Smart Control Ice Tube Machine Using PLC and HMI with Superheat Method Based on Compressor Low Pressure Parameters

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Abstract: Ice tube is a variant of ice cubes in the form of a tube or cylinder that has a hole in the middle with certain diameters and lengths. Ice tube machine is a cooling machine that has the main function of cooling substances so that the temperature is lower than the ambient temperature. The main components of the ice tube machine are the compressor, condenser, and evaporator as the working fluid that circulates on the parts of the ice tube machine. However, the average ice tube machine in operation is carried out by human operators, this can slow down the production process of the ice produced. Smart control system is needed so that ice production can be maximized every day called Smart Control PLC (Programmable Logic Controller) Based Ice Tube Machine. This control ice tube machine can work automatically and also no longer requires an operator in the work process of making ice tubes and this control system can be designed according to the needs of the machine. We can monitor the ice tube machine specifically when the machine process is working on the HMI (Human Machine Interface). This can make it easier to operate the Ice tube Machine.

1 INTRODUCTION

Ice tube is a variant of ice cubes in the form of a tube or cylinder with a hole in the middle with certain dimensions, diameters and lengths. Ice tube is in great demand by the public, in addition to its easy-to-use shape to mix various foods and drinks. This ice tube or ice crystal is more hygienic with a clearer and neater appearance. With a very wide market share, this ice making business can be said to be very potential, still wide open and very promising. Indonesia has many companies or home industries that use tube ice as a temporary cooler when shipping to various places (Triyono et al., 2019). Because it will not be possible if the freezer is also included during shipping. Thus, ice tube flakes are one of the shortcuts needed during the delivery process of frozen food or beverage products, so that the product will be maintained at low temperatures, and of course the freshness of the product will not be disturbed. In addition to shipping, it can also be used for storage of products and raw materials that will be used to make these food products. At this time, the demand for tube ice is very much in demand by the public. Therefore, an ice tube maker was made that has a large income capacity, in order to meet the needs of the community. The current tube ice machine can produce approximately up to 1 ton for 24 hours. With an ice tube machine, the process of making tube ice does not require a long time and the ice produced is more hygienic (Eidan et al., 2021; Hervatte, 2021; Salim et al., 2018). However, there will be not many people who understand the working principle of this tube ice machine, there must be an operator to run the ice tube machine.

Program Logic Controller (PLC) is a tool that is able to control the control system on a machine that can be adjusted automatically (Prasetyo, Triyono, et al., 2021). Human Machine Interface (HMI) is a communication medium for the processes that occur in the PLC (Mendoza et al., 2021; Prasetyo, Hidayatullah, et al., 2021; Triyono et al., 2021). One of the functions of HMI is as monitoring data that can be designed according to the needs of the machine used. PLC and HMI can be combined in the operation of the tube ice machine. The ice tube machine can work automatically and also no longer requires an operator in the process of making tube ice. The benefit of this PLC and HMI is that all the programs we want can be set in the PLC, and we can monitor specifically when the machine process works on the

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HMI. This can facilitate the operation of the tube Ice Machine.

2 MANUSCRIPT PREPARATION

2.1 Schematic Diagram

The design model of the PLC program is connected to a 220V AC source as shown in Figure 1. To start the circuit work, when the ON button is pressed it will send a signal to the PLC and start the work process. The stages of the ice tube machine work process are starting with filling the water tank, then the tank enters the freezing tank, namely the evaporator, along with the compressor and condenser turning on. When the filling is complete the Freeze process starts, this process will stop when the temperature in the evaporator reaches -9^{0}C. When the sensor detects it, the freeze process will stop and change to a defrost process in which the evaporator will be sprayed with hot wind to melt the ice cubes so that they are released from the evaporator and will go down to the ice storage container. The falling ice will be received by the cutting motor and cut the ice into small shapes. After the ice is cut out, the cutting motor will stop then the working system will loop and start again at filling the water tank with the compressor running continuously.

Figure 1: Schematic diagram of ice tube machine.

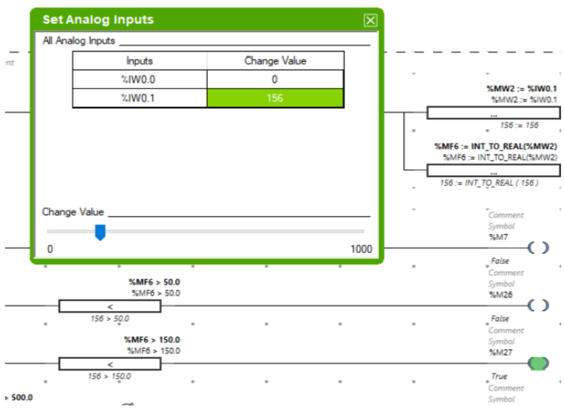

Figure 2: PLC program reads the data from sensors.

