Design and Development of Multi-point Online Monitoring System for Temperature & Relative Humidity around the TRIGA Mark-II Research Reactor

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Abstract. The present paper describes the design and development of multi-point environmental temperature and relative humidity (T & %Rh) online monitoring system around the TRIGA Mark-II Research Reactor in Bangladesh. Microcontroller (ATmega32) based data acquisition system has been designed to collect the sensor data (SHT75) from seven different points around the reactor facility using the full duplex differential mode transmission technique (RS422). Each point is identified by its position address which is user selectable in the hardware. Multi-drop network (Daisy Chaining) data communication is used to transfer all the data to a PC located in the control room. RS422 to USB converter is also designed for PC Interfacing. The data acquisition unit has also the provision to use in stand-alone mode for easy calibration and portability. The second phase of the program also includes the area radioactivity monitoring which will be incorporated in the hardware. A graphical program for user interface is developed in LabVIEW to acquire the data and display them continuously on the computer monitor. Also this monitoring system provides data-logging facility which keeps record of the T & %Rh as numeric value in a log file and performs as backup for further analysis of the measurements.

Keywords: Microcontroller, Multi-drop network, LabVIEW, SHT75, RS422, Online Monitoring

1 INTRODUCTION

Remotely monitoring of environmental parameters is important in various applications and industrial processes. In earlier period these monitoring systems are generally based on mechanical, electromechanical instruments which suffer from the drawbacks like poor rigidity, need of human intervention, associated parallax errors and durability. With the inclusion of electronics the instruments were made compact and cheaper. However, these systems lack flexibility of remote monitoring and data logging. Kang and Park have developed monitoring systems, using sensors for indoor climate and environment based on the parameters mentioned in 2000. Combination of these sensors with data acquisition system has proved to be a better approach for T & %Rh monitoring in 2005. Vlassov in 1993 introduces the usage of surface acoustic wave's devices as temperature sensor. These systems, however, are quite complex in nature as some of them require the use of on-chip transmitter circuit and involve fabrication process.

This demands the design & development of Multipoint online monitoring & logging system for T & %Rh which can be accessed remotely. Multipoint data logging is a method of automatic data capture from sensors located at different points at regular intervals as well as remotely logging and monitoring from a control room. Further, this data can be processed to provide analysis of the environment. In Industries, plants and manufacturing units during certain hazards it is very difficult to monitor the parameters at different locations. To overcome these problems we use long distance serial communication systems to monitor the parameters, so that we can take the necessary steps in worst cases. Also the logged data can be used to investigate the reasons in case of a disaster, so that it can be avoided in the future.

2 DESIGN & DEVELOPMENT METHODOLOGY

The design of the monitoring system involves various steps, such as selection of proper sensor to sense physical parameter, design of signal conditioning circuit which support digital logic device, selection of Central Processing Unit (CPU) and Display unit. The monitoring system designed in this paper has functions of T & %Rh automatic testing, sample data transmitting and results real-time displaying and logging. Functional requirements of the monitoring system are shown in Table 1.

Table 1. Functional Requirements of the Monitoring System

Parameters	Measuring range	Resolution
Temperature	0~+120 Centigrade	0.1 Centigrade
Humidity	0~100%RH	0.1%RH

The system consists of a host PC with a RS422 to USB converter and seven sensor modules at different locations connected via network cable around the Research Reactor as shown in Figure 1.

