

Emulated Control System for a Nuclear Reactor

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Abstract—This paper discusses some of the instrumentation aspects of process control system developed for a nuclear power plant. Monitoring and controlling are the essential elements in the normal, abnormal and emergency operation of nuclear power plant. Through their sensors and transmitters, control systems measure process variables and return to control valves, motors and other electromechanical equipments of the nuclear plant. In this context, we have developed a Labview based such control system aimed at developing a real time system to deploy via IoT(Internet of Things). We represent here our conceptual design developed in Labview platform integrated with Arduino Uno microcontroller.

The instrumentation and control system measures basic physical parameters like level, temperature and pressure using sensors. The monitoring and control of the temperature is done using virtual instrument software LabView, which acts as data acquisition module. It monitors performance and helps in controlling the nuclear plant operations to keep the process variables within the plant design limits and ensures the plant safety. The transmission of data from one end to another end is done through wireless technology ZigBee, to monitor and analyze plant processes and equipment on the Labview platform.

Keywords-Nuclear power plant, Arduino, Zigbee, Labview

I. INTRODUCTION

Temperature and pressure are the two important critical parameters in a nuclear power plant. The monitoring and the controlling actions are to be done in Labview from the control room. The temperature in the Nuclear reactor is sensed using temperature sensor which is interfaced with Arduino.

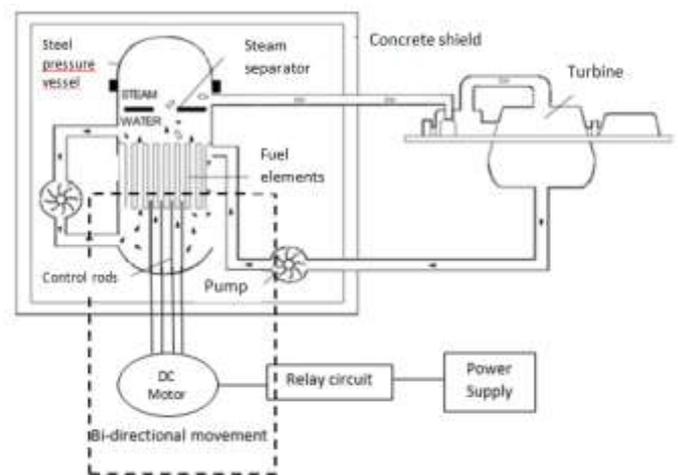
The Arduino is interfaced with Zigbee transmitting module for the wireless transmission of sensed temperature. This information is received in Zigbee receiving module which is interfaced with PC in which Labview simulation has been done. The sensed information is monitored in real time and the variations are observed.

A. POWER GENERATION PROCESS IN NUCLEAR REACTOR

The nuclear reactor consists of fuel rods in which there are hundreds of pellets enriched with Uranium-235 or Plutonium-239 during nuclear fission. The heavy nucleus splits into two or more lighter nuclei, releasing kinetic energy, gamma radiations, and free neutrons. Some portion of these neutrons are absorbed by other fissile atoms and trigger further fission events, which release more neutrons thus increasing the number of neutrons. This is known as a nuclear chain reaction.

A neutron is used to trigger the reaction. The position of control rods are adjusted in such a way that only one neutron is left behind to continue the chain reaction. This reaction is carried out and the heat released is transferred to non-radioactive water in the heat exchanger. The metallic pipes conduct heat from moderator to the normal water and convert normal water into

steam. This steam moves through the turbine which in turn moves the coil of the generator to produce electricity



. Fig.1. Inner view of Nuclear reactor

In the nuclear reactor as the nuclear fission proceeds the temperature goes on increasing due to fast moving neutrons released and it reaches to a certain stage where there is a drastic increase in the temperature beyond limits. If left unchecked the chain reaction will grow exponentially and results in nuclear accidents. Hence it is utmost important to monitor it continuously and control the temperature for the proper maintenance of a nuclear reactor. The control rods are the neutron absorbers and help in reducing the temperature by absorbing the neutrons produced due to chain reaction. Hence to supervise the movement of control rods according to the varying temperature is an important action in the Nuclear reactor.

II. LABVIEW AS PC BASED INSTRUMENTATION SYSTEM

LabVIEW is a graphical programming tool based on powerful test system, which is a well-connected, open, and has dedicated services and thus the test system development cycle is short, low cost, and yielding high quality [5]. It also creates appropriate user interface that suits the purpose of application and provides modularity.

