Implementation of a Smart Temperature Controller in Real Time using Lab VIEW

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Abstract - In modern era, the remote online control of any process becomes a real necessity in the industrial communities as well as in academic institutions all around the world. This paper presents a latest approach to design and develop a virtual instrumentation based online remote access control experiment laboratory, which allows users to perform control experiment through internet using latest LabVIEW technology. The software enables complex & expensive equipments to be replaced by simpler & less expensive hardware. This paper describes about the development and implementation of a temperature controller in real time using Data Socket Communication Protocol in LabVIEW. The proposed system is connected to a server computer using a digital temperature sensor circuit board. The objective of this experiment is to maintain the temperature inside a closed chamber that is heated by a set of light bulbs at some set point value, selected by a remote client. This controlling system can uniquely monitor the whole set-up and can control the temperature online successfully.

Keywords - *Virtual Instrumentation, Data Socket Communication Protocol, Remote Access Control, LabVIEW, Digital Temperature Sensor, Solid State Relay.*

I. INTRODUCTION

Various technologies are developed to perform the real time control using internet based technology. LabVIEW is one of the well known software packages used in process control applications [1]. A remote-access control experiment laboratory was developed at the Chinese university of Hong Kong, which allows users to perform control experiments over the Internet [2]. The research identified the advantages and disadvantages of this technology. The University of Florida has also developed an on-line engineering laboratory for real-time control over the Internet, using the Virtual Instruments (VI) in LabVIEW [3]. Lab VIEW uses various protocols such as TCP/IP, Data Socket, etc. that allow remote control using Internet. Several universities have developed Internet-based process control laboratories for distance education using LabVIEW and its communication protocols. Researchers at the Fort Valley State University studied Lab View's Internet capabilities [4].

II. PROPOSED SYSTEM

Figure 1 shows the internet based control set-up of the proposed system. A wooden chamber filled with a set of light bulbs is connected to the main server computer using a digital temperature sensor circuit board.

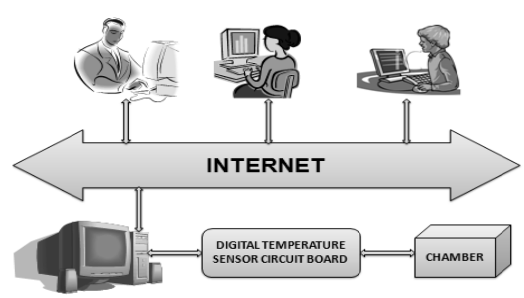

Fig. 1 : Internet Based Control Setup

The server is connected to the internet and it is assigned a static IP address. The clients could be any personal computer (PC) with the Network Interface Card (NIC) that can run the LabVIEW program.

III. HARDWARE FOR REMOTE TEMPERATURE CONTROL

In our proposed system, a chamber is heated with a set of light bulbs. The temperature inside the chamber is maintained at some desired set point value, within neutral zone limits using a two-state controller mode.

Figure 2 shows the schematic diagram of the temperature control experiment. A digital temperature sensor circuit is a combination of several ICs, such as: voltage calculators, voltage regulators etc. in order to sense the temperature, which is generated for the set of light bulbs in the chamber during the experiment.

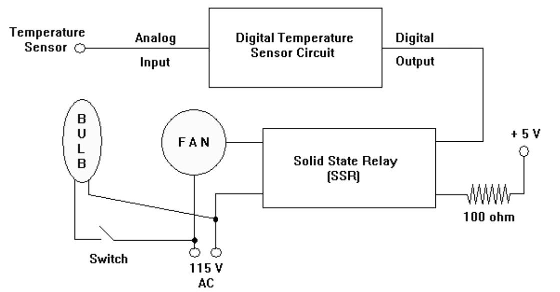

Fig. 2: Temperature Control Experiment: Schematic Diagram

The temperature sensor will feed an analog voltage to the digital temperature sensor circuit. This digital temperature sensor circuit will process the analog voltage and finally converts the analog voltage into digital form [5]. The output signal from the digital temperature sensor circuit is further fed to the input of a Solid State Relay (SSR). The output of the Solid State Relay is connected to a cooling fan and also with a set of light bulbs, situated inside a chamber. As the set of light bulbs glows, automatically increases the set point value of the rated temperature inside the chamber. Then the Solid State Relay will immediately break the circuit and turn on the cooling fan to get control over the rise in temperature inside the chamber [6].