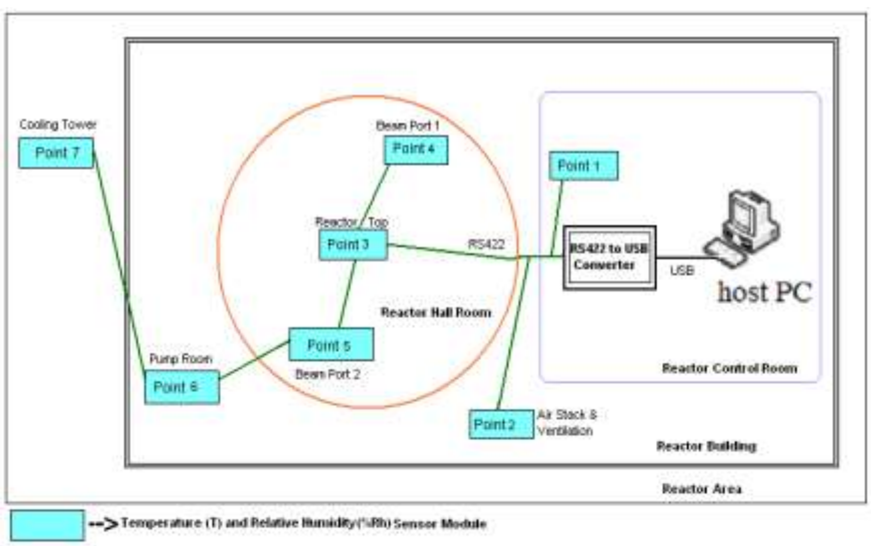


Fig. 1. Basic diagram of the designed system

2.1 Temperature and Relative Humidity Sensor Module

Sensor module has two basic functions, T & %Rh measurement and RS422 transmission. The diagram of sensor module consists of T & %Rh sensor chip (SHT75) produced by Sensirion Cooperation as shown in Figure 2. The sensor integrates sensor elements and signal processing in compact format and provides a fully calibrated digital output. A unique capacitive sensor element is used for measuring relative humidity while temperature is measured by a band-gap sensor. Both sensors are seamlessly coupled to a 14bit analog to digital converter and a serial interface circuit. This results in superior signal quality, a fast response time and insensitivity to external disturbances (EMC). SHT75 is individually calibrated in a precision humidity chamber. The calibration coefficients are programmed into an OTP memory on the chip. These coefficients are used to internally calibrate the signals from the sensors. The 2-wire serial interface (SPI) and internal voltage regulation allows for easy and fast system integration. The small size and low power consumption makes SHT75 the ultimate choice for even the most demanding applications.

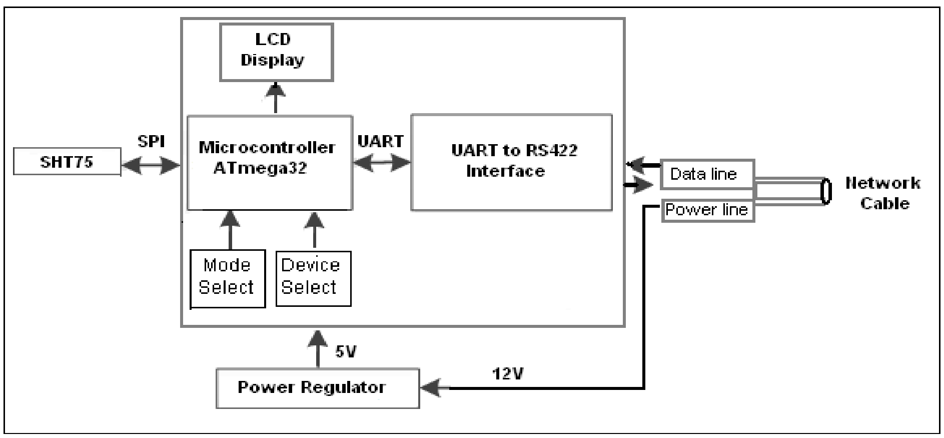


Fig. 2. Block Diagram of Sensor Module

The main component here is the Atmega32 microcontroller, which synchronizes all the module operations. The CPU use calibrated 16 MHz external Crystal Oscillator. The microcontroller is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed. LCD module (Qy-1602A) has been used for local real-time data display. The dot matrix alphanumeric LCD is configured in 4-bit mode with read-write control (WR) pin grounded. This configuration requires less number of I/O pins of microcontroller, typically 6 only. UART to RS422 Converter is used to covert Single ended signal into balanced differential signal for long distance communication. For multipoint data acquisition the device address at each location is selected manually by the 4-line DIP switch that is connected to the input port of the microcontroller. So that maximum sixteen sensor modules can be connected to the network. For easy calibration and portability, the module is designed to use in stand-alone mode by introducing a mode selector switch connected to the input port of the microcontroller.

