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Research Article

Design of Sensor Fault detection and Remote monitoring system for temperature measurement

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Abstract

This paper proposes the design of sensor based Fault detection & Remote monitoring system for temperature measurement using Atmel AVR controller and LabVIEW. Temperature is an important industrial parameter that needs to be monitored continuously. An entire system may fail; if the sensor fails. The failure of any system may cause losses such as economical, equipment damage and even risks the life of an individual. The purpose of the fault detection system is to ensure that simple faults can be detected at an early stage and necessary actions could be taken so that they do not develop into serious failure or cause any harm and increase plant availability. The fundamental design of fault detection is presented with help of temperature sensors, Atmel AVR development board (Arduino UNO) and Virtual Instrumentation platform (LabVIEW). To demonstrate the concept of sensor fault detection, the system comprises of a closed box with a variable intensity light source and temperature sensors. The temperature data is acquired by embedded module and is transmitted to LabVIEW application serially. Any failure in sensor will be annunciated locally and shall be notified remotely in the web browser panel. The host program on the LabVIEW platform is responsible to publish the data on internet via data socket. The data published is in monitor mode which allows displaying an animated snapshot of the data acquisition panel that updates continuously, enabling the user to monitor it from remote location.

Keywords: *Fault detection, Remote monitoring, LabVIEW, AVR Development Board (Arduino UNO).*

1. Introduction

Fault in any system causes its performance to degrade or leads to unacceptable changes. Faults in automated processes will often cause undesired reactions and shut-down of a controlled plant (Ron J Patton). Equipment damage, economical losses and fatal injuries to individuals can be few of many possible consequences of a system failure. Different types of faults can occur in any system such as faults due to sensors, actuators, etc. In a sensor based system the output of the sensor is constrained between two points if it exceeds or goes below these two points, the sensor is considered to be possibly failed (SuswethaParisineti*et al,* 2011). Another instance of sensor failure is where a sensor may appear to act normally but does not correspond to the correct value of physical parameter. A fault detection system must be able to detect these faults at initial stage so as to avoid serious failure.

1.1 Types of Faults

Faults can be of two types: (M. B. Djuria*et al,* 1995)

1). Permanent Faults

- Due to manufacturing defects, early life failures, Wearout failures.
- Wearout failures due to various mechanisms.

2). Temporary Faults

- Only present for short period of time.
- Caused by external disturbance or marginal design parameters.

1.2 Various Fault detection methods: (Rolf Isermann)

1. Process models and fault modeling.
2. Signal models
3. Fault detection with limit checking.
4. Fault detection with signal models.
5. Fault detection with process identification method
6. Fault detection with parity equations.
7. Fault detection with state observers and state estimation.
8. Fault detection with control loops.
9. Fault detection with principal component analysis (PCA).

Temperature is a critical condition for reaction, fermentation, combustion, drying, calcinations,

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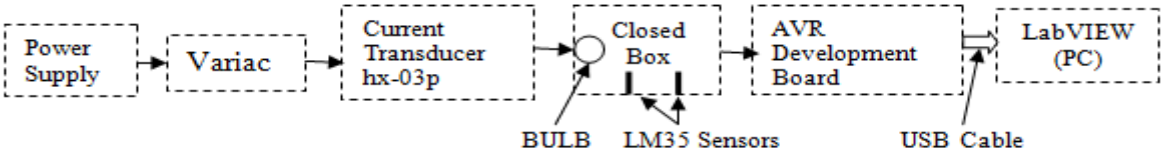

Figure 1: Block diagram of the system.

