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Programmable Logic Controller Based Electric Oven Temperature Remote Monitoring and Control

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Abstract

The design and construction of an electric oven employing a PLC controller are presented in this study. With the help of a switch, the user can choose a process to be carried out with pre-programmed temperature and timing, or they can choose a desired temperature and timing. The system reacts by automatically turning on and off the load (heating element) based on the temperature differential and the predetermined time which is attributed to the PLC controller. When the oven temperature falls below the predetermined level, the Heating Element is activated, and when the oven temperature rises over the predetermined level, the heater is turned off. The system has a WiFi module for a remote temperature data logger that records temperature changes and may be used to remotely set or adjust the desired temperature. When the switch for any desired process is pressed, the PLC Controller turns on, processes the data in accordance with the temperature and time that have been preset, and turns off when the timed is up. The temperature controller simultaneously flips on the heating element when the thermocouple detects the temperature in the oven and transmits the signal or variable to it. The PLC was powered by 24 VDC, while the data logger used a 12 VDC power supply. Due to the heating element's large wattage, a 220VAC supply was used to power it. The system's construction and design outcomes complied with the design brief.

Keywords: Oven, Heating Element, Programmable Logic Controller (PLC), Temperature

Citation

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Introduction

To obtain the desired product quality in process industries, physical quantities like temperature, level, flow, etc. must be measured and managed. Heating and cooling will reduce the possibility of hazardous bacteria contaminating food and prevent food waste. A high temperature of roughly 1300-1450^{0}C is necessary for the chemical reaction that forms clinker during the cement-making process. The clinker cooled to about 80^{0}C when it came out of the kiln, but the particles will harden quickly if the temperature drops below the predetermined level. The development of technology has allowed for a variety of controls, including flow control, temperature control, level control, and speed control. A temperature controller is an electronic device that is used to regulate a heater, cooling element, or other equipment (Melo et al, 2020) (Omron Inc., 2019). By comparing a sensor signal with a predetermined point and doing calculations based on the differences between those values. The purpose of temperature controllers is to maintain the temperature such that the process value (PV) stays close to the set point (SP).

Although there are numerous approaches available today to address temperature control system issues, the majority of them are employed in precision temperature control systems. Microcontrollers or embedded systems such as the PIC (peripheral interface controller), AVR (Alf and Vegard's RISC PROCESSOR), MSP (mixed signal processor) can be used in handling the process of temperature control. The deployment of digital automation compared to analogue designs, typically offer greater flexibility, ease of troubleshooting, reduced cost, reduced susceptibility to noise and interference from the circuit, and higher precision and accuracy (David et al., 2013).

An oven is one of the appliances found in an industrial and domestic environment utilising temperature control. It is a closed chamber that can be used for grilling, baking, and cooking various types of food. An oven is also used in the manufacture or making of pottery. This type of oven is known as kiln. The majority of ovens are made to maintain a specific temperature for various food processes; this causes the food to burn or spoil without allowing the food to be evacuated at the appropriate moment. Additionally, this could result in energy waste and harm to the heating element. With the employment of programmable logic controller, PLC and data logger, this project aims to improve the system's ability to cut off the supply when the designated temperature and timing are achieved, raise an alarm, and allows for the remote monitoring and control of the oven temperature, and prevent spoilage that may arise from the aforementioned issue. The remainder of this paper follows this format: section two is the reviews relevant literature, section three explains the idea of an electric cooker/oven based on a microcontroller, section four discusses performance evaluation, section five discusses findings, and the conclusion.

Materials and Methods

Design considerations

Considerations were given to the existing designs of various ovens through literature survey. The block diagram of the remote monitoring and control of electric oven temperature is shown in Figure 1.