2.2 Host PC and RS422 to USB interface

The T & %Rh data from different locations are transmitted to the host PC via network cable and RS422 to USB Converter and displayed on the monitor. The diagram of the host and Converter is shown in Figure 3. In this Module, PIC18F2550 microcontroller is used as USB controller. Two MAX485 chip is used for RS422 to UART interface. UART signal is then connected to PIC microcontroller's serial port. A precision power supply of 12V is used in this module which provides the required power of all sensor modules through network cable.

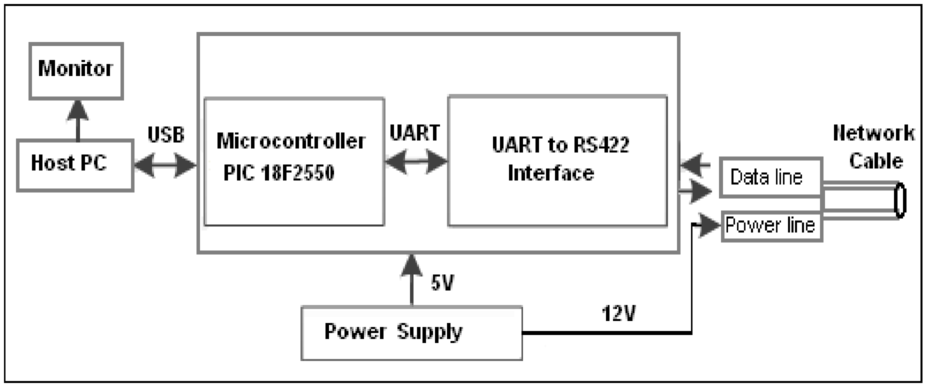


Fig. 3. Diagram of the Host PC and RS422 to USB interface

2.3 Communication Topology

When communicating at high data rates, or over long distances in real world environments, single-ended methods are often inadequate. Differential data transmission (balanced differential signal) offers superior performance in most applications. Differential signals can help nullify the effects of ground shifts and induced noise signals that can appear as common mode voltages on a network. In this work, communication topology was RS-485 multipoint system in 4- wire configuration (RS-422). In this configuration without repeater has one trunk cable, along which devices are connected, directly (daisy chaining). The maximum length depends on the baud rate, the cable (Gauge, Capacitance or Characteristic Impedance), the number of loads on the daisy chain, and the network configuration (2-wire or 4-wire). The following design parameters were used in this topology.

Table 2. Design parameters

Parameters	**Specifications**
Baud Rate	9600
Cable type	CAT-6 Network Cable
Network Configuration	4 wire
No of Nodes on network	7
Length	400 meter

This network is based on Master-Slaves protocol. Only one master (at the same time) is connected to the bus, and one or several (16 maximum number in our system) slaves nodes are also connected to the same serial bus. Communication is always initiated by the master.

The slave nodes will never transmit data without receiving a request from the master node. The slave nodes will never communicate with each other.

