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Design and Implementation of SCADA System for Sugar Production Line

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Abstract

SCADA is the technology that allows the operator to gather data from one or more various facilities and to send control instructions to those facilities. This paper represents an adaptable and low cost SCADA system for a particular sugar manufacturing process, by using Programmable Logic Controls (Siemens s7-1200, 1214Dc/ Dc/ Rly). The system will control and monitor the laboratory production line chose from sugar industry. The project comprises of two sections the first one is the hardware section that has been designed, and built using components suitable for making it for laboratory purposes, and the second section was the software as the PLC programming, designing the HMI, creating alarms and trending system. The system will have two HMI screens according to the two operating states of system (Automatic and Manual), the operator can choose between them by a selector switch, this method helps the operators when fixing a failure and wanting to check it without operating all the process. The result has accomplished the goals of controlling, the parameters (temperature, flow, humidity) were monitored, failure was detected by an alarm.

Keywords: *SCADA, Programmable Logic Controls, Integrated Automation, Sugar industry.*

1. Introduction

SCADA systems became popular to arise the efficient monitoring and control of distributed remote equipment. Today SCADA systems include operator-level software applications for viewing, supervising and troubleshooting local machines and process activities. Powerful software technologies are used for controlling and monitoring equipment in easy-to-use web-based applications, e.g., platforms: PCS7 – Siemens, CX-Supervisor – Omron, Genesis 32 – ICONIX [1].

The term supervisory control is associated with (i) the process industries, where it manages the activities of a number of integrated operation units to achieve certain economic objectives for process; and with (ii) the discrete manufacturing automation, where it coordinates the activities of several interacting pieces of equipment in manufacturing cells or systems, such as a machines interconnected group by a material handling system [2].

SCADA involves the collecting of information, transferring to the central site, carrying out any necessary analysis and control, and then displaying that information on a number of operator screens or displays. The required control actions are then conveyed back to the process [3]. Control and supervision tasks of industrial plants are distributed over wide areas, and are characterized by many sensing and actuation points (in order of hundreds or even thousands of units) as in petrol chemical plants, paper factories, newspaper rotary printing presses, plants for extraction, bottling of alimentary juices, energy monitoring, etc. They require the use of sophisticated automation schemes that must be able to grant access to production data and field distributed variables at large distances, and from various levels of factory automation (field, control, supervision, etc.) [4]. Programmable Logic Controls (PLCs) are used for system control. As the need to monitor and control more devices in the plant grew, the PLCs are distributed and the systems became more intelligent and smaller in size. SCADA and PLC are types of control systems. Nowadays, there are systems that incorporate all these concepts in one integrated automation system. Totally Integrated Automation (TIA) is the foundation to implement industry specific automation solutions that are coordinated with individual requirements, combining increased productivity with a high level of investment security. TIA offers uniform automation technology on one single platform for all applications of process automation, starting with input logistics, covering production or primary processes as well as secondary processes, up to output logistics. Many researches have been discussed this subject like:

R. Kumar et al. [5] designed a SCADA System for industrial purpose to control and monitor the process plant that consists of three units, where the temperature of these units are variable, so the developed automated system collects the temperature data of different cities and maintains the production according to the consumers demands. Where the consumer demand is varying according to the temperature. N. Burali[6] used Delta PLC to control the crane movement's. With the use of WPL software. SCADA used were, current and temperature of the drives have been observed by SCADA system in current instant. To achieve the point of automating and controlling. K. P. Bindu et al. [7]Managed an intelligent monitoring system of hardboard industry with the help of PLC. Allen Bradley PLC and the entire logic were created in MICROLOGIX Programming software to control the parameters of required pressure and time duration of each period. The system created a fast, real-time decision making environment. The process is adaptable to any changes in production capacity or safety requirements. Das.[8]Provided an analysis of the simulation and components required for the implementation of an automated level control system by the help of PLC(SIMATIC s7-300). Ahmed kh. et al.[9] gave a solution to plan application process by using the SCADA system and deal with another system (ERP v7.0 simulator). To record and make supply chain report, and expecting of accomplishment or failure of the system. The manufacturing process is designed by using SCADA simulator which is WINCC v6.0, the integration between the two systems was accomplished by OPC server. R. Sharma et al.[10]Presented the design of a prototype of automated storage and retrieval system for small loads and to reduce the human effort and manpower. This paper includes design and structure analysis of material storage and retrieval system with the help of PLC and SCADA. PLC used (DVP DVP-64EH), WPLSoft 2.30 is the software dedicated to the PLC for programming purpose, RS-232 is used for serial communication. The prototype model of automated storage and retrieval system developed consists of the control hardware and software SCADA.