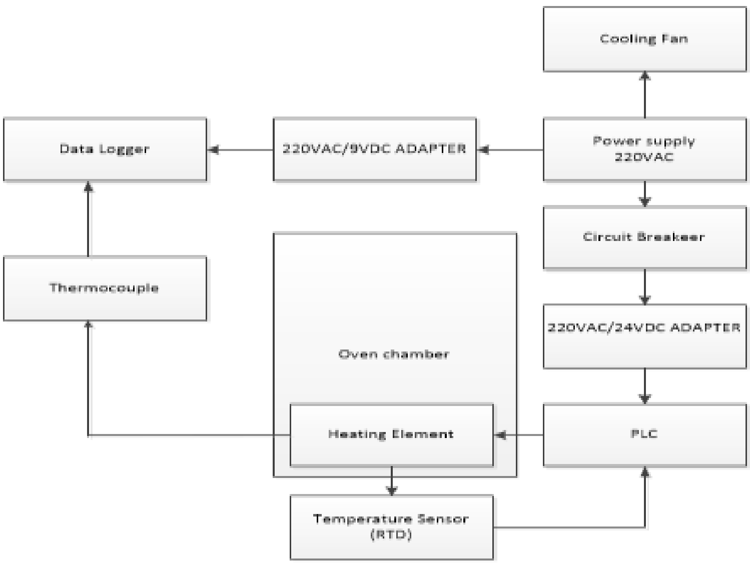

Figure 1 Block diagram of the electric oven

Working Principles of the Oven

The oven is designed to be controlled both manually and remotely. When the selector is turned on, the remote temperature controller data begins to operate, keeping the temperature at the desired value and recording the temperature data. The PLC is the project's brain because it handles the majority of the work; it keeps track of and maintains the temperature range and time for each process as assigned. It always receives a signal from the RTD, which causes the heating element to turn on and off automatically. It runs on 220VAC and has a temperature measurement range of 0 to 1300 degrees. The heat extractor is installed above the covering of the oven which aids the cooling of the control section, and when it is powered, it turns on to indicate that the system is powered.

Heating element

The heating of the oven chamber is provided by a heating. The heating element selected for this work is an Alloy of FeCrAl. It is a corrosion-resistant material with a high-temperature resistance property. The specifications of the heating element is shown in Table 1.

Table 1: Specification of Heating Element

Specifications	
Power	2500 W
Material	FeCrAl
Length	745 mm
Maximum Temperature	1400 ^{0}C
Specific resistance at room temperature	140μΩ/cm^3

Construction of the Oven

The oven is 500 mm long, 740mm in height, and 459 mm in breadth. For easy mobility, a rubber wheel was attached to each of the four legs of the oven. Figure 4 and Figure 5 shows the front view and orthographic projection of the oven.

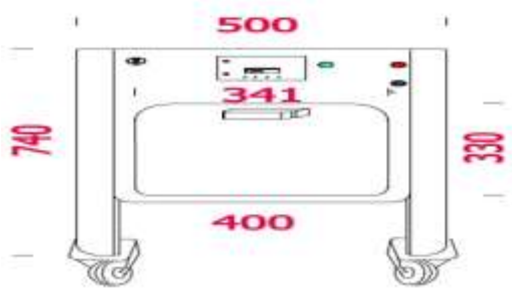

Figure 1: Front View of the Oven

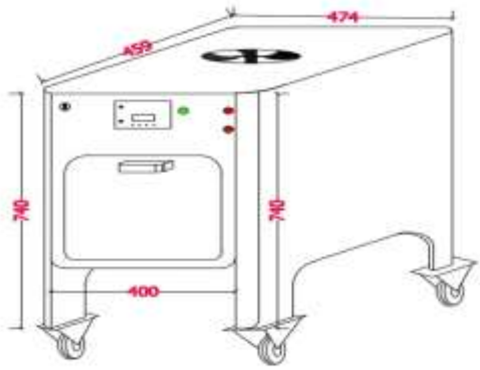

Figure 2: Orthographic Projection of the Oven

Inner chamber

The inner chamber of the oven is a doubled walled made up of steel sheet 33 cm in length, 12.6 cm in breath and 11 cm in height. Aluminium foil was used as the lagging material between the two inner walls to prevent heat loss and maintain the inner temperature of the oven.