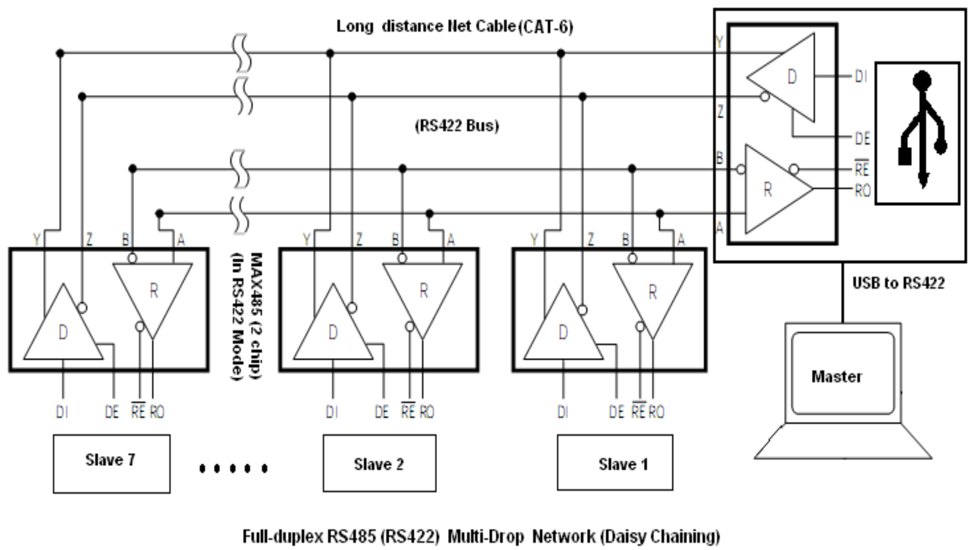


Fig. 4. Communication scenario

The master node initiates only one transaction at a time. It sends a data frame consisting of a device address and the instruction to the slave. After receiving and processing the request, the slave returns a message (a 'reply') to the master. In this case, a transaction consists of 2 messages: a request from the master, and a reply from the slave.

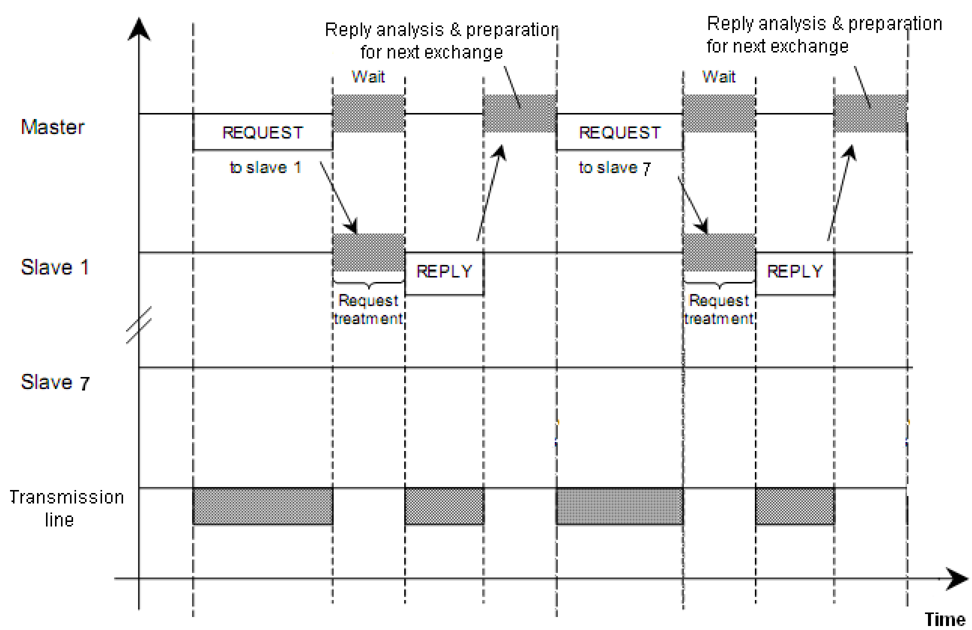


Fig. 5. Master / Slave communication time diagram

Each slave must have a unique address (from 1 to 16) so that it can be addressed independently from other nodes. Figure 5 shows the time diagram scenarios of Master / Slave communications. The duration of the REQUEST, REPLY phases depends on the communication features (frame length and throughput) and the duration of the WAIT and TREATMENT phases depends on the request processing time needed for the slave application.

2.4 Software Design

A graphical programming interface is designed to monitor T & %Rh at different target points around TRIGA Mark-II Research Reactor using LabVIEW 9.0 software. The host PC sends request sequentially to all the sensor modules which have specific device address connected to the network. The specific sensor module replies only when its address goes with the device address requested by PC. Depending on the types of request such as Device Check or Read Data, the corresponding device does the specific task as per instruction. This instruction firmware for the sensor module has been developed in BASIC platform using BASCOM – AVR software.