Figure 3 shows the circuit diagram of the temperature control experiment. A digital temperature sensor circuit is a combination of several ICs, such as: voltage calculators, voltage regulators etc. in order to sense the temperature, which is generated for the set of light bulbs in the chamber during the experiment.

The detail descriptions of the ICs are as follows:

IC 1 = IC 7805

IC 2 = IC LM 317

IC 3 = IC LM 35

IC 4 = IC ADC 0804

IC 7805 :

IC 7805 is a voltage regulator circuit. This IC features overheating protection, stops supplying current in case of excess heat [7]. This IC provides +5 volt output at about 150mA current, but can be increased to 1 Amp when good cooling is needed to the 7805 regulator IC.

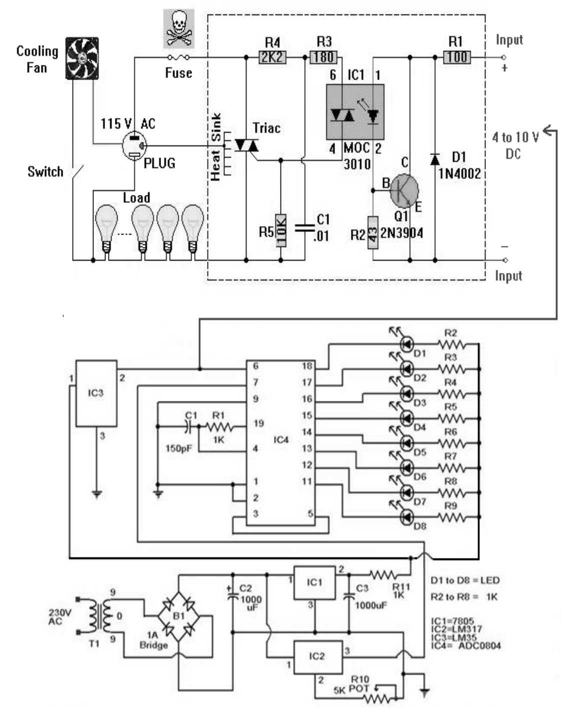

Fig. 3: Temperature Control Experiment: Circuit Diagram

IC LM 317 :

IC LM 317 is a handy online output voltage calculator, which can take the input voltage of 3 to 40 volts DC and a fixed output voltage from 1.2 to 37 volts DC [8].

IC LM 35:

IC LM 35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature [9]. The LM 35 thus has an advantage over the linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM 35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level [10]. The LM 35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy.

IC ADC 0804 :

IC ADC 0804 is an analog to digital converter circuit. This IC converts an analog voltage into its corresponding digital output value, which is represented by the D1 to D8 light emitting diodes (LED), connected with R2 to R9 resistors (1K) in series respectively [11]. From the pin number 6 of IC ADC 0804 the DC signal is coming out, which is further fed to the input of the Solid State Relay (SSR) of the setup.

Solid State Relay :

A Solid State Relay (SSR) is an electronic switching device where a small control signal controls a larger load voltage or current [12]. The SSR comprises a voltage or current sensor which responses to an appropriate input control signal, an electronic switching device which switches power to the load circuitry either ON or OFF. The relay is designed to switch either AC or DC to the load [13]. The Solid State Relay mainly operates using IC MOC3010, which is a six pin DIP random phase opto isolator TRIAC driver [14]. The Solid State Relay gives the AC output voltage of nearly 115 volts. A plug is fit at the output side from where the load i.e. set of light bulbs is connected. A cooling fan is also connected through a switch for safety measures.