In this work, a new method is added to control the process and promote the work which is creating two states for the system and chose any one of them by selective switch to help the operator through checking failed parts. PLC (s7-1200) is used to control the implemented mechanical part and the SCADA system is created by TIA v13 software, HMI is accomplished through Wincc v13.

2. Mechanicaland Electronic Parts

The system consists of three main mechanical parts, the first one is the heating unit that combines normal water electrical heater [11] plated inside by stainless steel to suit food industry and water proof, anti-resistant temperature sensor (Ds18b20), placed inside the tank to measure the syrup temperature. The second part is consisted of solenoid valve joined by typical water pipes, which served as a gate for passing the syrup after the evaporation step. Then a water flow sensor is placed under the solenoid valve to determine and allow a specific amount of syrup to pass to the third part, which consists of a centrifugal container that has concaved design to allow both of mixing and Centrifuging processes. The outside of the centrifugal container is covered by a layer of heavy cloth to prevent the escape of sugar crystals during the rotation. AC motor of 1600 rpm was used to rotate the centrifugal container, in addition to measure the humidity inside the crystallization unit the humidity-temperature sensor (DHT11), were used. On the other hand the system also includes electronic parts: three uno-arduinos[12], each of them is responsible for one of the sensors and to convert

Analog-to-digital signal (ADC). Six relays as a latching relays, that were used to convert the DC arduinos output signals into appropriate signals to enter the PLC as an input. Siemens S7-1200 PLCserves as the major controlling unit of the system. Based on the ladder logic program the PLC achieves its decisions, and communicated to the computer by using PN/IE. Finally the last part is the HMI Siemens WINCC V13 (TIA) that presents the status of the system. Tags were used to empower connection between the PLC and HMI.

3. Design and Implementation

This section can be divided into:

3.1 Mechanical Design

Laboratory production line as hardware system has been designed, this system consists of three units: heating unit as a tank with capacity of 20L, transferring elements (valve, flow sensor) and centrifugal unit, with dimensions of (60, 60,190) cm for the iron frame, (D= 28cm) for the tank and (30, 60) cm for the board of electronics. The system was designed to be used for laboratory purposes only. Figure 1. Presents the design of the system.

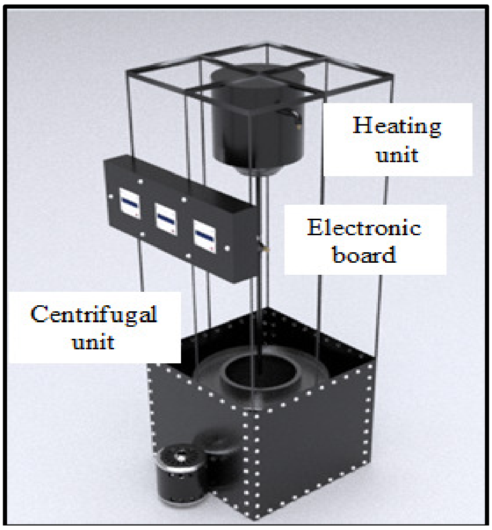


Fig. 1. The design of laboratory production line.

3.2 Circuit Design

The main part of the automated production line machine is the Siemens s7-1200 PLC as shown in Figure2. where the input signals of temperature, flow and humidity are given to the PLC as analogue and digital outputs from uno-arduino, from the computer by the arduino software integrated development environment (IDE). The output signals of the PLC are given to the components that connected to the PLC as actuators, like heater, valve and motor, for controlling them specifically.