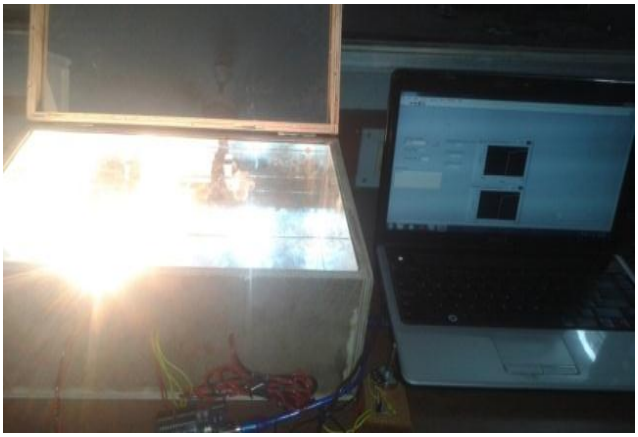

Figure 2: Experimental setup

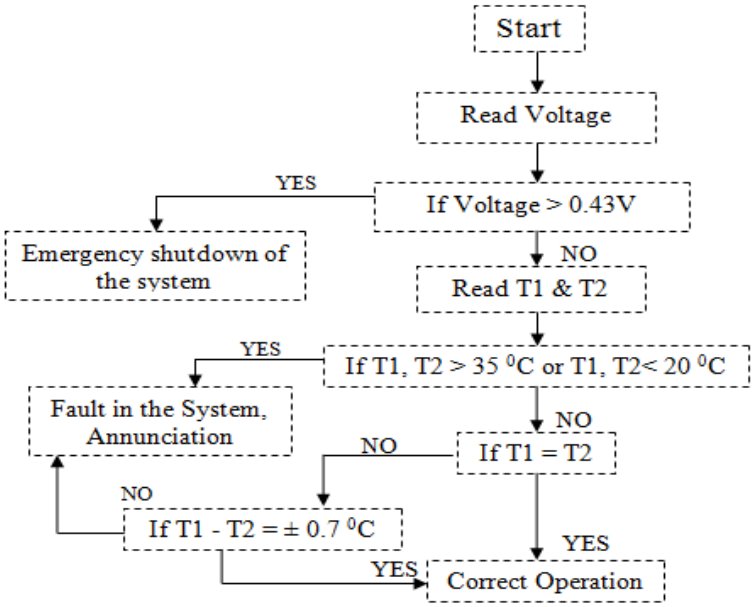

Figure 3: Fault detection system algorithm

crystallization, extrusion, or degradation rate and is an inference of a column tray concentration in process industries. Good temperature control is important during research, reaction, separation, processing, storage of products and feeds, thus a key to product quality. It is also of importance for environmental control and energy conservation (Gregory K. McMillan).

This paper proposes a fundamental approach in determining the fault in sensor failure. AVR development board (Arduino UNO) acts as a standalone system to determine the sensor failure while LabVIEW platform is used to publish data over web.

2. System Design

2.1 Hardware Prototype

A wooden box of 29cm × 38cm × 16cm dimensions acts a confined space of which the temperature parameter is of prime interest. A light source of 60 watts is placed inside the wooden box that causes a variation in the temperature according to intensity. Since the volume inside the box is a three dimensional space the temperature would be spatially distributed. In order to minimize the spatial distribution of temperature, the inner walls of the box are

affixed with mirrors that ensure total internal reflection of light. This leads to constant temperature distribution with minimum deviation in the region as well as reduces the energy loss. This also aids in heating the volume space faster. The temperature sensors are placed inside the box at the farthest point from the light source in order to avoid direct heating of the sensor. The sensors used have a sensitivity of 10mV/ºC. The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. It possess low self heating and does not cause more than 0.1 ºC temperature rise in still air while the operating temperature range is from -55°C to 150°C. With respect to the changes in temperature, the embedded system will check for any abnormal conditions existing within the system. The embedded system essentially checks for sensor fault and temperature fluctuation within the defined limits. It annunciates for abnormal conditions viz sensor faults and temperature exceeding certain limits.
A prototype model is designed to detect sensor fault and allow remote monitoring of the closed system. The power supply to the light source shall be varied by a Variac causing a change in current supplied to the bulb, thus varying intensity. An analog ammeter is connected in series between variac and bulb so as to relate the change in intensity to change in current.

The fault detection is based on algorithm mention in flow chart The upper limit and lower limits of the sensor are set to 35ºC and 20ºC respectively.

If the temperature exceeds either of the limits a sensor fault (failure) is detected or system fault is sensed. Another possibility is where the sensor may not fail totally but still show temperature values within the range but may not be correct. The solution to this problem has been obtained by using another temperature sensor placed in vicinity of the other sensor. The temperatures from both sensors are compared in order to identify a sensor fault in either of the sensor. A hysteresis band of 0.7ºC is kept around in order to prevent false alarms. Also a current is read by hx-03p sensor placed in series with the bulb whose output voltage is related to temperature values in order to corroborate the temperature values and prevent wrong annunciations

Table 1: Temperature, Current and Voltage readings obtained by varying potentiometer in terms of percentage.

