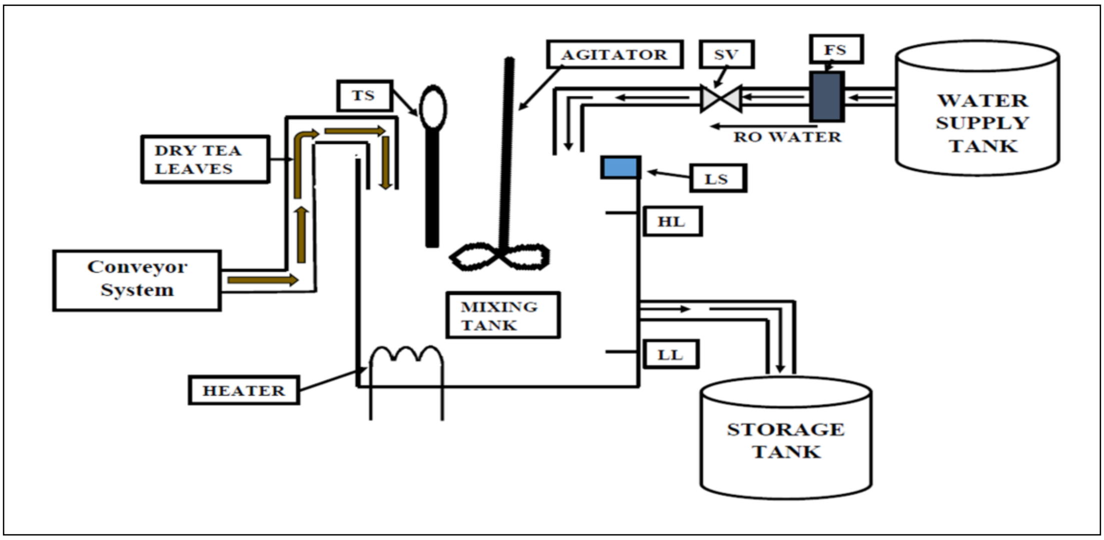


Figure 3: Proposed hardware set-up

TS→ Temperature Sensor
FS→ Flow Sensor
LS→ Level Sensor
SV→ Solenoid Valve
HL→ High Level
LL→ Low Level

Main objective is to automate a process using ladder logic and to monitor different parameters like level, temperature, flow rate and status of the outputs through the **SCADA**. The real time plot of the parameters can also be observed in trend page using Trend Server of the **SCADA**. This page displays the level and temperature graph with respect to time.

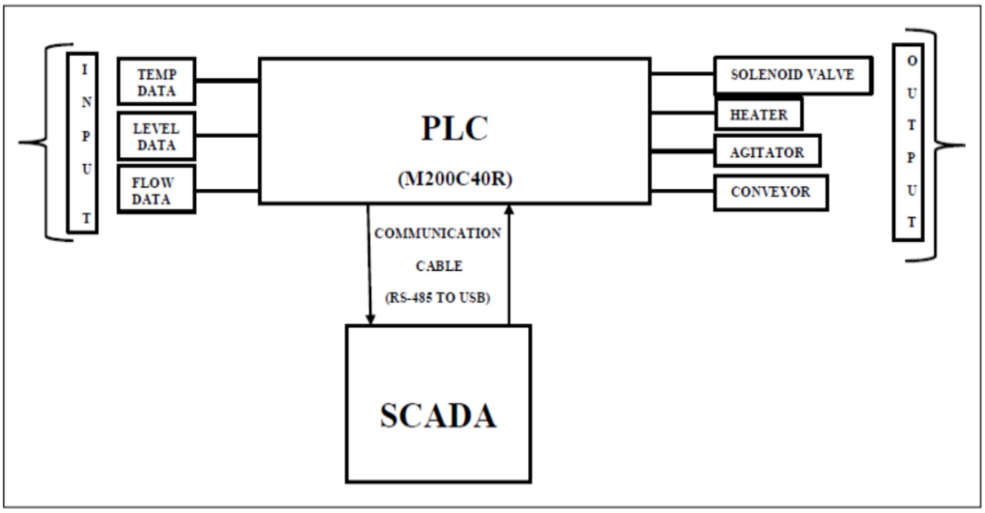


Figure 4: Proposed Block Diagram

The proposed block diagram has been shown in Figure 4. The inputs and outputs to be connected are shown here.