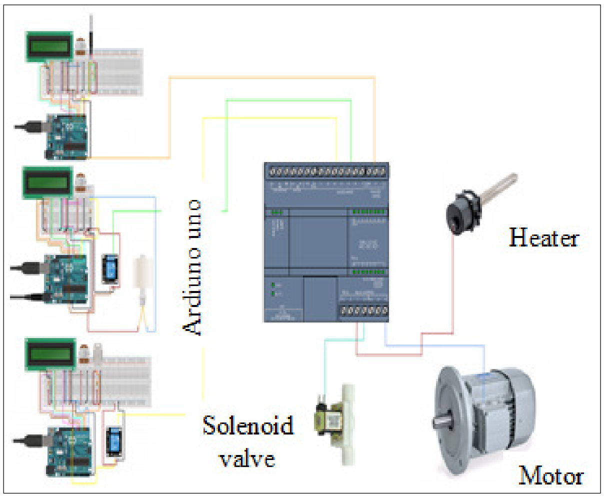


Fig. 2. (The Designed Circuit of the Project).

3.3 Production Line Implementation

The implementation is divided into four steps:-

a. Building the system: The production line has been accomplished and the electric parts were wired according to the design of hardware and circuit design. Figure 3. Presentsthe final shape of the laboratory production line.

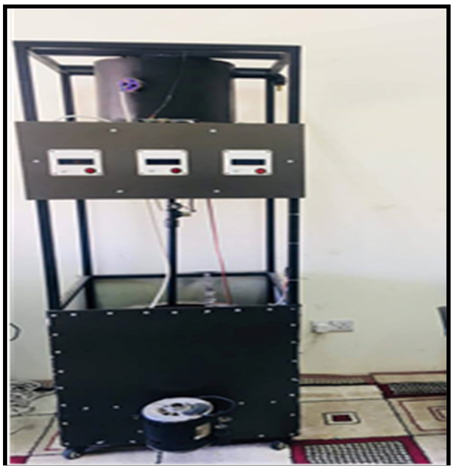
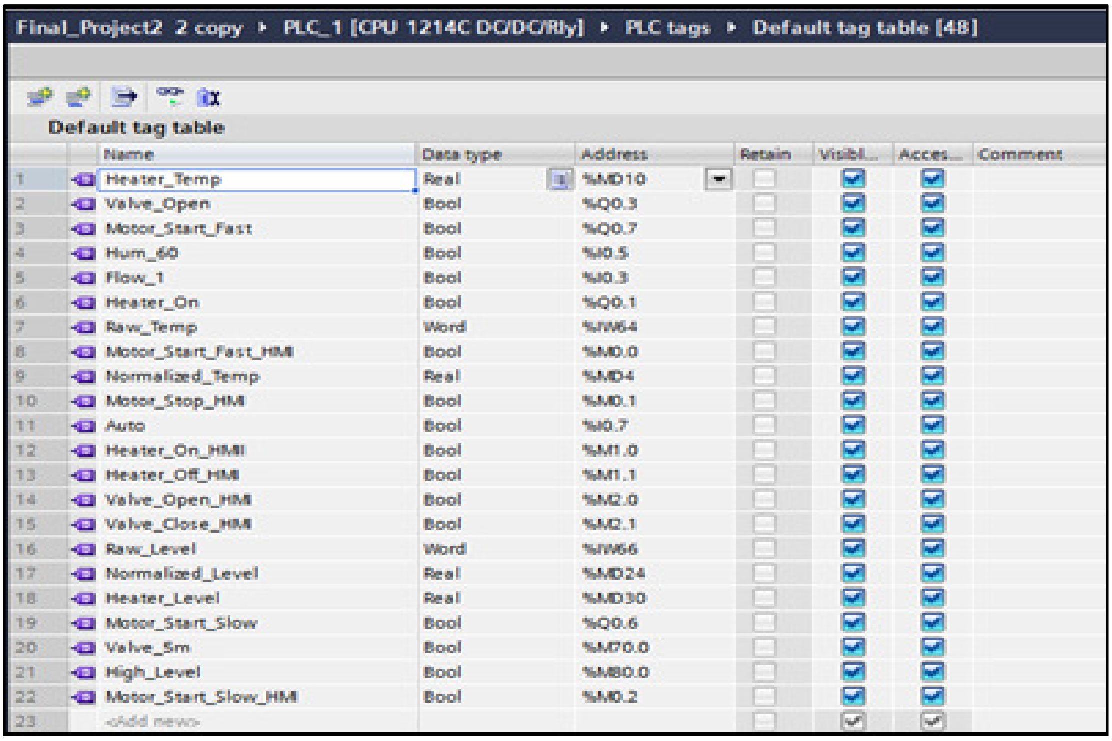


