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Performance Evaluation and Continuous Monitoring of Ice Plant with R134a Refrigerant by Using NI LabVIEW™ DAQs of System

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ABSTRACT

The paper aims at study of performance evaluation and its continuous monitoring with auto control system. This Ice plant works on the principle of Vapour compression cycle using eco-friendly refrigerant R134a. The refrigerant R134a is used as it is best alternative to R12, have zero Ozone Depletion Potential (ODP) and have similar thermodynamic properties to R12. Performance of Ice plant is very much sensitive with operating parameters so that continuous monitoring is very much needed with the provision of data backup.

NI LabVIEW™ DAQs is used for real-time monitoring of the Ice plant setup. The DAQs can realize the real-time data acquisition of temperature, pressure as well as data processing and display, in addition to provide users with historic data and alarms regarding operation of the Ice plant system. NI module creates an interface between temperature sensor and computer. The computer Program calculates the refrigerating effect produced and different COP of setup using property table of refrigerant fed in it. It saves a lot of manual operation and also made measurement more convenient and fast

KEYWORDS : *ODP, VCC, Hermetically sealed, Reciprocating, Compressor, Thermodynamic, Expansion valve, NI Lab view DAQs*

I. Introduction

Ice plant is used for producing refrigeration effect to freeze potable water in standard can spliced in rectangular tank which is filled by brine. A good definition of refrigeration is the removal of heat energy so that a space or material is colder than its surroundings. An ice plant based on same principle as a simple refrigeration system. An ice plant contains various parts such as compressor, condenser, receiver, expansion valve, and evaporator and refrigeration accumulator. A refrigeration is always been a great deal for human being and play a vital role in preserving food , chemical, medicine, fisheries and providing appropriate temperature in working entity of any industry. Refrigeration in the coming years becomes very essential deal for drastic development of the industrial sector. The continuous monitoring and control of ice plant is very much essential because operating parameters are continuously changing during one cycle of water to ice block formation.

Basic principles of refrigeration and need of ecofriendly refrigerant for better performance and environment friendly are discussed[1-2].

The parameters which are influencing the performance of Ice plant refrigeration process control system are discussed by [3].

Winkler [4]presents a simulation tool that simultaneously serves the industry needs of an integrated steady state and transient vapor compression simulation tool. The tool is developed using a component-based architecture allowing for the users to incorporate inhouse component models into the simulation and the component-based framework is discussed in detail. Ice plant is used for producing refrigeration effect which uses the vapour compression cycle and by using this cycle Performance Analysis of Ice Plant Using Ecofriendly Refrigerants carried out[.5-6]. NI Labview is used for simulation of solar vapour absorption system[7].

In this paper performance and continuous monitoring is discussed with the help of NI Labview. The parameters like properties of refrigent, operating parameters of VCC, i.e condenser pressure, evaporator pressure, temperatures etc are continuously tracked with respect to time and linked with control system for better performance.

II. Front Panel

Front panel is a window which gives graphical interface to monitor the setup. User can input data to the program in front panel. It shows output in different formats like graphs, tables or numeric indicators. There are 3 tabs in front panel; each tab has different event panels.

A. Tab 1

Input Panel: It is use to give different input parameters to program like pressure at different stages of cycle, voltmeter and ammeter readings and different constant parameters like initial brine solution temperature, mass of brine solution, water. User has to give an alarm sound path in this panel which give signal after every specified time to enter new value of pressure. The feed value button has to be press after each time the new reading is given by user. It has also function to convert pressure in psi to MPa or bar.

Thermophyscical properties: It shows different thermophysical properties of refrigerant in evaporator and condenser.Time Elapsed: It shows the time duration for how long the setup has been running.

Apart from this it has a save data button which is use to save readings directly on word file. The Stop button is use to stop the program. It also display the current data and time of experiment.

B. Tab 2

Refrigerating effect and Compressor Power Vs. Time graph: This panel shows the real time graph of refrigerating effect produce in evaporator and energy consumed by setup in watt. The graph is updated after every 60sec. It also show refrigerating effect and energy consumed in numeric indicator.

COP Vs. Time Graph: It shows the graph of different COP of setup with respect to time. COP is also displayed in numeric format. Graph updates after every 60sec of interval.
Temperature Indicator: It gives different temperature sensor reading which are attached at different stages of setup. The stages are shown in schematic diagram of setup with each number indicating position of a sensor.