III. HARDWARE IMPLEMENTATION

Figure 5 shows the implemented hardware set-up. TM200C40R PLC from Schneider Electric is used as the main controller. DTC1000 temperature controller from Delta has been used to read the temperature from the thermocouple. Delta SMPS has been used to get 24V DC supply for the temperature controller.

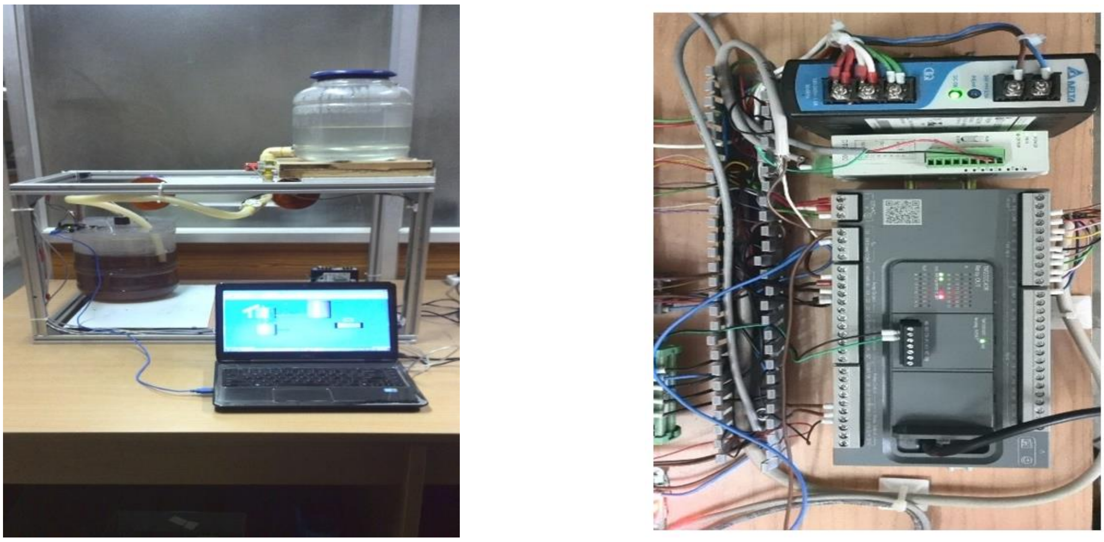


Figure 5: Implemented Hardware Setup

One conveyor system has been set up with 12V DC, 60 RPM motor and an agitator has been designed using 12V DC, 200 RPM motor.

Three sensors has been used: a J type Thermocouple for temperature measurement, an Ultrasonic sensor HC-SR04 for level measurement and a Flowmeter YF-S201 to count the flow pulses. The Thermocouple is inserted into the mixing tank through its lid and the Ultrasonic sensor is mounted on the lid. One zero pressure solenoid valve has been used to make the water flow from the supply tank to the mixing tank and one 500W small immersion heater has been used to heat the water. An analog cartridge TMCR2AM3 of the PLC TM200C40R has been used to receive analog level input from the level sensor.

IV. SOFTWARE IMPLEMENTATION

A. Algorithm

Step 1: Start button is pressed from the SCADA screen

Step 2: The solenoid valve gets on and the water flows from the supply tank to the mixing_tank.

Step 3:The Flowmeter counts pulses when the water flows through it and the water level is measured using the level sensor

Step 4: When the water level reaches the set-point i.e. 24 cm, the solenoid valve gets off, the heater and the agitator turn on and the thermocouple measures the temperature

Step 5: When temperature reaches the set-point i.e. 40 ºC, the heater gets off and the conveyor turns on. Agitator keeps on running to make a uniform distribution of temperature

Step 6: Conveyor runs for 1 minute and the tea leaves are thrown into the mixing_tank during this interval.

Step 7: After 1 minute, the conveyor turns off, but the agitator keeps on running for the proper mixing of the tea leaves.

Step 8: After 1 minute the agitator turns off

Step 9: The system completes one cycle of automation and stops

B. Software details

Ladder Logic Programming Language has been used to program the PLC. For this purpose **SoMachine Basic EL Software** has been used. The programming logic has been set according to the process flow. High Speed Counter (HSC) has been used in the program to count the number of pulses while liquid flows through the Flowmeter. Timers have been used to restrict the running of the conveyor and the agitator. Comparison blocks are used to compare the current value with the set-point (Figure 6).