Fig. 3. Final Hardware System.

b. Sensor Positioning: Three sensors were used in this project, temperature sensor (mw0) was used to sense the heat inside the heater placed inside the tank, flow sensor was used to measure a specific amount of syrup, placed inline under the valve (I0.3), and humidity sensor (I0.5) fixed in the top of container to measure humidity inside the container during crystallizing process.

c. Ladder Programing: The ladder programming of s7-1200 was done by STEP7 of TIA software. The symbols used in the ladder are shown in figure 4 in the PLC tags table, while Fig 5. is the ladder program for this experimental work.

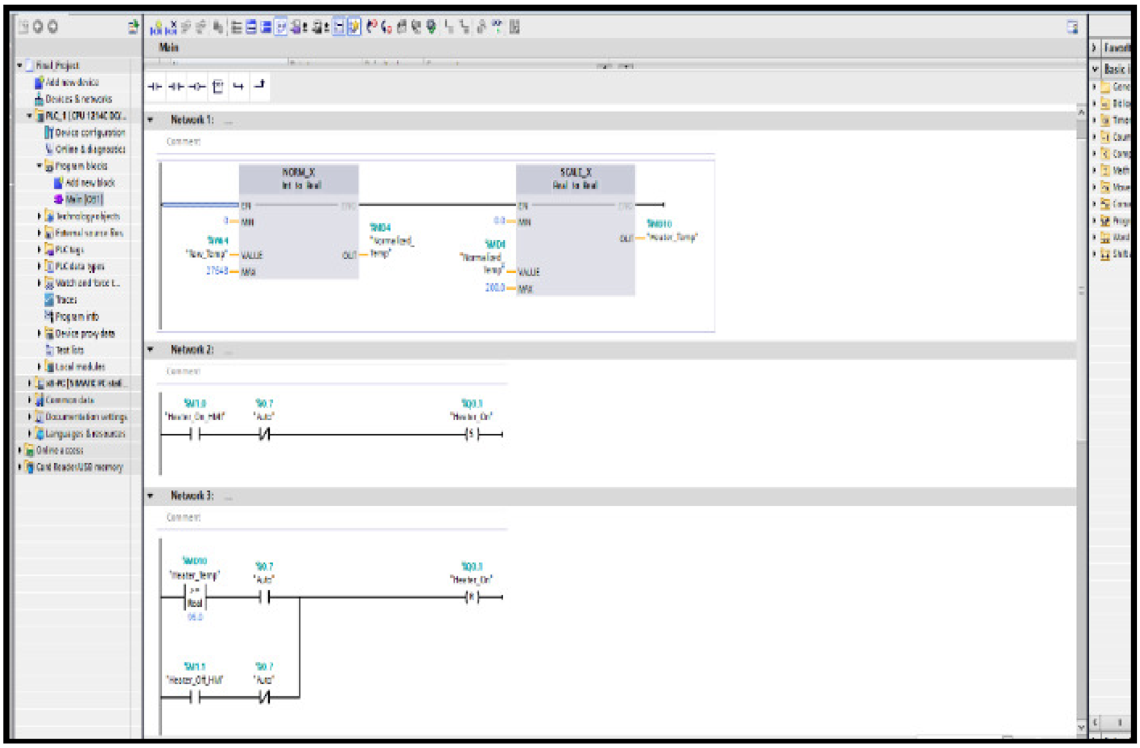


Final_Project2 2 copy ▸ PLC_1 [CPU 1214C DC/DC/Rly] ▸ PLC tags ▸ Default tag table [48]