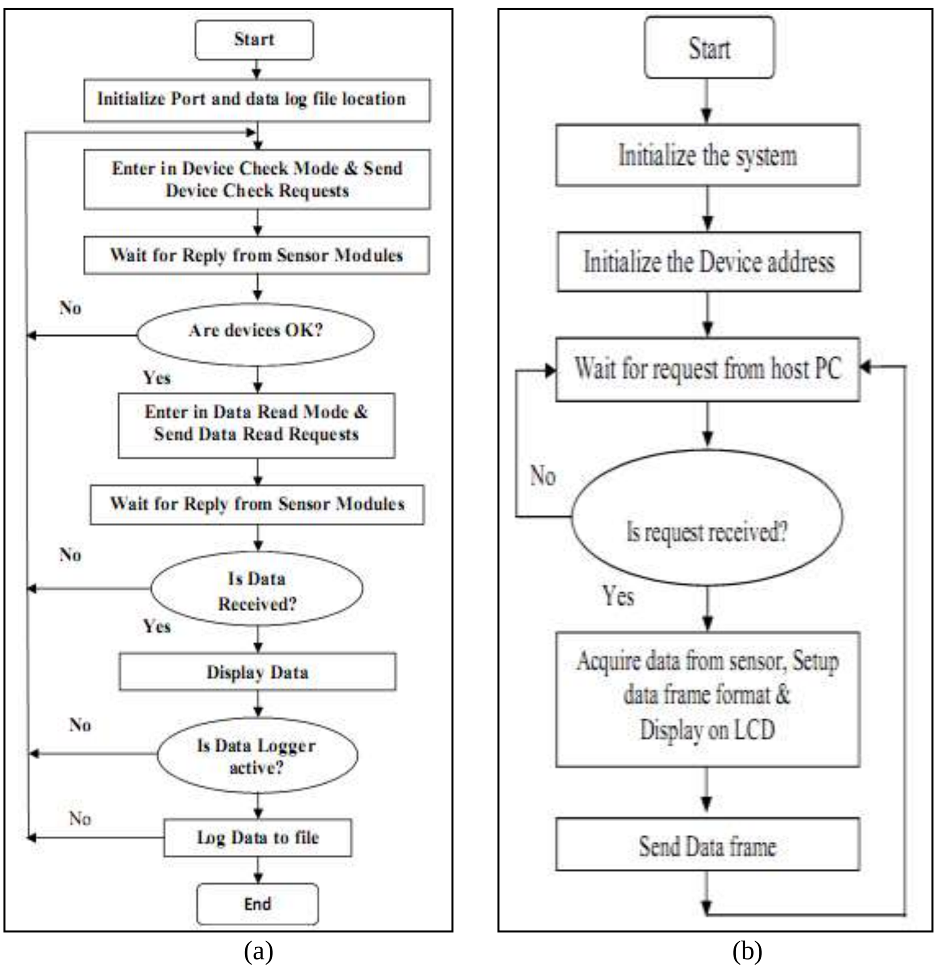


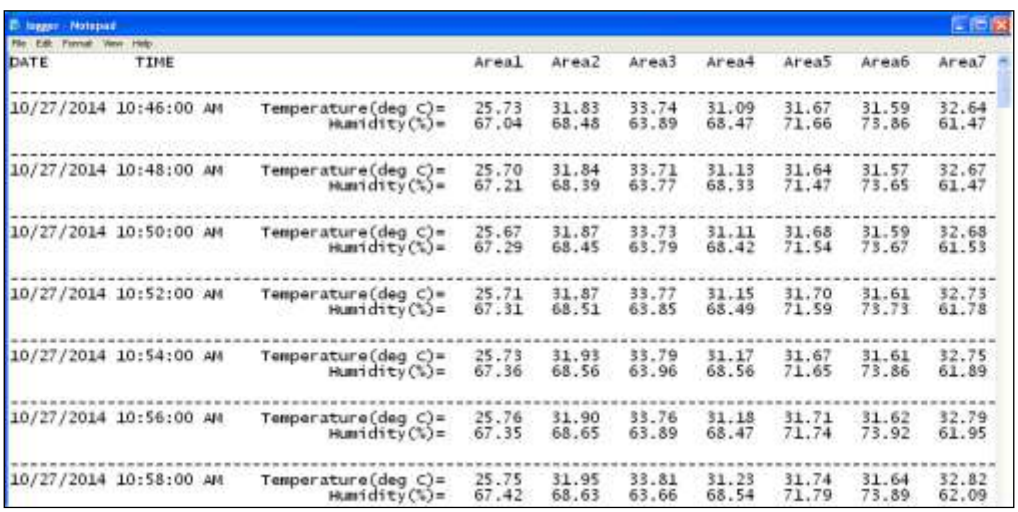
Fig. 6. Flow diagram of software design (a) Host PC (Master) (b) Sensor Module (Slave)

The PC side software has two operational modes, one is Device Check mode and other one is Read Data mode. Device Check mode confirms that all the target sensor modules are in working condition and able to send data to host PC. While in Read Data mode the sensor module with appropriate device address sends data to host PC as per requests. The designed software also has an option to log real time data received from all sensor modules. This logged data will be helpful for further analysis of T & %Rh of the targeted points.

3 RESULTS AND DISCUSSION

The T & %Rh data were collected from seven different locations around the TRIGA Mark-II Research Reactor and displayed the monitored data on host PC at Main Control Room in Figure 7 (a).

(a)



DATE	TIME		Area1	Area2	Area3	Area4	Area5	Area6	Area7
10/27/2014	10:46:00 AM	Temperature(deg C)=	25.73	31.83	33.74	31.09	31.67	31.59	32.64