Testing using a PLC Schneider Modicon with a working step that is in the PLC program with temperature mode. The temperature mode working system is when the ON button is pressed, the compressor, condenser, pump, freeze will work. Then when the pressure sensor reads the pressure as shown in Figure 2. Temperature – 9^{0}C is configured as pressure, the process will move to the second stage, namely the defrost process and ice cutting.

2.2 HMI Design

Making the HMI program using the Schneider type, namely HMI Magelis as shown in figure 3. The ice tube machine works in 2 stages, namely stage 1 of the ice making process and stage 2 of the ice cutting process starting with the compressor on, followed by the condenser, pump, and valve defrosting, then after the sensor or timer works then stage 1 is complete and turns off. Then stage 2 of the cutting process starts with Valve defrost flashing (on – off repeatedly) after a while followed by cutting lit at the specified time and after the process is complete the machine will loop back to the stage 1 process.

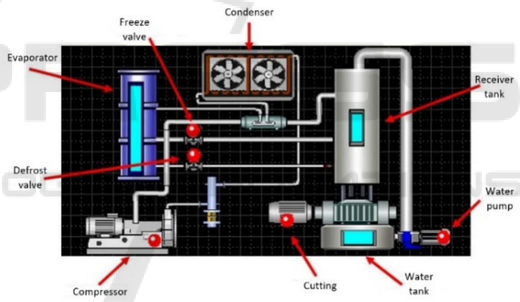

Figure 3: First view of HMI design of ice tube machine.

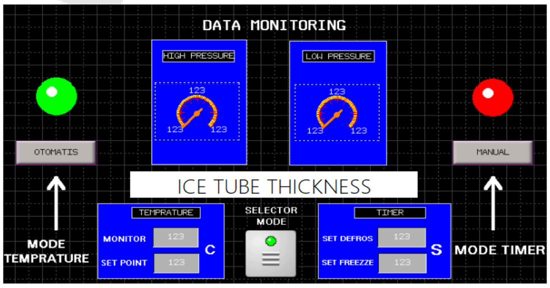

Figure 4: Second view of HMI design of ice tube machine.

Parts of tube ice machine

1. Compressor: serves to supply air to the engine.
2. Evaporator: air tank from freeze and defrost.
3. Condenser: a fan that serves to help the freeze process
4. Receiver tank: ice tube formation.

5. Water pump: a water pump that delivers water to the receiver tank
6. Water tank: a water reservoir.
7. Motor cutting: serves to cut the ice that falls from Receiver tank.
8. Valve freeze: serves as a regulator of the cold wind pressure opening valve for the freezing process.
9. Valve defrost: serves as a regulator of the hot air pressure opening valve for the defrosting process.

The second display consists of set points for the timer and temperature as well as monitoring for the sensors used and then there are manual and automatic buttons for switching panels/pages as shown in Figure 4.

3 RESULTS

3.1 Specification Data on Pressure Sensor

The bit value is the configuration value to be entered on the PLC. Here, the test is carried out when the sensor is given wind pressure, the maximum bit value that is read in the PLC is 106bit. Because the bit value is unstable up and down, the bit value is rounded up to 100. This value will later be used as the basis for calculating the PLC configuration.

The sensor voltage value is the value that becomes the basis for calculating other values. Here the test is carried out when the sensor is given a maximum wind pressure, the voltage value that can be read on the sensor is 3 Volt with a maximum wind pressure of 110 Psi as shown in table 1.

1 psi = 0.06 bar
110 psi x 0,06 bar = 6,6 bar
3 V: 100 bit = 0,03 V
Output voltage in PLC is 110 psi: 100bit = 1.1bit

Table 1: Test Specification Data.

No	Test Data	Condition value
1	Pressure sensor capacity	110 Psi/6,6 Bar
2	Maximum output voltage on sensor	10-13 Volt
3	Maximum output pressure on sensor	110 Psi
4	Range bit read by sensor	100
5	Measurable voltage	3 Volt
6	1 bit in PLC	0,03 Volt
7	1.1 bit in PLC	1 Psi

Maximum low pressure on the compressor 110 psi = 11^{0}C. Sensor read data on refrigerant R404A Ice tube freezing temperature -9^{0}Celsius = 50 Psi as shown in table 2.

The working process of the tool is sequential with stages starting with stage 1 of the freezing process then after stage 1 is complete proceed to stage 2 of the defrost process and the program will loop back to the beginning as in table 3.

Table 2: Calibration sensor on compressor.