Default tag table

	Name	Data type	Address	Retain	Visibl...	Acces...	Comment
1	Heater_Temp	Real	%MD10	☐	☑	☑	
2	Valve_Open	Bool	%Q0.3	☐	☑	☑	
3	Motor_Start_Fast	Bool	%Q0.7	☐	☑	☑	
4	Hum_60	Bool	%I0.5	☐	☑	☑	
5	Flow_1	Bool	%I0.3	☐	☑	☑	
6	Heater_On	Bool	%Q0.1	☐	☑	☑	
7	Raw_Temp	Word	%IW64	☐	☑	☑	
8	Motor_Start_Fast_HMI	Bool	%M0.0	☐	☑	☑	
9	Normalized_Temp	Real	%MD4	☐	☑	☑	
10	Motor_Stop_HMI	Bool	%M0.1	☐	☑	☑	
11	Auto	Bool	%I0.7	☐	☑	☑	
12	Heater_On_HMI	Bool	%M1.0	☐	☑	☑	
13	Heater_Off_HMI	Bool	%M1.1	☐	☑	☑	
14	Valve_Open_HMI	Bool	%M2.0	☐	☑	☑	
15	Valve_Close_HMI	Bool	%M2.1	☐	☑	☑	
16	Raw_Level	Word	%IW66	☐	☑	☑	
17	Normalized_Level	Real	%MD24	☐	☑	☑	
18	Heater_Level	Real	%MD30	☐	☑	☑	
19	Motor_Start_Slow	Bool	%Q0.6	☐	☑	☑	
20	Valve_5m	Bool	%M70.0	☐	☑	☑	
21	High_Level	Bool	%M80.0	☐	☑	☑	
22	Motor_Start_Slow_HMI	Bool	%M0.2	☐	☑	☑	
23	<Add new>			☐	☑	☑	

Fig. 4. The PLC tag table.