C. Tab 2

Temperature Vs. Time graph: Different temperature sensor readings are shown in graph with respect to time. Readings are updated after every 10sec. Thermo physical properties at different stages of cycle: This panel gives different thermo physical properties of refrigerant at different stages of cycle. By clicking on different buttons user can access properties of refrigerant at different points mentioned in the P-h diagram. Observation table: It stores every temperature sensor readings, refrigerating effect, compressor power

III. NI LABVIEW Programming

A. Main Circuit:

This circuit involves the calculation of thermo physical properties of refrigerant at different stages and Theoretical COP and Carnot COP of cycle. The property table of R134a is stored in the form of Array [B1]. For each column in property table there is 1 D array of numeric data type. The flow of signal through different stages in this circuit are as follow:

- All the pressure readings given by user from Control [B3] are fed to this circuit from “Feed Value Circuit” using Local Variable [B8].
- These pressure values are first converted from psi to MPa unit using mathematical operation.
- All pressure in MPa are then searched in array of pressure from property table of refrigerant using Threshold 1 D Array [B5] which return the fractional index (elements in array are located using index) at which given pressure can be located in array.
- Using fractional index of all pressure values, other thermophysical properties of refrigerant

at different pressure are calculated from other arrays using Interpolate 1 D Array [B6]. Now all these values are used for further calculations.

- All temperature sensor reading are read by program using DAQ Assistant [B7]. This function read samples from sensor through modules connected to PC using USB cable. All information about sensor like its type, constants are already stored in the function. The output of DAQ Assistant is bundle of dynamic data which is then splitted to single data using Split Signal [B9].
- Different thermophysical properties calculated from property table and temperature from sensors are used for calculation of other parameters. Parameters calculated are as follow-

1. Enthalpy- Enthalpy at different points are calculated using formula
2. For ex. at point 1

$$h_1 = h_{g1} + C_{pv}(T_1 - T_{sat}) \quad \text{(At pressure P1)}$$

3. Superheating or subcooling is checked first before using formula by Select Function [B11]. If superheating or subcooling is present then only formula is applied otherwise property at saturation temperature is assigned.
4. Entropy -

   Formula used for ex. at point 1

$$s_1 = s_{g1} + C_{pv}\ln\left[\frac{T_1}{T_{sat}}\right] \quad \text{(At pressure P1)}$$

5. Carnot COP -
6. COPcarnot $= \dfrac{T_{evaporator}}{T_{condensor} - T_{evaporator}}$
7. Theoretical COP -

$$COPtheoretical = \frac{h_1 - h_6}{h_2 - h_1}$$

8. Dryness fraction (x) at point 6

$$x = \frac{h_6 - h_{f(\text{at mean evaporator pressure})}}{(h_g - h_f)_{(\text{at mean evaporator pressure})}}$$

9. Entropy at point 6 -

$$s_6 = s_f + x(s_g - s_f)$$

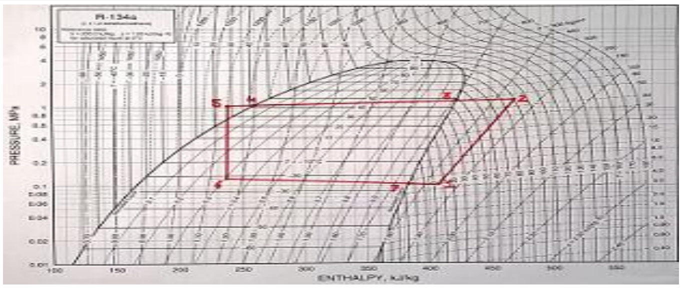

Fig. 1. P-h diagram for R134a

a. Main circuit has delay of 200ms using **Wait (ms) Function** [B12]. **While Loop** [B2] is executed after every 200ms. Delay is given to the program to give some relaxation time to the processor.
b. Program is abort using **Stop Function** [B13].

B. VI and Actual COP circuit:

This circuit calculate Actual COP of cycle and power consumption by setup. The flow of signal through different stages are as follow:

- Brine solution temperature value is given to circuit using Local Variable [B8] from main circuit. The initial brine solution temperature given by user is stored in left terminal of Shift Resister [B14].
- Program first compares initial and current brine solution temperature. If they are not equal, difference of both value will give temperature drop of brine solution.
- Now current temperature of brine solution is stored is right terminal of Shift Register which is transfer by LabVIEW to the left terminal. The loop then uses data from left terminal as the initial value for next iteration. This process continue until the loop terminates.
- The While Loop [B2] has given a delay of 59sec using Time Delay [B15]. It means temperature drop of brine solution is calculated after every 59sec.
- Mass of water given by user is first converted to equivalent mass of brine solution and then added to mass of brine solution.