Circuit implementation

A 220 VAC power supply was connected to the circuit breaker whose output is connected to 24 V and 9 V output adapter to power the PLC and the data logger respectively. The Resistance Temperature Detector (RTD) is connected to the input of the PLC to sense the temperature of the oven, and the heating element is connected to the output of the PLC for the temperature control of the oven chamber. The heater was placed at the bottom of the oven. For the remote monitoring of the oven temperature, a data logger which uses a K type thermocouple was utilised in this work. Figure 6 shows the circuit diagram implementation. Ladder logic programming was used in programming the PLC, figure 7 shows the display of the programming.

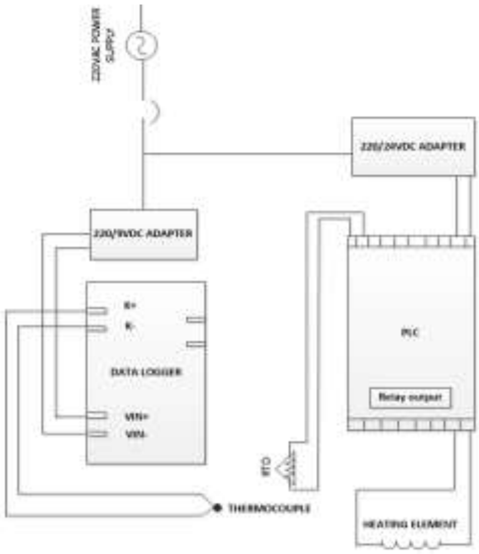

Figure 3: Circuit Diagram

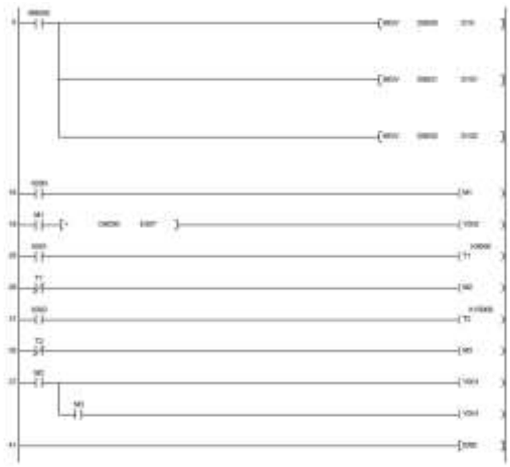

Figure 4: Ladder Programming used for the PLC

Connection of Data Logger to Device

The data logger can be operated remotely for the temperature monitoring and recording function using Sinilink APP. The following are the steps taken to connect the data logger to a device (mobile phone) for remote monitoring, recording, and control purposes:

- Download Sinilink APP on Google playstore.
- Launch the APP and register with your email address. A verification code will be sent to your email to complete the registration.
- The APP prompts a page showing an icon of PLUS sign, click on the icon to add device.
- Select the suitable means of connection (WIFI or Bluetooth) for the Data logger. But in this case, you will select WIFI because we are using WIFI module Data Logger.
- It prompts a page to verify if the indicator flashes, click verify.
- It prompts the page to configure the WIFI network you need to connect your device by inputting the WIFI name and password.
- Enter the custom device name and device classification.
- Click the “go to link device hotspot” button below on the next page and connect your mobile phone to the WIFI name “SinilinkProduct”, password: 12345678. Press the button on the WIFI module more than 5 seconds or till it display “AP” that is pairing mode. After the WIFI link is successful, return to the APP.
- It adds the device after few seconds.

Note: The process requires internet data to be ACTIVE.

Results and Discussions

Presented in Table 2 is the measurement taken when the temperature of the oven was set to cut off at 180^0 C while baking banana with the oven. Figure 8 shows the graphical representation of the data taken for proper analysis.