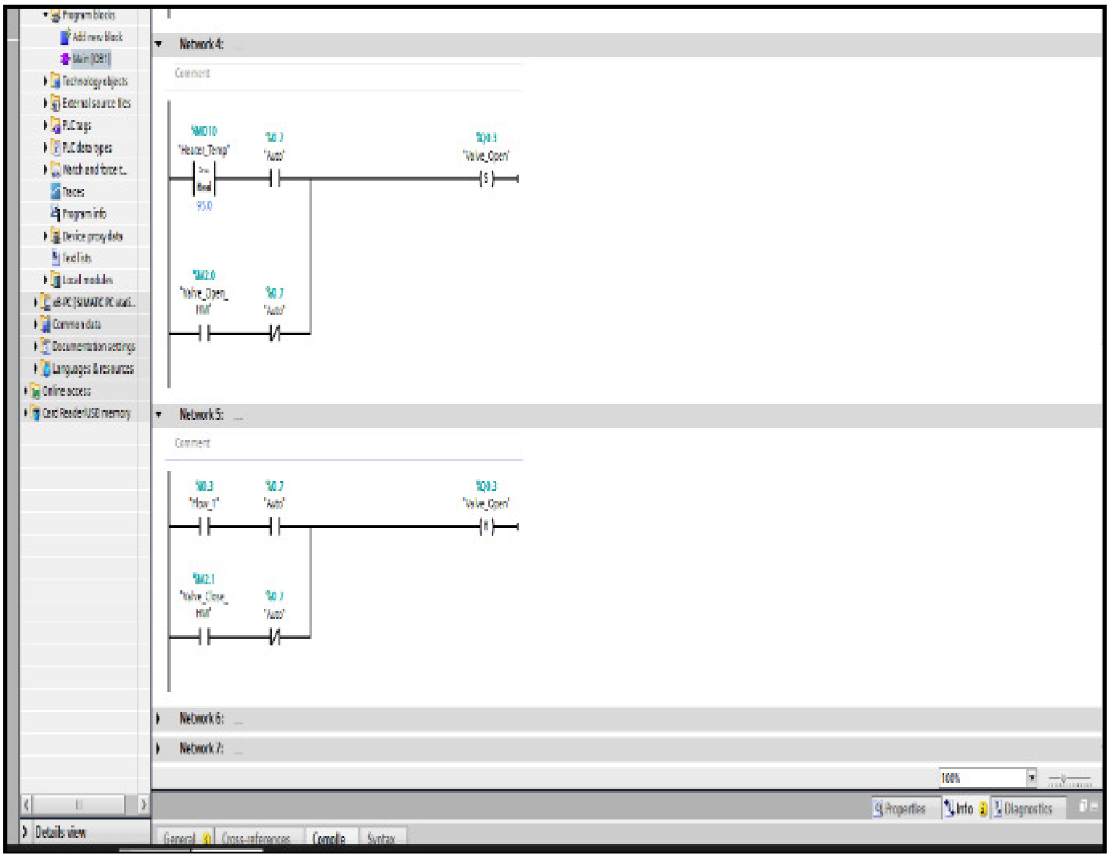


Fig. 5. The ladder logic program.

d. HMI Creation: The HMI was implemented in WINCC v13 of TIA software. Tags have been used to create a connection between the PLC with the HMI. Since the system works in two modes, two HMI were created the first one is AUTO for a full automatic system, and MANUAL one for operating each component of the system separately, the benefit of these two screens is to help an operator to fix or check any failure can be occurred inside the system, This method helps in finding the failed part without operating the whole system. Every action during real process will appear on this screen. Figure 6. a and b shows the two implemented HMI.

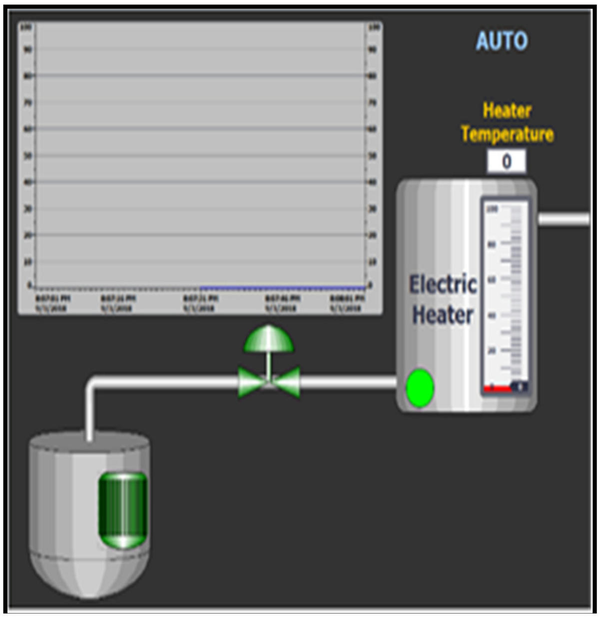


Fig. 6.a The AUTO mode.

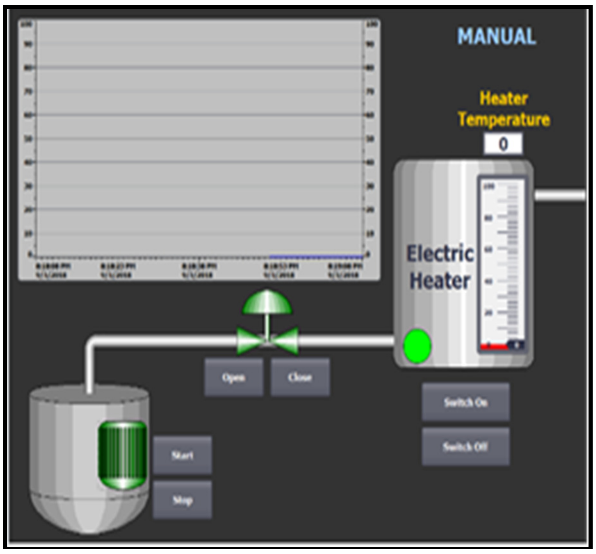


Fig. 6.b The MANUAL mode.

4. Results and Discussions

Scenario of process:

The over tank is to be filled with syrup. The heater will automatically be on when the system is powered. The evaporation process inside the tank is checked always by temperature sensor, when temperature reaches 100 C, the PLC indicates the valve to be open, at the same time the flow sensor starts mounting 1L of syrup to pass to the last step. When flow meter stops, the motor starts rotating the centrifugal container with the syrup inside to start crystallization process, during this time the humidity sensor checks the humidity percentage inside the container. Figure 7. shows the block diagram of the whole process.