The sensed information is acquired and displayed in the chart designed in the labview. The designing of block diagram is done in such a way that there is a complete hold on over the processes of nuclear reactor. To communicate between Labview virtual instrument and the sensors and actuators, a NI-DAQ (National Instruments –Data Acquisition) hardware is used. DAQ consists of several electronics components such as LEDs, microcontroller, ADC, DAC, timers, counters to convert the measured physical signal into an electrical signal. It digitizes the incoming analog signals so that the computer can interpret them. Here Arduino is used as DAQ device. The sensed temperature is preserved as an excel sheet for the analysis of the system. Here Lab view acts as data base system.

III. BLOCK DIAGRAM OF TRANSMITTING AND RECEIVING MODULE

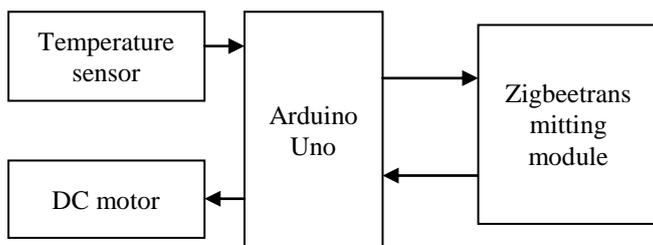


Fig.2 Schematic block diagram of Transmitting end

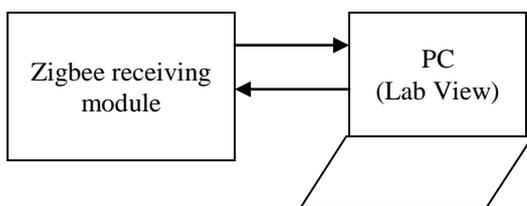


Fig.3. Schematic block diagram of Receiving end

A. TEMPERATURE MONITORING

The temperature sensor to be used in nuclear reactor is to withstand high temperature. Here, to design a prototype, LM35 is used. It has three pins in which one end is connected to ground and the other end is connected to Vcc. The middle pin is the output pin which gives analog signals to the arduino in millivolts. The LM35 series are precision integrated circuit

temperature sensors, whose output voltage is linearly proportional to the Celsius temperature [3].

B. INSTRUMENTATION MODULE

Arduino is a microcontroller which is based on ATmega-328 chip with six analog input pins, fourteen digital input output pins of which six are pwm, Arduino can sense the environment by receiving input from temperature sensor and can affect its surroundings by controlling lights, motors, and other actuators [3]

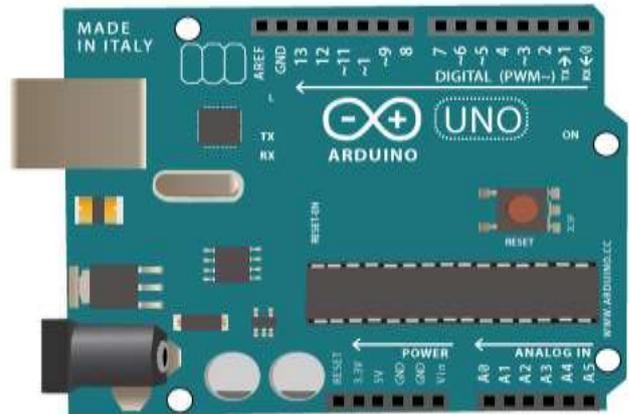


Fig.4 Arduino Uno Board

C. WIRELESS SENSOR NETWORK

IEEE 802.15.4 Zigbee protocol is used for wireless transmission. The ZigBee specification enhances the IEEE 802.15.4 standard by adding network and security layers and an application framework [2]. Its operating frequency is 2.4GHz and is appropriate for real time monitoring applications. It is also suitable for industrial applications due to low power consumption. As it is governed by AES-128 bit security system, the security issues are solved.

D. CONFIGURING ZIGBEE MODULES

It is important to set ZigBee Module Source address and Destination address, to transfer data from one ZigBee (Source) to another ZigBee module (Destination) so that it does not interfere with the other module in the same network. Also to set ID address to both Zigbee X-CTU software is used. X-CTU (Xbee configuration and utility test) software communicates with ZigBee, to change configuration or Transmit/Receive data.

Zigbee has mainly three systems- Co-ordinator, Router and End device. Coordinator forms the root of the network tree and might bridge to other networks, Router acts as intermediate nodes, relaying data from other devices. End Device can be low-power or battery-powered devices which collect various information from sensors and switches [2]

The PAN ID of both the zigees must be same. The destination address of co-ordinator is changed to the MAC address of the router and vice versa using the write option. Thus one of the zigees is made as the co-ordinator and one as router for communication.