The SCADA has been used here to monitor the current status of the inputs and the outputs of the process. For this purpose PC and PLC are interfaced using RS-485 to USB communication. Vijeo Citect SCADA 7.20 has been used for the SCADA. To denote each component of the process, tag variables have been created corresponding to the PLC input and output addresses. For communication setting, IO devices (PLC, DTC etc.) are added using Express Wizard. In the present context two IO devices are used, i) PLC and ii) temperature controller. This temperature controller stores the current temperature value in a register with address 1000H or equivalent 4096 Decimal. So for this device %MW4096 has been used in the tag variable address. This device is configured using DTCOM software. Here the communication settings for all the devices communicating with the SCADA has been set as follows,

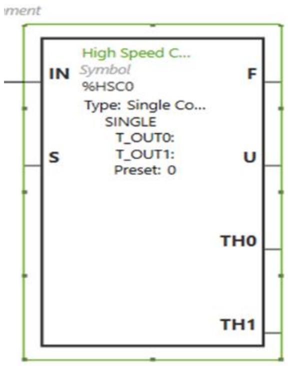
i) Baud rate : 19200

ii) Protocol : Modbus RTU

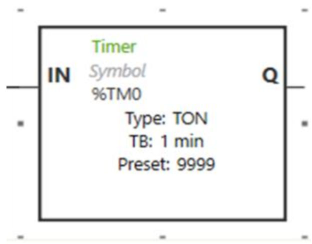
iii) Stop bit : 1

iv) Parity : Even

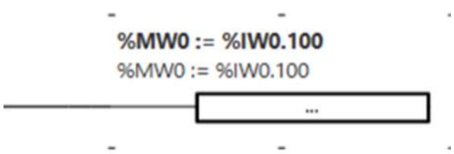
v) COM port 2



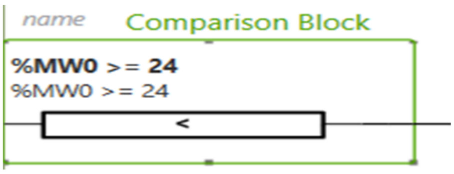
i) High Speed Counter



ii) Timer Block



iii) Operation Block



iv) Comparison Block

Figure 6: Ladder diagram blocks used

C. Analog level sensor design

Ultrasonic sensor (HC-SR04) has been used as level sensor. Level data are acquired from this senor by using Arduino UNO microcontroller. Since output from Arduino is PWM output and the PLC accepts only true analog input. Therefore the output is mapped to make it true analog voltage (0-5V). Then the mapped output of Arduino is provided as input to the PLC through the analog cartridge TMCR2AM3. As a result PLC receives corresponding analog level values from the sensor.

V. PROCESS FLOW CHART

Figure 7 shows the process flow chart.

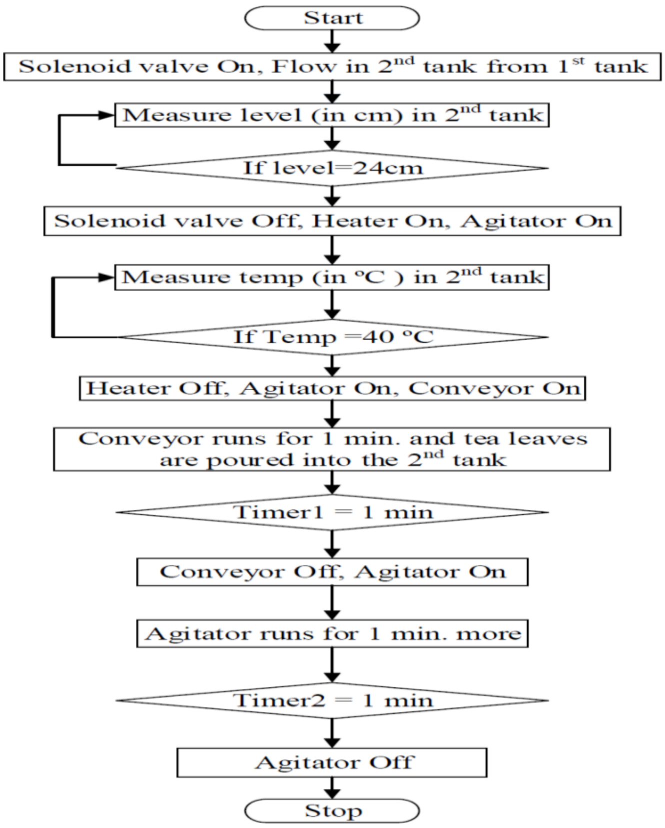


Figure 7: Process flow chart

VI. RESULT AND DISCUSSION

The level and the temperature sensors have been tested using an Arduino microcontroller. The acquired data tables and the corresponding graphs are shown below.