IV. SOFTWARE FOR REMOTE TEMPERATURE CONTROL

The digital temperature sensor circuit is connected with the server machine where the LabVIEW software is used to develop the lab experiment to control the remote temperature control system. The voltage (V) from the analog to digital converter circuit is converted to temperature (T) [15]. Where T is the process temperature inside the chamber and V is the input voltage from the digital temperature sensor circuit. The LabVIEW software reads the temperature from the circuit.

The high limit temperature and the low limit temperature are constant for a particular chamber and known to the server. The process temperature of the chamber, high limit and the low limit temperature are sent to the client by the server through internet. The client sets a set point value based upon the high limit temperature of the chamber. An error is being calculated by the client where,

Error = Set Point Value – Process Temperature

If the error is positive, then it indicates that the temperature of the chamber is under control. But if the error is negative, the rise in temperature has to be controlled and therefore the cooler fan gets turned ON.

The cooling fan ON and OFF indicator are used in the LabVIEW in the server machine [16]. The cooling fan ON indicator becomes green when the process temperature becomes higher than the desired set point value. The logic of the server program is as follows:

<u>Case 1</u>

<u>Test Condition:</u>

Error > 0

AND

T > Low Limit

<u>True Situation</u>: Assign the following values to the variables

Cooling Fan ON Indicator: False

Cooling Fan OFF Indicator: True

<u>False Situation:</u> Go to Next case

<u>Case 2</u>

<u>Test Condition:</u>

Error ≤ 0

AND

T ≤ High Limit

<u>True Situation:</u> Assign the following values to the variables

Cooling Fan ON Indicator: True

Cooling Fan OFF Indicator: False

<u>False Situation:</u> Assign the following values to the variables

Cooling Fan ON Indicator: False

Cooling Fan OFF Indicator: True

V. INTERNET COMMUNICATION USING DATA SOCKET PROTOCOL

Socket is an interface between application process and transport layer where the application process can send and receive message(s). A connection is denoted by 5 tupple: from IP, from Port, protocol, to IP, to port. Generally the client uses the domain name and every domain name has its own IP address [17]. The Domain Name System (DNS) translates the domain name to IP address. In our proposed system, the data socket is working as a communication protocol. The data socket transfer protocol (DSTP) is used by the data socket which allows both way communication and data exchange between applications [18]. The server and the client both are using this protocol. Several SubVI’s in LabVIEW can be used within Data Socket Programming [19], [20]. It includes create connection, close connection, read, write, sent, receive messages etc.

A. Data Socket Programming Implementation

1. At Server View

A server machines are always at a port number to listen whether there are any request for connection or not. A socket is created & bind by the client & is sent to the server by using a URL i.e. dstp://localhost/filename. The DNS find the IP address and come to the server and then server listen the connection. The clients here simultaneously monitor the process and control the temperature remotely. There can be n number of clients who can monitor the whole system. But the particular client is selected by the login system i.e. which client logs first that will monitor the whole system. The server simultaneously receives the process temperature from the digital temperature sensor circuit and sends it to the client. The client also receives the high and low limit temperature of the system from the server. The server LabVIEW front panel I and II is shown in figure 4 and 5 respectively.