Variac Variation (%)	Current (Amps)	Voltage (Volts)	Temperature1 (^{0}C)	Temperature2 (^{0}C)
0	0	0	26.37	26.37
10	0.2	0.27	27.00	27.13
25	0.2	0.27	27.95	28.00
35	0.25	0.34	28.32	28.32
50	0.26	0.35	28.61	28.61
65	0.26	0.35	29.00	28.81
75	0.3	0.40	30.07	29.30
85	0.3	0.40	30.76	30.76
95	0.31	0.41	32.71	32.71
100	0.32	0.43	35.00	35.16

The rate of change of temperature is also monitored in the algorithm. The rate of change of temperature helps to determine the faulty sensor besides the fault occurrence notification. The sensors are connected to Atmel AVR development board (Arduino UNO) and the board is further interfaced with a computer via USB port. An application program is developed in LabVIEW that communicates data via a host server. As soon as, the fault is detected it will make annunciation and alert the operator of the occurrence of fault with the help of buzzer. The main purpose of this system is to detect the fault at an early stage so that the operator can take necessary action immediately and the system does continuous functioning and does not damage any part of the system.

Table 2: Analysis of sensor based fault tolerant system

Temperature	**Operation**
If Voltage greater than 0.43 V	Emergency Shut Down of the system.
If either of temperatures of sensor 1 If temperature of sensor 1 and sensor 2 are not equal	Annunciation
Greater than the specified limits (+/- 0.06 ºC/s)	

A similar concept can be applied to various industrial processes such as, combustion, drying, calcinations, and crystallization, extrusion where temperature is a critical parameter, and sensing failure may cause the system to fail or shut down or cause any fatal injury

2.2 Atmel AVR Controller (Arduino) Interfacing

Arduino is a tool for making computers that can sense and control more of the physical world than desktop computer. It is an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. AVR (Arduino UNO) development board is a programmable microcontroller board with on-board analog IO and digital IO. Arduino language is used for embedded programs. It has USB interface with PC. It has external plug in modules to extend its functionality (Alan J. Smith, 2011). An Arduino board consists of an Atmel 8-bit AVR microcontroller with complementary components to facilitate programming and incorporation into other circuits (Alan J. Smith, 2011).
The steps used for interfacing Arduino with LabVIEW are as follows:

(1) Install LabVIEW software in the computer
(2) Install the NI-VISA Drivers for communication with serial peripheral like Arduino
(3) Install JKI VI package Manager (VIPM) community edition
(4) Install the LabVIEW interface for Arduino as per KB 5L38JQYG.
(5) Connect Atmel AVR (Arduino) board to PC as per KB 5INA7UYG.
(6) Load the LabVIEW interface for Arduino Firmware on Arduino as per KB 5LPAQIYG. The firmware can be found in <LabVIEW>\vi.lib\LabVIEW Interface for Arduino\Firmware\LVIFA_Base .

2.3 Remote Monitoring by Web Publishing

Fault is not just important to detect but also to notify the user or the concerned authority. Hence there is a need to keep the person informed in any part of the world. This could be useful in almost all process industries and necessary corrective action can be taken immediately. In-time action can prevent fatal injuries and economical losses

Web publishing, or online publishing, is the process of publishing content on the Internet. It includes creating and uploading websites, updating webpage's, and posting blogs online. The published content may include text, images, videos, and other types of media. In order to publish content on the web, you need three things: 1) web development software, 2) an Internet connection, and 3) a web server.

The Web Publishing Tool is used to create an HTML document and embed static or animated images of the front panel or to embed a front panel in an HTML document so a client computer can view and control the front panel remotely. Three options namely Snapshot, Monitor and Embedded are available of which any one can be used at a time. The application developed hereby allows monitor mode providing animated images on the web page at any remote location visible by an internet browser.

3. Results

The figure 4 below shows the output of temperature sensors obtained on Serial port of controller board.

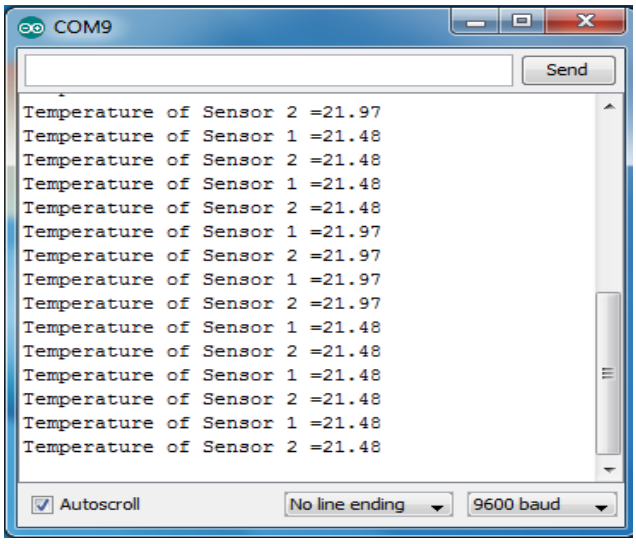

Figure 4: Values of temperature obtained on arduino serial monitor

The output of sensors is plotted on the software front panel developed in LabVIEW. The output has been plotted and is within the limits in the figure 5 shown below that indicates correct operation.