Table 1 represents the variation of the voltage (in volt) with the change in level (in cm) as tested by Arduino.

Table 1: Voltage-Level variation

Level (in cm)	Voltage (in volt)
19.03	2.97
18.26	3.06
17.69	3.15
16.24	3.25

Table 2 represents the variation of the temperature (in ºC) with respect to time (in second) as tested by DTC1000 temperature controller.

Table 2: Temperature –Time variation

Time (second)	Temperature (ºC)
0	31.3
20	36.7
40	42.2
60	50.1

Figure 8 shows the graph of level (in cm) vs the voltage (in volt) as per the data obtained from Table 1. Figure 9 shows the graph of temperature (ºC) vs time (in second) as per the data obtained from Table 2.

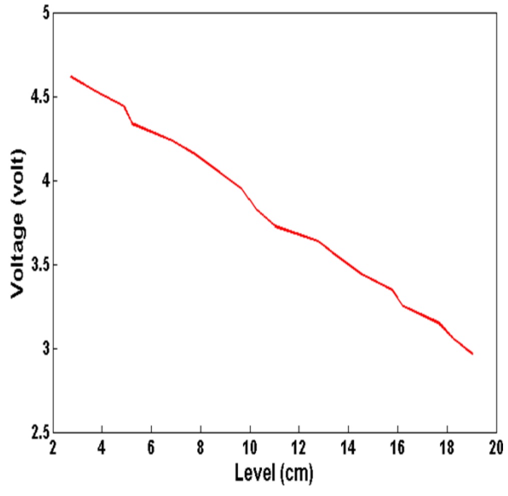


Figure 8: Level vs Voltage plot

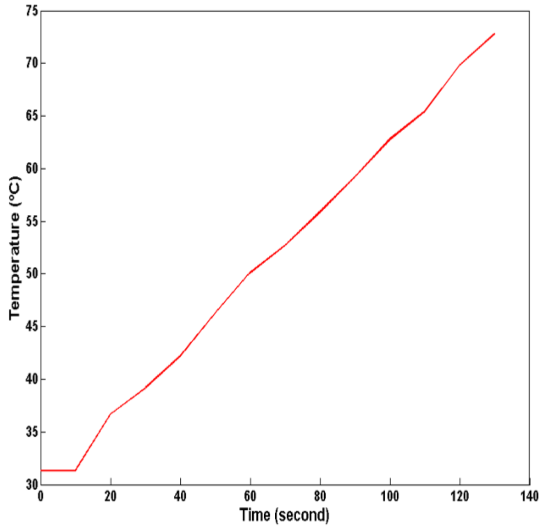


Figure 9: Time vs Temperature plot

Figure 10 shows the graphical user interface screen of the SCADA at 40 ºC set-point. Values of the level (in cm) and the temperature (in ºC) are displayed on the screen. The status of the outputs (heater, agitator, conveyor etc.) are also observed from the screen. The SCADA trend page plots the graph of different parameters on real time data.Trend server has been created to show the real time graph for the level and the temperature. Figure 11 shows the trend graph of the level (in cm) and the temperature (in ºC).