		Humidity(%)=	67.04	68.48	63.89	68.47	71.66	73.86	61.47
10/27/2014	10:48:00 AM	Temperature(deg C)=	25.70	31.84	33.71	31.13	31.64	31.57	32.67
		Humidity(%)=	67.21	68.39	63.77	68.33	71.47	73.65	61.47
10/27/2014	10:50:00 AM	Temperature(deg C)=	25.67	31.87	33.73	31.11	31.68	31.59	32.68
		Humidity(%)=	67.29	68.45	63.79	68.42	71.54	73.67	61.53
10/27/2014	10:52:00 AM	Temperature(deg C)=	25.71	31.87	33.77	31.15	31.70	31.61	32.73
		Humidity(%)=	67.31	68.51	63.85	68.49	71.59	73.73	61.78
10/27/2014	10:54:00 AM	Temperature(deg C)=	25.73	31.93	33.79	31.17	31.67	31.61	32.75
		Humidity(%)=	67.36	68.56	63.96	68.56	71.65	73.86	61.89
10/27/2014	10:56:00 AM	Temperature(deg C)=	25.76	31.90	33.76	31.18	31.71	31.62	32.79
		Humidity(%)=	67.35	68.65	63.89	68.47	71.74	73.92	61.95
10/27/2014	10:58:00 AM	Temperature(deg C)=	25.75	31.95	33.81	31.23	31.74	31.64	32.82
		Humidity(%)=	67.42	68.63	63.66	68.54	71.79	73.89	62.09

(b)

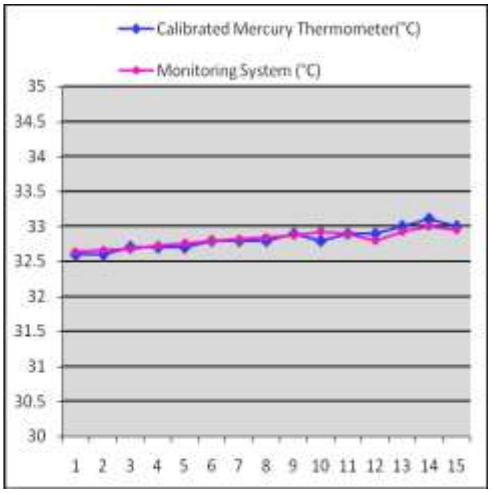
Fig. 7. (a) Display of Monitoring System at the main control room (b) data log file