Another figure 7, displays the panel that contains output of sensors with plotted graph with a faulty condition that violates one or more conditions as stated in the algorithm indicating a fault in the sensor. The notification is displayed in the dialog box and is replicated in the browser panel remotely

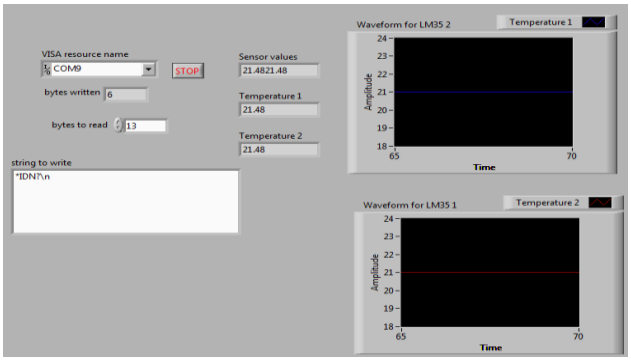

Figure 5: GUI displaying output of temperature sensors in LabVIEW indicating correct operation.

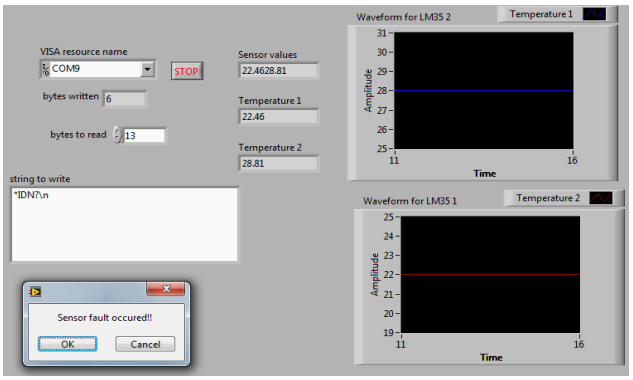

Figure 6: GUI displaying output of temperature sensors in LabVIEW indicating fault in the system.

Figure 7 below shows the Web Published VI of temperature sensor by using Web Publishing Tool in LabVIEW.

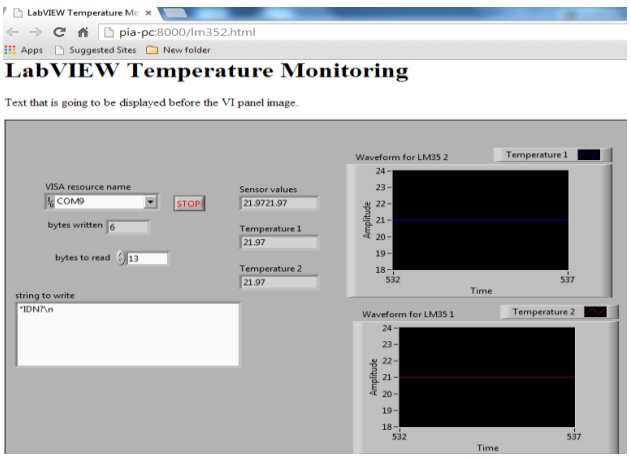

Figure 7: Web Published VI of temperature sensor

4. Conclusion and Future Scope of Work

In the proposed work we have described the design of sensor based fault detection system. Here, temperature of a

prototype system is measured using AVR (Arduino) Development Board and LabVIEW. As the current varies, intensity of bulb changes which affects the system by change in temperature. The controller is programmed according to the algorithm stated in order to detect sensor fault. The system can be monitored remotely by the application built in the LabVIEW. The limitation of the present system is that it cannot control the fault. To extend this system to fault tolerant system, we need to identify corrective action for fault isolation. Features like wireless monitoring of the system using ZigBee and incorporating GSM technology for notification and emergency control is path forward for the system.

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