IV. INTERFACING LABVIEW WITH ARDUINO

The following softwares are required to interface Labview with Arduino .LIFA (Labview interface for Arduino) ,VI manager, Arduino IDE, NI VISA drivers are required. LIFA is a VI based API and it supports Arduino 1.05.1 r2 .It allows to acquire data from the arduino microcontroller and process it in the labview graphical programming environment. As Arduino language is text based programming language it must be converted to graphical programming language which is done by loading the Arduino library LIFA_base.ino into the Arduino chip. This program which runs on Arduino responds to commands sent on the USB bus from the Labview program.

The block diagram is designed on labview platform. The Arduino block modules are initialized and configured to proceed with the connections. The baud rates in the Arduino initializer and the code loaded must be similar in order to operate. The VIs provided allow to read the analog input and control digital I/O lines.

V. CIRCUIT OPERATION

The sensed temperature is transmitted to Arduino which in turn sent to Zigbee transmitter. This information is received in zigbee receiver which is interfaced with Labview. In the front panel of Labview the variation of temperature can be seen in the waveform chart.

There are two set points to set the upper and lower limits of temperature. If the sensed temperature goes beyond upper limit the alarm gets on, LED glows and the signal is given to the input of relay circuit. This drives the DC motor which in turn

drives the control rods into the nuclear reactor .As the control rods absorb neutrons and thereby help in controlling the chain reaction and thus decreases the temperature. Similarly, if it goes below the lower limit the LED indicates that the temperature is low and hence control rods are moved into the reactor vessel for the chain reaction to be continued.

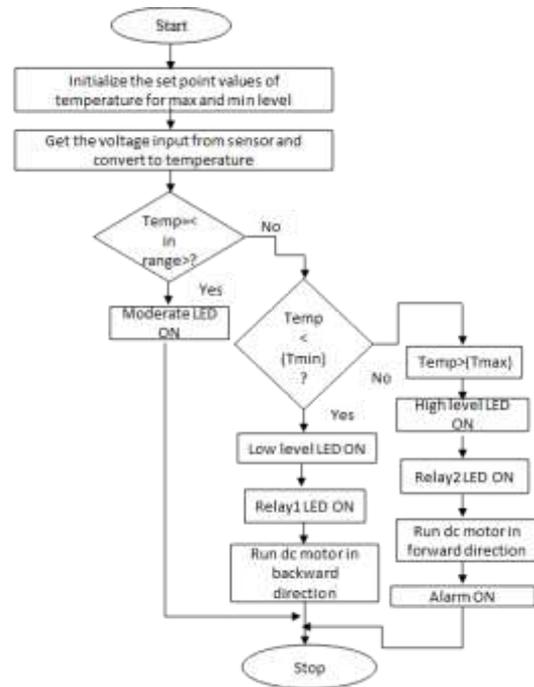


Fig.5. Flow chart of designed control system

VI. SIMULATION RESULTS

A. LABVIEW FRONT PANEL

It acts as user interface which stimulates the front panel of a physical instrument and is used for data representation. The controls and indicators like LEDs, numerical indicators, stop button and waveform chart are seen.