Figure 8: Front view of the constructed oven

Table 2: Data Recorded for Day 1

S/N	Time	Temp
1	11:54:58	158.5
2	11:54:59	158.5
3	11:55	158.5
4	11:55	158.5
5	11:55:01	158.5
6	11:55:02	158.5
7	11:55:03	158.1
8	11:55:04	158.1
9	11:55:05	158.1
10	11:55:06	158.8
11	11:55:08	158.9
12	11:55:09	158.9
13	11:55:11	159
14	11:55:12	159
15	11:55:13	158.6
16	11:55:14	158.6
17	11:55:15	158.6
18	11:55:16	159.4
19	11:55:17	159.4
20	11:55:19	159.4
21	11:55:20	159.4
22	11:55:21	159.5
23	11:55:22	159.5
24	11:55:23	159.5
25	11:55:24	159.8
26	11:55:25	159.8
27	11:55:25	159.8
28	11:55:26	159.8
29	11:55:27	159.8
30	11:55:28	159.8
31	11:55:30	159.6
32	11:55:31	159.6
33	11:55:33	159.4

34	11:55:34	159.7
35	11:55:35	159.7
36	11:55:36	159.7
37	11:55:37	159.9
38	11:55:38	159.9
39	11:55:39	160.3
40	11:55:41	160.3

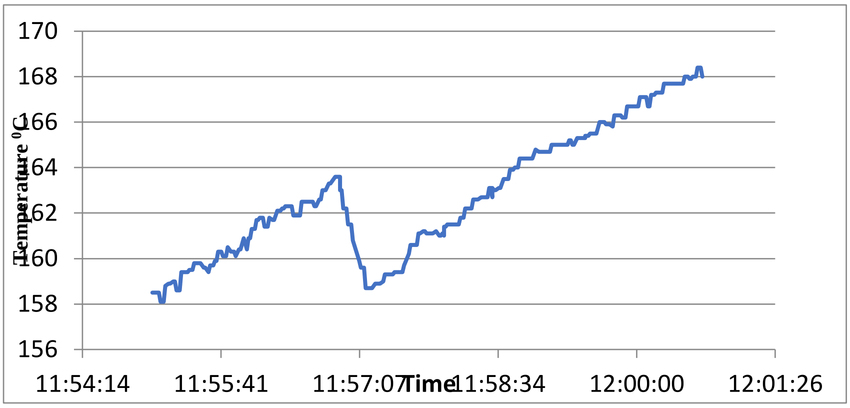

Figure 9: Graphical representation of Temperature changes on Day 1

Presentation of Result for Day 2

Present in Table 3 is the measurement taken when the temperature of the oven was set to cut off at 150^0 C while fermenting a banana with the oven.

Figure 10 shows the graphical representation of the data taken for proper analysis.