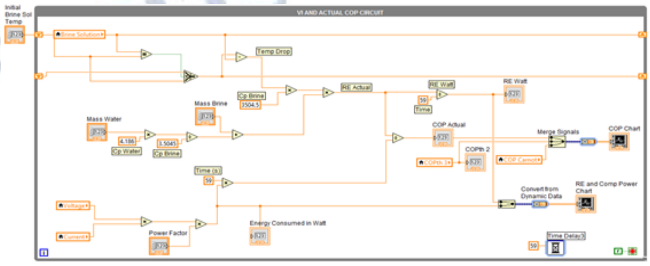

Fig. No.2 VI and Actual COP Circuit

C. Table Generating Circuit:

This circuit generates a result table of all the temperature sensor reading, refrigerating effect, energy consumed and different COP.

The flow of signal through different stages are as follow:

a. All the data to be stored are first converted into string using **Format into String** [B18] function.
b. A **Data Table** [B19]is used to store all values in the form of 2 D array. All data in string format are concatenated using **Build Array Function** [B20]which creates a 1 D array (i.e. a single row) of set of reading recorded at specific time.
c. This 1 D array is stored in Data Table using **Insert into Array** [B21],which is also get stored in right terminal of shift register.
d. LabVIEW transfer this array from right terminal to left terminal of Shift Register which is used as initial array for next iteration. As loop gets executed again and again rows of set of readings are stored in Data Table.
e. To save data directly on file **Write to Measurement File** [B22] function is use which creates text-based measurement file (.lvm extension). All data to be stored are first given signal name and unit (if any) using **Set Dynamic Data Attributes** [B23]and are merge into one signal.
f. Time delay of 60sec is given to circuit using **Time delay** [B15]. Therefore after every 60sec new set of reading is stored in table.

NOTE: Delay time of "VI and Actual COP Circuit" and "Table Generating Circuit" differs by 1 second. Difference in delay time is given to ensure that first actual COP is calculated and then it is stored in table. If both circuit have same delay time it might happen that first data is stored in table and then actual COP is calculated due to some lag in processing of both the circuit.

D. Date and time Circuit:

This circuit is use to display the current date and time of performance. Current date and time from PC is called using **Get Date/Time In Seconds** [B24]function. The current date and time is converted into string using **Get Date/Time string** [B25] and are displayed using **Indicators** [B3].

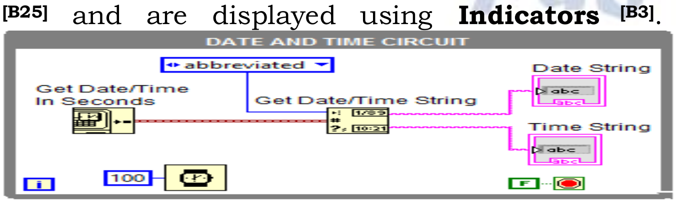

Fig. No.3 Date and Time circuit

E. Alarm Signal and Message Circuit:

The circuit is designed to display a message along with an alarm sound, after every specific period of time to inter new values of reading. The delay time between two message and alarm sound is count by **Elapsed Time** [B26]which return true value after every specific period of time has been passed.

This true signal is passed to different **While Loop** [B2]using **Local Variable** [B8] from first circuit. It is given to selector terminal of **Case Structure** [B27] which contains codes to display message and play alarm sound. For every true value the case structure is executed once. The case structure contains Path Control where user give path of alarm sound file (LabVIEW supports only .wav format sound file.) which is read by **Sound File Read Simple** [B28].The Read simple function return array of waveform which is played by **Play Waveform** [B29]function. Message is displayed to user using **Display Message to User** [B30]function. Both while loop do not have any delay function.

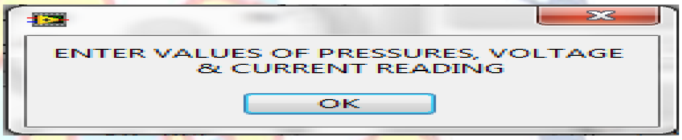

Fig. No. 4 Alarm Message

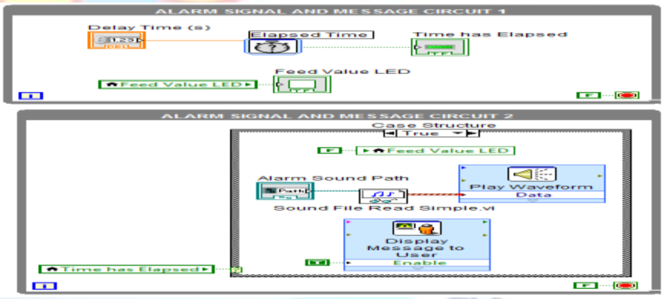

Fig. No.5 Alarm Signal and Message Circuit

F. Feed Value Circuit:

Whenever a user enters data into the program, it requires some time. The program should not accept any new data until all data has been given by user. Otherwise it will affect the calculations.

