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An Improved Approach For Automation Of Nuclear Reactors To Enhance Connectivity And Expanding Efficiency

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Abstract **-** Wireless technology represents the transmission of data or information between the two devices over a long distance, without wires or any other electrical conductors by using low-powered radio waves. ZigBee technology developed by IEEE 802.15.4 Standard has the feature of low power consumption, low cost and self-organizing. This paper presents the use of ZigBee for monitoring and controlling the heating and coolant activities of up to four nuclear reactors at a time automatically in nuclear power plant. The temperature sensors sense the temperature of the nuclear reactors and through the microcontroller the temperature is transmitted to monitoring and controlling system via ZigBee. Here using the PIC microcontroller to reduce the cost of ADC's as PIC has inbuilt ADC's in it.

Keywords— **PIC Microcontroller, Temperature Sensor, IEEE 802.15.4 standard – ZigBee Wireless Protocol**

I. INTRODUCTION

Automation is the use of machines, control systems and information technologies to optimize productivity in the production of goods and delivery of services. They are called automated because they perform their operations automatically with less human participation. The temperature of nuclear reactor can be controlled automatically by using the concepts of fuzzy sets or rules based expert systems which are provided by Artificial Intelligence. This makes the nuclear reactor to act in a smart way to control the temperature by itself. It itself decides when to turn off heating, when to turn on cooling and what amount of coolant is needed at which temperature range. It totally eliminates human interaction with controls of reactors.

The monitoring and controlling temperature in Nuclear Power Plants and large scale industries are of crucial importance with respect to safety and efficient operation. The temperature of Nuclear Reactors should be monitored and controlled continuously automatically without the human intervention. This can be done in better way by using wireless network. Wireless network allow transmitting the signal or data between the two devices with high speed, low power consumption and with low cost. The main aim of this research is to design a low cost monitoring and controlling temperature with 8-Bit RISC microcontroller (PIC16F877A controller) and ZigBee transceiver This research provides support to monitor and control the heating and coolant activities of four nuclear reactors automatically at a time that are located at different locations.

II. ZIGBEE WIRELESS TECHNOLOGY

ZigBee is a specification for a suite of high level communication protocols used to create wireless personal area networks. It is one of the famous latest and upcoming technologies in the field of wireless sensor networks (WSN). ZigBee is low cost, low power usage provide longer life with smaller battery and wireless network standard. ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. ZigBee has a data rate of 250 Kbit/s that is best used for transmitting data. The specification of ZigBee technology is simpler than other wireless personal area networks such as Bluetooth, Wi-Fi etc. Although Bluetooth is better than ZigBee for transmission rate, but ZigBee has lower Power Consumption.

ZigBee devices are of three types:

ZigBee Coordinator (ZC): The coordinator mainly the parent node of the network tree that must be always active. The coordinator might join to the other networks. The coordinator is only responsible for controlling the entire network. It must never go down. There is exactly one ZigBee coordinator in each network. This is the only coordinator that actually starts the network. It stores information about the network, including acting as the Trust Centre & repository for security keys.

ZigBee Router (ZR): A router can act as an intermediate router that passes the data from one device to other devices. The router is required to be always on.

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Zigbee End Device (ZED): End Devices join to the parent node or router to perform its functionality. End devices communicate to the parent node or router. End devices can send data to each other.

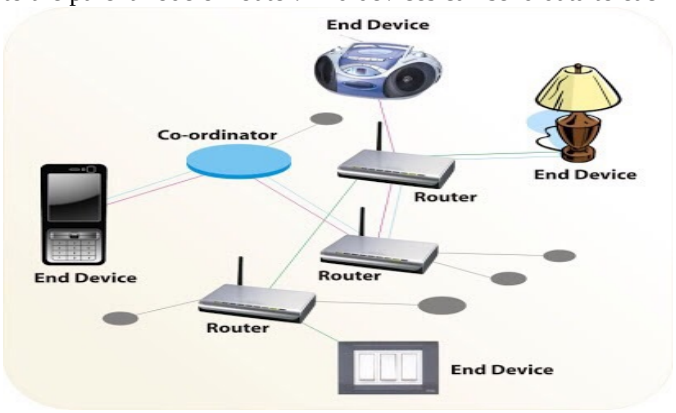

Fig. 1: Zigbee Coordinator (ZC), Zigbee Router (ZR), Zigbee End Devices (ZED).