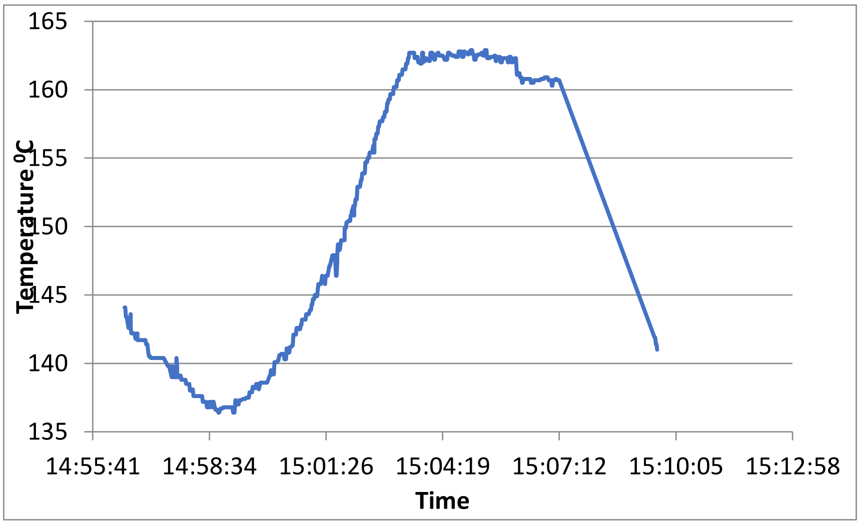

Figure 10: Graphical representation of Temperature changes on Day 2

Table 3: Data Recorded for Day 2

S/N	Time	Temp
1	14:59:59	138.6
2	15:00:03	139.1
3	15:00:04	139.1
4	15:00:05	139.5
5	15:00:06	139.5
6	15:00:07	139.2
7	15:00:08	139.2
8	15:00:09	139.2
9	15:00:10	140.1
10	15:00:11	140.1
11	15:00:12	140.1
12	15:00:13	140.1
13	15:00:14	140.1
14	15:00:15	140.2
15	15:00:16	140.2
16	15:00:17	140.6
17	15:00:18	140.6
18	15:00:19	140.6
19	15:00:20	140.7
20	15:00:21	140.7
21	15:00:22	140.7
22	15:00:23	140.7
23	15:00:24	140.7
24	15:00:25	140.3
25	15:00:26	140.3
26	15:00:27	140.3
27	15:00:28	141.1
28	15:00:49	142.8
29	15:00:50	142.8
30	15:00:51	143.2
31	15:01:01	143.6
32	15:01:03	143.9
33	15:01:06	144.3
34	15:01:09	144.7
35	15:01:13	145
36	15:01:34	147.5
37	15:01:36	147.9
38	15:01:36	147.9
39	15:01:38	147.9
40	15:01:38	147.9
41	15:01:39	147.9
42	15:01:40	147.9
43	15:01:41	146.4
44	15:01:42	146.4
45	15:01:43	147.5
46	15:01:43	147.5

47	15:01:43	147.9
48	15:01:44	148.7
49	15:01:45	148.7
50	15:01:45	148.7
51	15:01:47	148.3
52	15:01:47	148.3
53	15:01:54	149.9
54	15:01:55	149.9
55	15:01:56	149.9
56	15:01:57	150.3
57	15:01:58	150.3
58	15:01:59	150.4
59	15:02	150.4
60	15:02:01	150.4
61	15:02:02	150.4
62	15:02:03	150.8
63	15:02:04	150.8
64	15:02:05	151.2
65	15:02:06	151.2
66	15:02:07	151.5
67	15:02:08	150.8
68	15:02:08	150.8
69	15:02:08	151.5
70	15:02:09	151.5
71	15:02:25	154.7
72	15:02:26	154.7
73	15:09:34	141.9
74	15:09:35	141.4
75	15:09:36	141.4
76	15:09:37	141

The results from the data recorded in Table 2 and Table 3 at variegated temperature thresholds, proved that when the pre-determined temperature was pegged at 180^0C, the recorded maximum temperature was 160.3^0C at an early time of 11:55 am before noon. Before the timing of the maximum temperature, the oven has shown a consistency in temperature readings over some time duration, in contrast with day 2 readings with a pre-determined temperature pegged at 150^0C, the maxim temperature recorded 154.7^0C at an instantaneous time of 15:02 pm afternoon. Similarly, the temperature readings equally showed a uniform reading at some specific time instances. variations in attaining the preset temperature can be attributed to various environmental factors such as weather, the moisture content of the food crop been dried, and the preset time of the oven. Since the temperature was plotted against time, the study has demonstrated that the temperature changes in an oven is a function of the above-stated factors.

Conclusion

Processing food and speeding up the production rate, while also mitigating the spoilage of food produced and reducing the strenuous and laborious work carried out by workers in various factories, has been the fundament objective of machine automation specifically ovens. This study articulated the design and construction of an electric oven that can be controlled based on the utilisation of PLC was achieved. Demonstrated results based on practical tests revealed that the oven can be preset to a specific temperature to dry any type of food produced. Moreso, results proved that the lower the preset temperature the longer the drying duration.

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