After several attempts and corrections such as in the wiring or in the ladder logic, and the software. The results for this work are the following:

1. Two moods for automatic and manual mode are created (Fig.6. a and b)
2. Trend view to monitor the temperature value in the same screen is created (Fig. 8.)
3. One analog alarm is created: when the humidity being above 60% inside the container (Fig.9.)

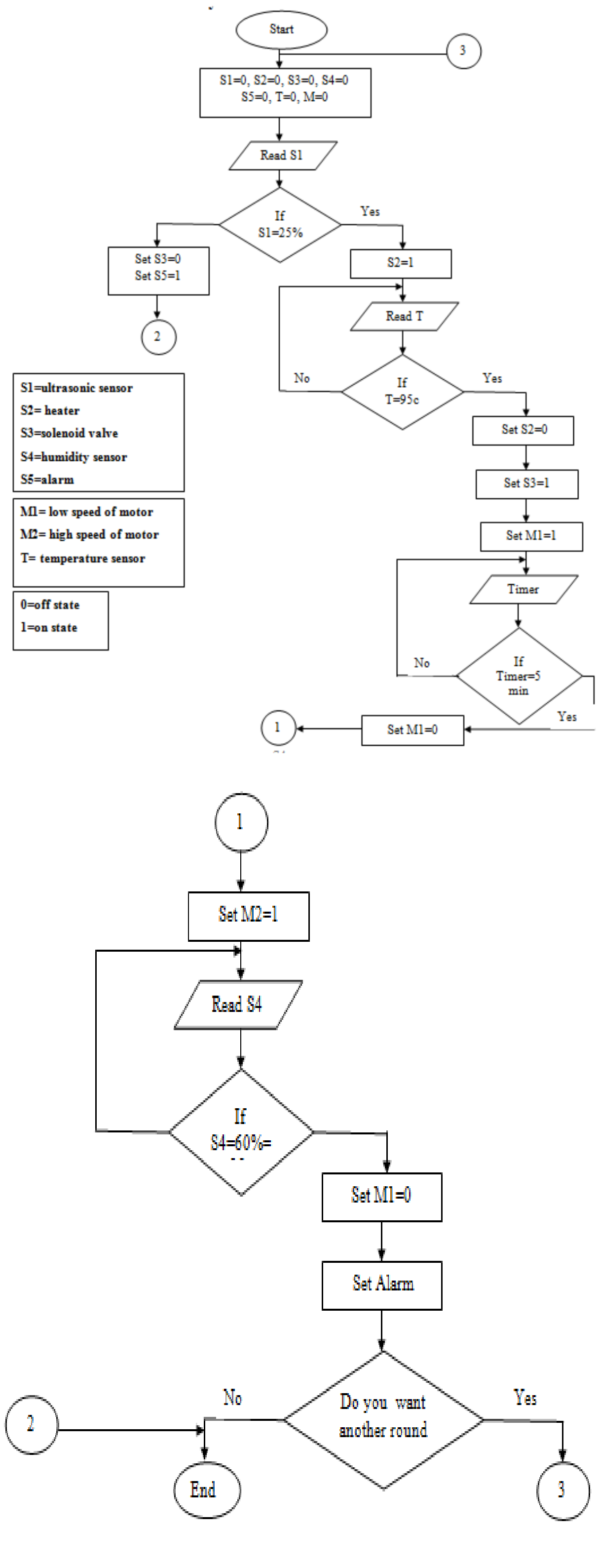


Fig. 7. The block diagram of the system.