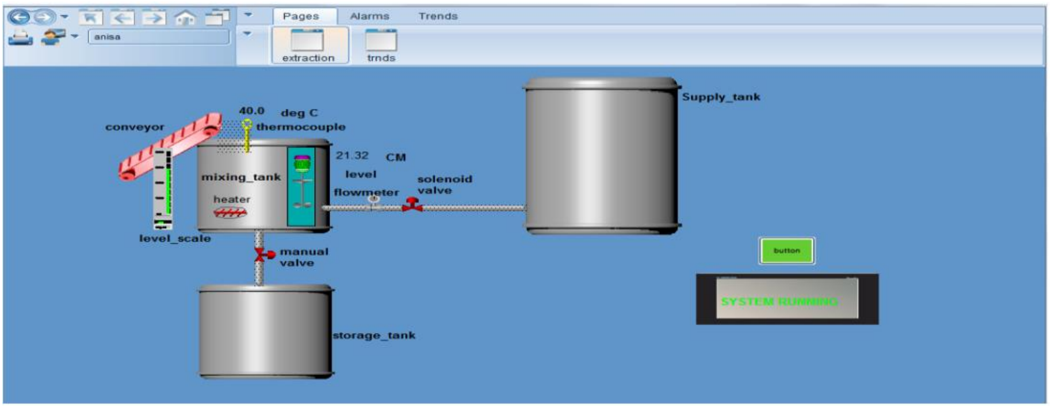


Figure 10: Graphical interface screen at 40 °C set-point

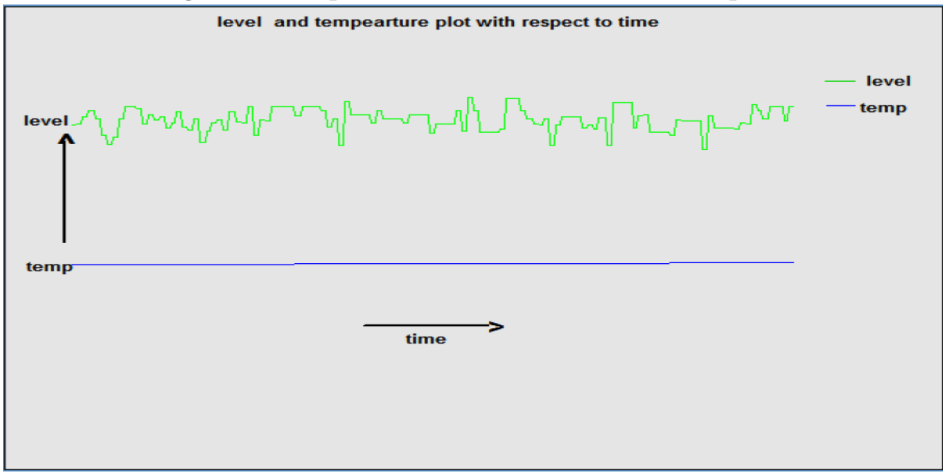


Figure 11: Level and Temperature trend graph

The blue line represents the graph of the level and the green line represents the graph of the temperature. Since the agitator runs continuously the level graph shows frequent fluctuation.

Table 3: Real time Level and Temperature variation during the experiment

LEVEL (cm)	TEMP (°C)
0.0	32±0.1
2.49±0.01	32±0.1
4.99±0.01	32±0.1
7.51±0.01	32±0.1
10.01±0.01	32±0.1
12.49±0.01	32±0.1
14.99±0.01	32±0.1
17.51±0.01	32±0.1
20.01±0.01	32±0.1
22.49±0.01	32±0.1
23.99±0.01	32±0.1
24.0±0.01	32±0.1
24.0±0.01	32.1±0.1
24.0±0.01	32.3±0.1
24.0±0.01	32.5±0.1
24.0±0.01	32.8±0.1
24.0±0.01	33.0±0.1
24.0±0.01	33.2±0.1
24.0±0.01	33.4±0.1

PC is used as the Visual Display Unit (VDU) for the SCADA here. PC is interfaced with the PLC using RS-485 to USB converter. The SCADA graphical interface screen displays the current status of all the inputs and outputs of the running process. The continuously changing current values of the parameters can be observed from the screen. Set-point for the level has been chosen as 24 cm and for the temperature, it is 40 ºC.

VII. CONCLUSION

In the present project the PLC-SCADA communication has been successfully established. Real time monitoring of the process has been achieved. The process for different set-points (32 ºC - 40 ºC) has been checked. The set-point can be changed from the SCADA screen as well as in the PLC programme. The Ultrasonic sensor has been used to design an analog level sensor with the help of Arduino IDE and analog voltage output (0-5 V) corresponding to the level output from Arduino has been given to the PLC through the analog cartridge TMCR2AM3. Thus the cost of ready analog level sensor has been cut out. The SCADA safety feature has also been observed. User has to login each time to access or to make any change in the system, this prevents the system from unauthentic user manipulation.

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