This circuit is use to feed all input at the same time into the program. It uses an **Event Structure** [B33] which waits until an event occur and then execute the appropriate case to handle that event. The data entered by user in **Control** [B3] is passed to its **Indicator** [B3] only when feed value button is pressed i.e. only when feed value changes its value from false to true.

The data is then transfer to different circuit wherever required using **Local Variables** [B8].

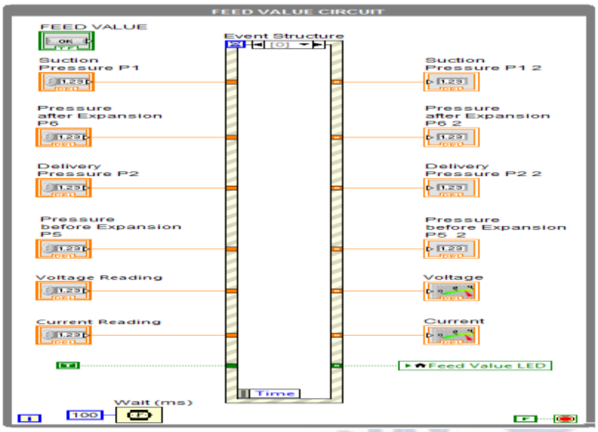

Fig. No. 6 Feed Value Circuit

G. Pressure conversion circuit:

It converts the different pressure in psi to MPa or bar. The conversion is done by mathematical operation. The output is converted to string using **Number to Fractional String** [B32] with specified precision. The pressure is converted either into Mpa or bar using **Event Structure** [B33] which uses two event case to execute either Mpa conversion formula or bar conversion formula. The output is displayed on same indicator.

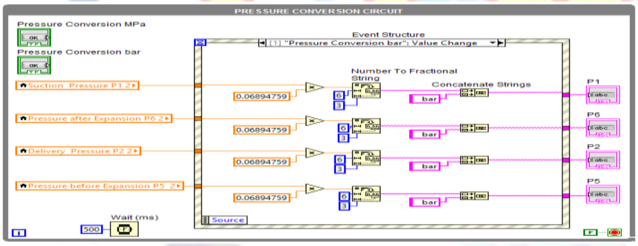

Fig. No.7 Pressure Conversion Circuit

H. Temperature chart circuit:

It display different readings of temperature sensor in graphical formats. The value of temperature are called using **Local Variable** [B8]from "Main Circuit". All temperature values are merged into one signal using **Merge Signal** [B10] which is then passed through **Convert from Dynamic Data** [B16] to convert it into array signal. Array signal is given to **Waveform Chart** [B17]to plot Temperature Vs. Time graph. Chart is updated after every 10sec.

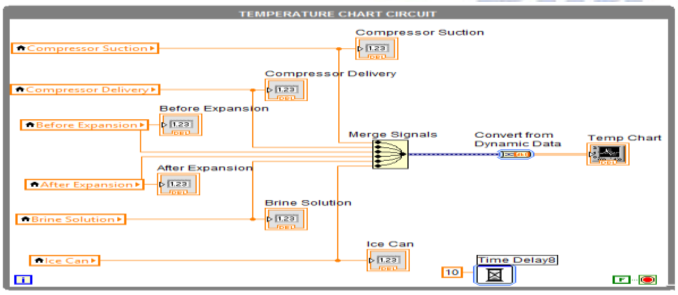

Fig. No.8 Temperature Chart Circuit

I. Thermo physical Properties Display Circuit:

The thermo physical properties at different stages of cycle is displayed using this circuit. All data to be displayed are called using **Local Variable** [B8]. **Event Structure** [B33] is use to decide properties at what point to be displayed on indicator. Change of value of different buttons causes different event caseto execute.

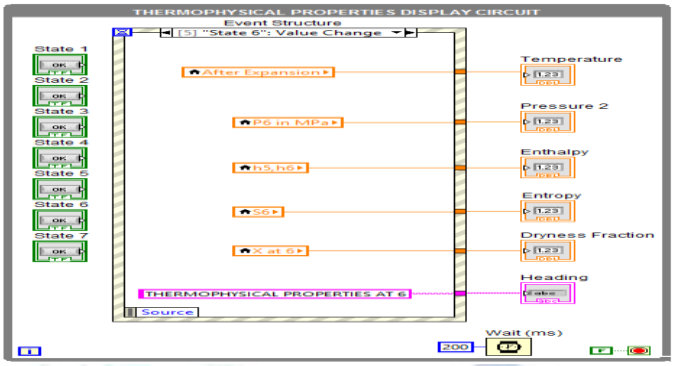

Fig. No.9 Thermo physical properties display circuit

J. Help circuit:

In front panel of LabVIEW each panel consist a help button which give information about that panel to the user by displaying a dialog box. It uses **Display Message to User** [B30]function which is executed when help button is pressed.