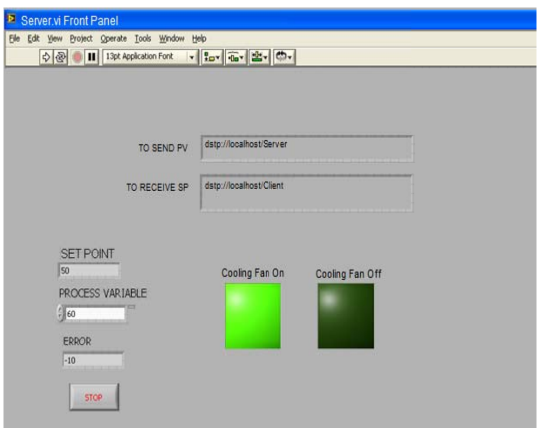

Fig. 4 : Server Front Panel – I

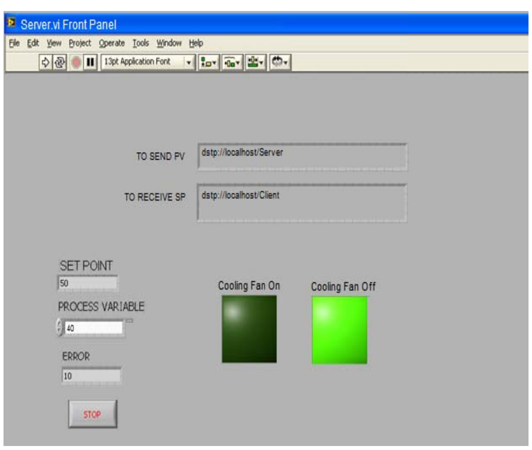

Fig. 5: Server Front Panel - II

2. At Client View

The client computer supports the bi-directional communication using Data Socket protocol. The client selects the server using the URL dstp: //domain_name/filename. After receiving the acknowledgement from the server the client starts monitoring. The values of process temperature sent by the server are plotted on a graph on the client's computer. The client sends the signal to the server to ON/OFF the cooler fan depending upon the error. The client keeps monitoring the system till the connection is closed. The LabVIEW block diagram of the clients program VI is shown in the Figure 6.

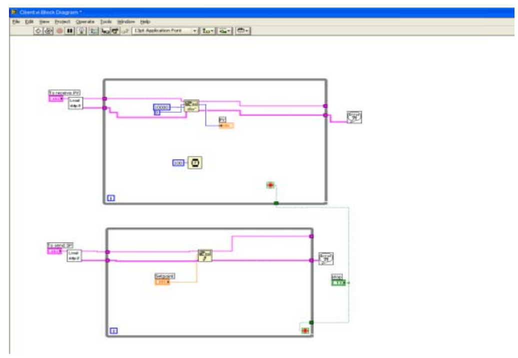

Fig. 6 : Client Block Diagram

B. Socket Programming Algorithm

The algorithm of the communication between server and client mainly describes the flowchart of the process. The Data Socket programming algorithm for temperature control (Table1) is as follows:

TABLE I. ALGORITHM FOR SERVER AND CLIENT COMMUNICATION

No.	**Server** ***Table column subhead***	**Client** ***Subhead***
1.	Ready to get connected at some port number	
2.		Log In (Request for the connection) [Command: **socket, bind**]
3.	Attempted Connection is sensed [Command: **listen**]	
4.	Accept connection request [Command: **accept**]	
5.	Send acknowledgement	

No.	Server *Table column subhead*	Client *Subhead*
	to the client. [Command: **send**]	
6.		Login Successful [Command: **recv**]
7.	Send high and low limits temperature (one time) and process temperature (simultaneously) [Command: **send**]	
8.		Receives all the temperatures. [Command: **recv**]
9.		Fixes set point value depending upon the high limit temperature.
10.		Simultaneously compare set point value with process temperature.
11.		Test Condition if(process>=set point value) then send signal to ON Cooling Fan [Command: **send**]
12.	Receives the signal and do Cooling fan on← true Cooling fan off←false [Command: **recv**]	
13.	Send the acknowledgement to the client [Command: **send**]	
14.		Receives acknowledgement. [Command: **recv**]
15.		Test condition if (process<set point value) then send signal to OFF cooling fan [Command: **send**]
16.	Receives the signal and do Cooling fan on←false Cooling fan off←true [Command: **recv**]	
17.	Send the acknowledgement to the client [Command: **send**]	
18.		Receives the acknowledgement [Command: **recv**]
…	………………………	…………………
(n-2).		Log out [Command: **shut down**]
n/ (n-1).	Close Connection [Command: **close**]	Close Connection [Command: **close**]

VI. CONCLUSION

The overall objective of this paper is to develop and implement a real time temperature controller to monitor and control a real time process. The setup of a temperature controller using data socket protocol is programmed in LabVIEW. The experiment was successfully synthesized and tested. This remote real time monitoring and control capability will provide an opportunity to various industries and academic institutions to control and monitor the process remotely. This setup can be used successfully as this reduces the load of man power and also gives excellent online services which can save our valuable time. Web publishing tool in LabVIEW can also be used for remote monitoring and control.

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