The T & %Rh values were recorded in degree Celsius and in percentage respectively and displayed on the PC screen and logged on a log file as a text format. The accuracy of this monitoring system has been tested through experiments, although final accuracy of monitoring system depends on sensor accuracy. For testing accuracy, the observed data from point 7 (Cooling Tower) located at maximum distance from the control room, is compared with the actually measured data using conventional thermometer and hygrometer. The results obtained are summarized in Table 3.

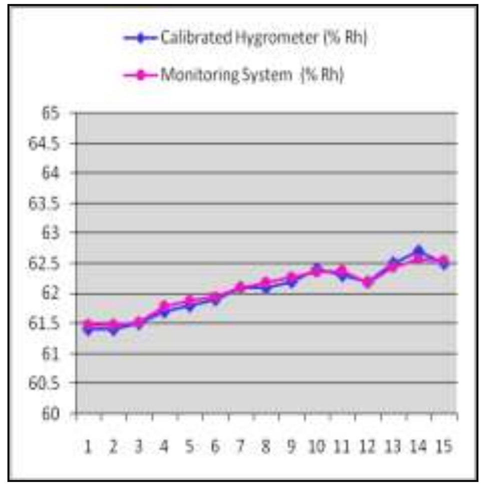
Table 3. Comparison of Temperature and Relative Humidity Measurements

No. of observ ations	**Time**	**Calibrated Mercury Thermo-meter (°C)**	**Temperature of Monitoring System (°C)**	**Calibrated Hygro-meter (% Rh)**	**Relative Humidity of Monitoring System (%Rh)**
1	10:46:00 AM	32.6	32.64	61.4	61.47
2	10:48:00 AM	32.6	32.67	61.4	61.47
3	10:50:00 AM	32.7	32.68	61.5	61.53
4	10:52:00 AM	32.7	32.73	61.7	61.78
5	10:54:00 AM	32.7	32.75	61.8	61.89
6	10:56:00 AM	32.8	32.79	61.9	61.95
7	10:58:00 AM	32.8	32.82	62.1	62.09
8	11:00:00 AM	32.8	32.85	62.1	62.17
9	11:02:00 AM	32.9	32.87	62.2	62.28
10	11:04:00 AM	32.8	32.92	62.4	62.35
11	11:06:00 AM	32.9	32.9	62.3	62.37
12	11:08:00 AM	32.9	32.8	62.2	62.17
13	11:10:00 AM	33.0	32.93	62.5	62.43
14	11:12:00 AM	33.1	33.00	62.7	62.57
15	11:14:00 AM	33.0	32.95	62.5	62.56

From Table 3, it can be observed that the temperature sensor shows a good level of stability as well as accuracy. The average error is approximately ±0.05^{0}C. The humidity sensor of developed system also shows very good accuracy as shown in Table-III. An average error of ±0.06%Rh is observed mainly due to the internal error of the sensor. The comparison graphs of T & %Rh values from table-III are shown in figure 8.



(a)



(b)

Fig 8. Graph of Comparison between two measurements (a) Temperature (b) Relative Humidity

4 CONCLUSIONS

In this paper, a low cost and easily operative multipoint online T & %Rh monitoring and logging system is presented around TRIGA Mark-II Research Reactor. This system is very useful as data logger and remote monitoring where T & %Rh plays vital role, hence it is necessary to monitor and control these parameters. From the graphs of T & %Rh it is clear that there is very close agreement between the data collected by our system and that measured by already available and calibrated systems, which validates the measurements made by our system. The designed monitoring system is extensively commended by personnel of Reactor Operation and Maintenance Unit (ROMU). In addition, the presented system can be useful for studying behavior of nuclear radiation around the Reactor. In future, Area Radiation Monitoring System will be incorporated with this developed system.

Acknowledgments

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