No	Pressure (Psi)	Temperature (^{0}C)	Bit	Voltage (volt)
1	1	-50	1,1	0,03
2	10	-35	11	0,33
3	20	-27	22	0,66
4	30	-20	33	0,99
5	40	-14	44	1,32
6	50	-9	55	1,65
7	60	-5	66	1,98
8	70	-1	77	2,31
9	80	3	88	2,64
10	90	6	99	2,97
11	100	9	110	3
12	110	11	220	3,3

Table 3: Calibration sensor on compressor.

Step	Compressor	Condenser	Cutting	Pump	V. Freeze	V. Defrost
1	1	1	0	1	1	0
2	1	0	1	0	0	1

3.2 PLC Program Testing in Temperature Mode

System testing using PLC Modicon and HMI Magelis. The test runs according to the working stages of the tool. When the temperature mode must wait until the adjusted temperature is reached. The results of parameter testing on the PLC in temperature mode are as in table 4.

Temperature Mode Stages:

a. Display the monitoring data page on the HMI by pressing the DATA button.
b. Select in the selector to temperature mode.
c. Select the thickness of the ice tube on the selection buttons provided on the HMI monitor, namely 2cm, 3cm, 4cm, before running the program.
d. When the selection is correct and the ON button is pressed then the program can run. The effect of temperature on the ice machine is that it can

adjust the thickness of the ice using the bit value setting point on the PLC control in the HMI as shown in table 5.

Set points are entered on the HMI monitor when you want to make changes to the thickness of the ice tube. The following is a display of the thickness of the ice tube on the HMI monitor. When the ice thickness is set to a thickness of 2 cm with a temperature of -1^{0}C, the sensor will read the bit value at 55bit and display it on the HMI monitor as shown in Figure 5.

When the ice thickness is set at a thickness of 3 cm with a temperature of -5^{0}C, the sensor will read the bit value at 66bit and display it on the HMI monitor as shown in Figure 6. When the ice thickness is set at a thickness of 4 cm with a temperature of -9^{0}C, the sensor will read bit value in the 77bit number and displayed on the HMI monitor figure 7.

Table 4: Test parameters on PLC in temperature mode.

No.	Pressure (Psi)	High	Low	Temperature	Step 1	Step 2
1	> 350	1	0	0	0	0
2	< 20	0	0	0	0	0
	Temp. (^{0}C)	**High**	**Low**	**Temperature**	**Step 1**	**Step 2**
1	< -9	0	0	0	1	0
2	> -9	0	0	1	0	1

Table 5: Result in mode temperature.

No	Thickness of ice tube (cm)	Temperature	Bit value in PLC
1	2	-1	55
2	3	-5	66
3	4	-9	77

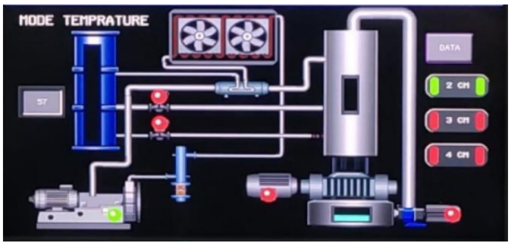

Figure 5: HMI display when the ice tube thickness is 2 cm.

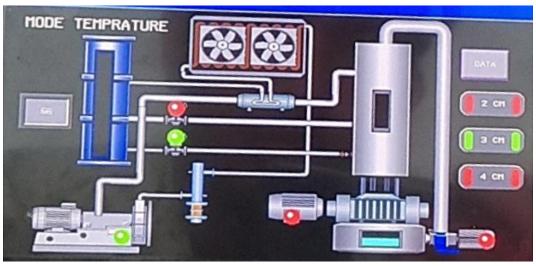

Figure 6: HMI display when the ice tube thickness is 3 cm.

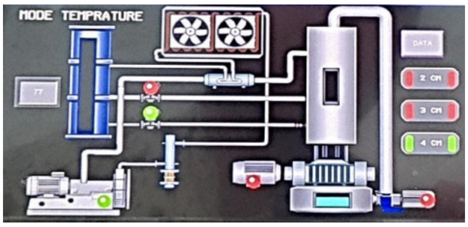

Figure 7: HMI display when the ice tube thickness is 4 cm.

4 CONCLUSIONS

The ladder diagram program in the PLC and the tool design display in the HMI work smoothly according to the working stages of the ice tube machine. The effect of temperature on the ice tube machine is as a regulator of the thickness parameter on the ice tube in temperature mode. The effect of wind pressure on the ice tube machine is that it functions as a helper for the freezing process and the melting process of tube ice formation and is also one of the main components of the tube ice machine.

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