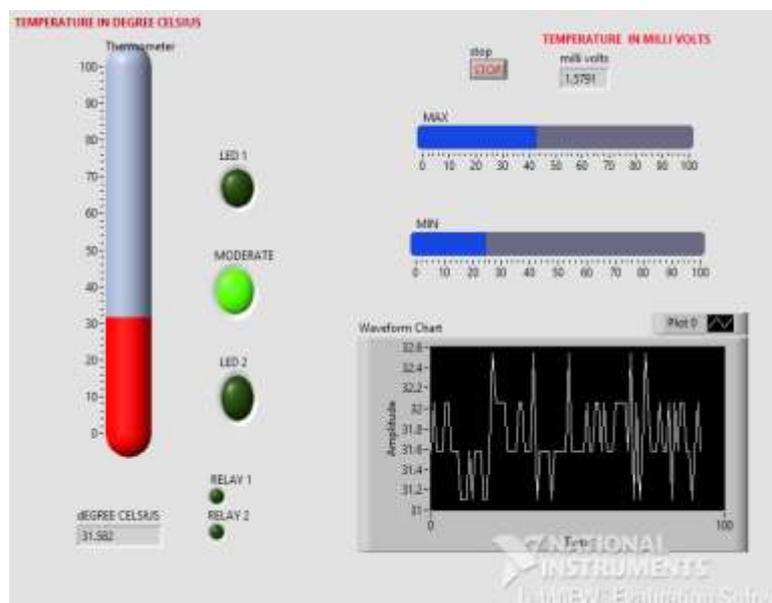


Fig.6. Graphical User Interface of Labview Simulation

V. LABVIEW BLOCK

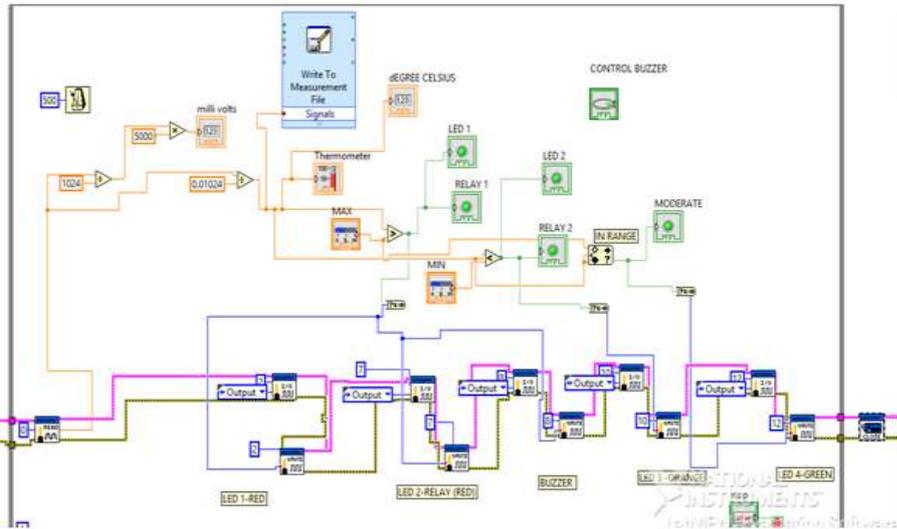


Fig.7. Block Diagram of Labview Simulation

VI. DIAGRAM

The arduino initializer is chosen to select the port, packets, baud rate and the type of arduino that is used. The value obtained from this module is in millivolts. It is converted to degree Celsius for better understanding. The temperatures values are stored into excel sheet using file management I/O for reference and analysis. To control the signals back, digital write blocks are selected and the arduino resource port is connected till the arduino close block. Arduino close block is used at the end of the design to complete the circuit.

A. FILE MANAGEMENT I/O

The File I/O virtual instrument is used to read from and write to files, create directories and files that is specified in the path control, retrieve directory information and write numbers, arrays or clusters to files. The sensed temperature which is converted to degree Celsius is the input to the file I/O block. This information is saved as .lvm format and it is dragged and dropped in to the excel sheet and is used for Data analysis and reference.

Time	TEMPERATURE CELSIUS
00:00:00	28.8
00:00:01	28.8
00:00:02	28.8
00:00:03	28.8
00:00:04	28.8
00:00:05	28.8
00:00:06	28.8
00:00:07	28.8
00:00:08	28.8
00:00:09	28.8
00:00:10	28.8
00:00:11	28.8
00:00:12	28.8
00:00:13	28.8
00:00:14	28.8
00:00:15	28.8
00:00:16	28.8
00:00:17	28.8
00:00:18	28.8
00:00:19	28.8
00:00:20	28.8
00:00:21	28.8
00:00:22	28.8
00:00:23	28.8
00:00:24	28.8
00:00:25	28.8
00:00:26	28.8
00:00:27	28.8
00:00:28	28.8
00:00:29	28.8
00:00:30	28.8

Fig. 8. Data acquisition sheet in Excel acquired from Labview

VII. CONCLUSIONS

This system provides an efficient continuous monitoring and data acquisition system. It provides flexibility and scalability across multiplatform and application distribution. As wireless technology is used it reduces the complexity involved in the cable installation and maintenance costs. Data acquired using the temperature sensor deployed with respect to the necessary

parameters in the industry processed by LabView functionalities. The necessary control signals were generated and sent back to the LED for indication and to switch on the alarm. The DC motor is driven to control the movement of control rods in and out of the reactor so as to maintain the required temperature.

Further, the work is underway to enable the system via IoT for real time for real time applications like to prevent any catastrophe and other kind of disasters. In the future, this can be IoT enabled for real time monitoring irrespective of the presence of operator in the control room and data to be stored in cloud which acts as database so that it can be retrieved at any point of time.

VIII. ACKNOWLEDGEMENT

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IX. REFERENCES

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