III. PIC MICROCONTROLLER

There are many types of microcontroller that are designed to implement various tasks. The PIC and 8051 microcontroller are the most widely used. The 8051 is the most popular 8-bit microcontroller. The 8051 has many different I/O features. The main feature of 8051 microcontroller is the need of very little support of extra hardware to do most of the jobs. The 8051 has disadvantage that it does not have an internal analog to digital converter (ADC). PIC16F877A is an 8-bit microcontroller which has 40 pin DIP and is based on Harvard Architecture. PIC stands for Peripheral Interface Controller and F for flash memory. The PIC16F877A has internal 8 channels of 10-bit analog to digital Converter (ADC), 256 bytes of EEPROM data memory, self-programming, an LCD, 2 comparators, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface for the 2-wire Inter-Integrated Circuit bus and a Universal Asynchronous Receiver Transmitter. All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications**.**

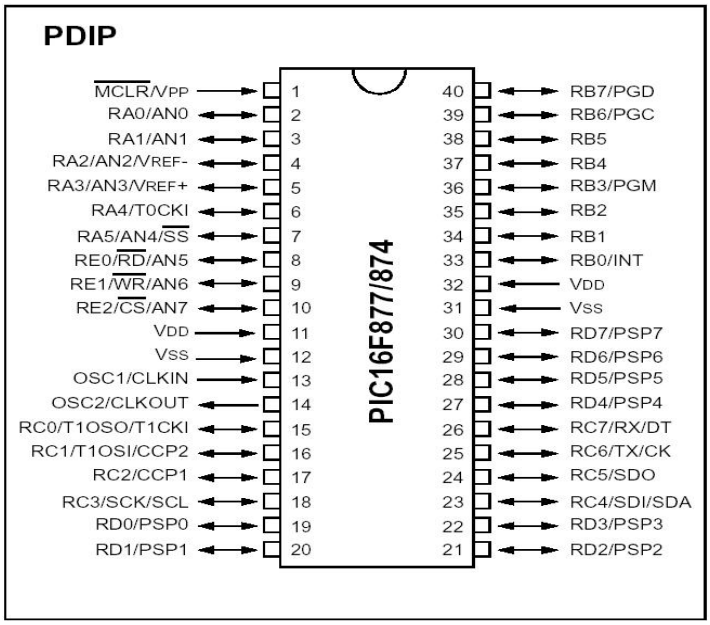

Fig 2: Pin Diagram of PIC16F877A

IV. PROBLEM FORMULATION

All the research done in the field of nuclear power plant in monitoring and controlling the temperature of nuclear reactor is expensive, of low performance and not that much reliable till date. The main significance of our proposed work is to design a low

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cost monitoring and controlling wireless system. The wired controlling and monitoring systems need large no. of wires to establish a network that become very complex and expensive.

In earlier system of monitoring and controlling temperature, communication medium between the system and nuclear reactors was not wireless. Numbers of wires were used to establish the entire system. Wired network becomes very complex and become very difficult to handle. Many researches has been done over monitoring and controlling temperature of one nuclear reactor automatically at a time using ZigBee technology. But In proposed research, four nuclear reactors can be automatically controlled at a time that are placed at different locations or at a far distance using ZigBee wireless technology. Hardware is enhanced using PIC16F877A microcontroller with in-built ADCs. In Earlier Thermal Monitoring System, hardware cost was more and that became expensive.

As in Earlier Thermal Monitoring System the communication medium between the system and nuclear reactors was not wireless, relocation became the main problem. The networks with large no of wires were very difficult to relocate. The wired network has limited range. But the ZigBee wireless technology increases the range of communication and easy to install. Fuzzy Logic methodology is used to automatically control the furnaces and coolant units. It also predicts the upcoming and downfall reading of temperature. Many researches has been done on only two modes. This research includes three modes: manual mode, semi-automatic mode and intelligent mode.

V. OBJECTIVES OF PROPOSED WORK

The main aim of this research is to design a low cost monitoring and controlling wireless system with 8-Bit RISC microcontroller (PIC16F877A) and ZigBee transceiver. ZigBee has been used in the field of nuclear power plant to monitor the temperature of nuclear reactors. Some of the research work has been implemented in monitoring green-house environment, home automation, distributed solar panels, high voltage switch gears in substations. Temperature is one of the main and common parameter which needs to be monitor in various application areas.

- The main objective is to improve the communication medium of automation of nuclear reactor using ZigBee wireless technology and to reduce the cost of hardware.
- To enhance the features of Smart Thermal Monitoring System.
- To cut down the cost of hardware.
- To make the communication medium between the transmitter and receiver wireless.
- To enhance the software functionality.
- To enhance the hardware.