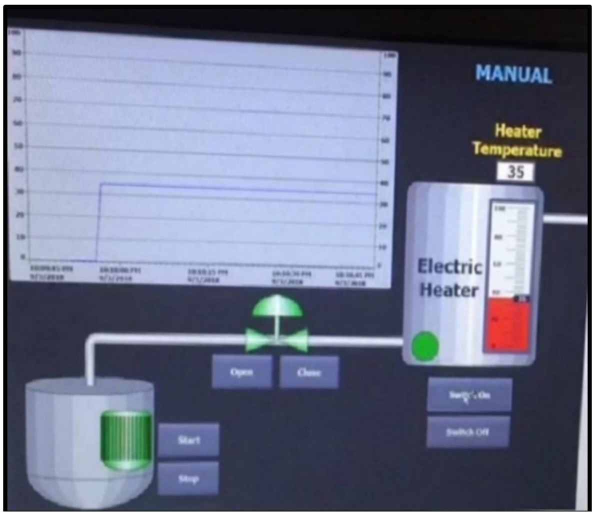


Fig. 8. Trend view for temperature sensor.

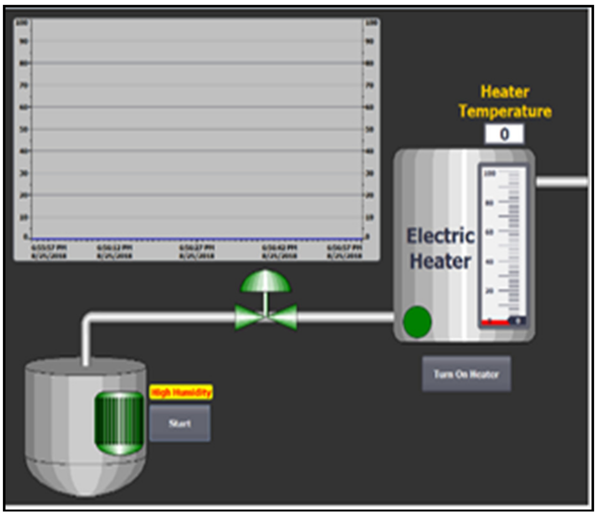


Fig. 9. Alarm.

5. Conclusions

Automated sugar production line is designed and implemented, assisted by predicted model and standard values. The designed SCADA system can control and monitor the production line. The input parameters are voltages of temperature, flow and humidity (V). furthermore, turn on and off of the heater, valve and motor automatically through a computer by using PLC Siemens s7-1200. The results of the measured and analysed parameters have been displayed on GUI.

This work has provided the following points

1) Low cost custom built monitoring and controlling.

2) The project can be customized to suit any other industrial requirements.

In the future it is possible to apply AI, Connect the system to the Wifi so it can be managed by other controller by an application for PC or Phone. This project can be expanded to all other process variables such as pressure, level, and other types of sensors.

6. Abbreviations

SCADA supervisor control and data acquisition
PLC programmable logic controller
HMI human machine interface

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تصميم وتنفيذ نظام تحكم اشرافي لخط انتاج السكر

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الخلاصة

SCADA هي التقنية التي تسمح للمشغل بجمع البيانات من واحد أو أكثر من الاجهزة او المرفقات المختلفة وإرسال تعليمات التحكم إلى تلك المرفقات. يمثل هذا البحث تصميم وبناء نظام SCADA منخفض التكلفة وقابل للتكيف لجزء من عملية تصنيع مادة السكر وذلك باستخدام (Siemens s7-1200 PLC، 1214Dc / Dc / Rly). سيتحكم النظام ويراقب خط الإنتاج المختبري الذي تم اختياره من صناعة السكر.
يتألف المشروع من جزء المواد الصلبة الذي تم تصميمه وبناؤه باستخدام مكونات مناسبة للصناعات المختبرية، أما القسم الثاني فيتألف من البرنامج المتحكم مثل برمجة PLC، تصميم الواجهات HMI، فضلاً عن إنشاء أجهزة الإنذار ونظام الاتجاه. وسيحتوي النظام على شاشتين HMI طبقًا للحالتين التشغيليتين للنظام (تلقائي ويدوي)، ويمكن للمشغل الاختيار بينهما بوساطة مفتاح تبديل، وتساعد هذه الطريقة المشغلين عند إصلاح اي خلل والرغبة في التحقق من ذلك دون تشغيل جميع العمليات.
وقد جائت النتائج لتحقق أهداف البحث في السيطرة فضلاً عن رصد العناصر مثل درجة الحرارة، والتدفق، والرطوبة وتم الكشف عن اي خلل يحدث من التنبيه عليه.