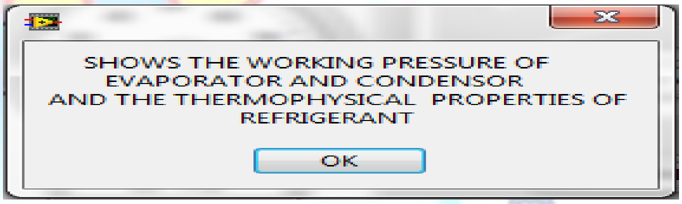

Fig. No. 10 Example of Help Message

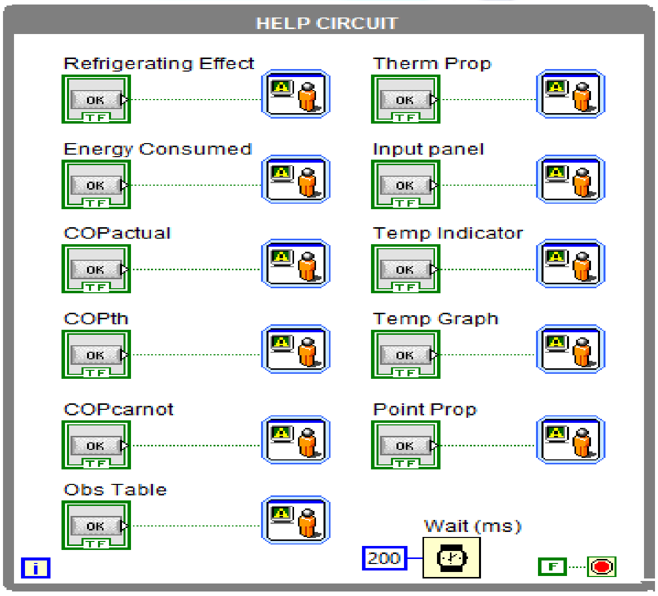

Fig. No. 11 Help Circuit

Table 1 Observation and Result Table Using NILabview

Time min	T1 (⁰C)	T2 (⁰C)	T3 (⁰C)	T4 (⁰C)	T_{brine}	T_{water}	RE (W)	P (W)	COP_{th}	COP_{actual}
0	15.02	95.01	41.96	-0.96	7.53	8.74	1944.08	1208.9	2.41	1.608
1	14.92	95.08	42.00	-1.08	7.34	8.56	2019.52	1197.91	2.4	1.686
2	14.84	95.18	42.07	-1.12	7.15	8.38	1937.56	1197.91	2.39	1.617
3	14.75	95.06	41.80	-1.41	6.97	8.19	1885.52	1197.91	2.4	1.574
4	14.61	95.12	41.75	-1.39	6.79	8.01	1885.52	1197.91	2.39	1.549
5	14.49	95.13	41.64	-1.58	6.6	7.83	1927.69	1197.91	2.38	1.609
6	14.36	95.17	41.6	-1.63	6.41	7.65	1891.4	1197.91	2.38	1.579
7	14.31	95.17	41.65	-1.73	6.22	7.45	1990.42	1197.91	2.38	1.662
8	14.26	95.22	41.71	-1.8	6.05	7.29	1765.32	1181.12	2.36	1.495
9	14.20	95.34	41.89	-1.97	5.88	7.11	1796.69	1181.12	2.37	1.521
10	14.09	95.22	41.69	-2.16	5.69	6.93	1861.1	1181.12	2.36	1.576

IV. Conclusion

1. Actual COP is less than Theoretical and Carnot COP due to assumption made during experimentation.
2. As time passes, refrigerating effect produce decreases or rate of decrease of brine solution temperature decreases because of decrease in temperature difference between brine solution and refrigerant in evaporator coil. Therefore actual COP always decreases with time.
3. As brine solution temperature decreases, to create further refrigerating effect refrigerant is throttled to even lower evaporator pressure. As an effect both condenser and evaporator pressure decreases with time therefore COP Carnot decreases.
4. Experimentation using NI LabVIEWTM DAQs is more accurate and precise than manual experimentation. DAQs gives better understanding of setup during running condition.

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