VI. PROPOSED WORK

This system is designed to monitor and control the temperature by controlling heating and coolant activities of four nuclear reactors at a time that are placed at a far distance by using ZigBee wireless technology. The main significance of proposed work is to design a low cost monitoring and controlling wireless system. PIC microcontroller is used to cut down the cost of ADC's as PIC microcontroller has in-built ADC's in it. The main key areas of wireless communication are:

- Ease of Installation
- Total Cost
- Reliability
- Performance
- Security

This system works in three modes, out of two modes are concerned with artificial intelligence, which has used fuzzy logic to provide autonomous control to heating and cooling controls of reactor. Two ZigBee modules are used for communication between transmitter end and receiver end. One ZigBee module is located at transmitter end and the second ZigBee module is located at receiver end. At the transmitter end, when reactor turned on, hardware that is installed in reactor, senses the temperature by help of temperature sensor, and hands it up to a high speed PIC MCU. This MCU hands over the temperature reading to computer system located in monitoring office far away from reactor using ZigBee module. At the receiver end, the second ZigBee module accepts the temperature readings and shows it on the computer software. Reactor's coolant and heating controls is also connected to MCU in reactor itself. At an instance, processor controls both coolant and heating devices as per the commands received from computer software system using ZigBee. MCU continuously extracts temperature from all four nuclear reactors and addresses these four nuclear reactors to computer software to let this software recognize an individual reactor to be dealt with. After

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addressing four reactors to software, processor of system sends the temperature value to software for display and decision making processes. Software will then respond to processor by the mean of AI. Processors have following tasks to do: -

1. Extracting temperature from temperature sensors.
2. Addressing of four nuclear reactors to distinguish the read values for computer software.
3. Getting commands from AI of computer software.
4. Controlling coolant and heating systems.

Application software is programmed on computer system which receives updated data from reactor's MCU using ZigBee and display current temperature in it. It gets set limit values initially from user and whenever incoming temperature matches or crosses the set limits then it is fire the various outputs according to values set to provide amount of coolant, and decisions to turn the controls of reactor automatically.

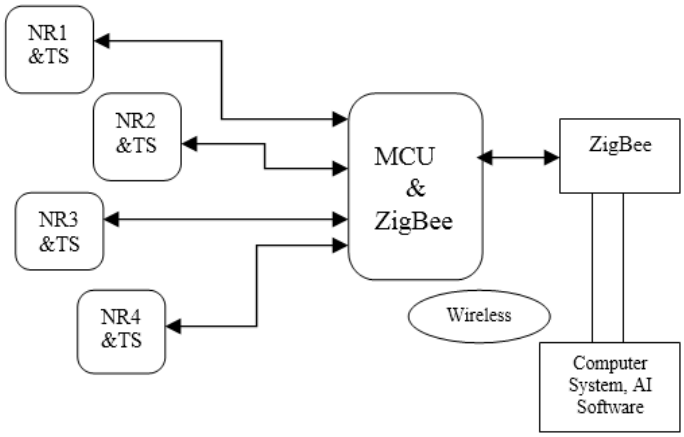

Fig 3: Functional Structure of proposed work

Basically the computer software of proposed work is broadly classified into five main modules: -
1. User Authentication.
2. Mode Selection.
3. Manual Mode.
4. Semi-Auto Mode.
5. Intelligent Mode

A. **User Authentication**

In this module, an authorized or intended user of monitoring office is being authenticated for his recognition and to prevent unauthorized access to system to stop its illegal use. A user has to enter his user name and password to login window of computer software to pass his authenticity. If user successfully passes his authenticity then he can easily access all the operational modes of system otherwise system will ask user only three times for his correct credentials to be entered. If user fails to enter correct credentials even after three attempts, then user will be recognized as intruder by system and system will lock it, and protects the controls of reactor from being used from a person that is not authentic.

Fig 4: Login form for authentication of intended user at receiver end

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B. Mode Selection

In this module, an authorized user has to select one from the three modes to monitor and control the reactor subsystems either in manual or automatic way. Upon selection any of the module, system will automatically activate the chain reaction by activating the heating control of reactor. Selected mode will send heating activation command out to processor which further initiates the beginning of process in reactor. Upon selection of a particular mode, software automatically sends activation code outside to MCU.

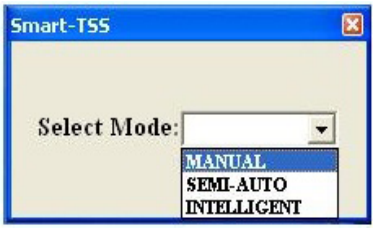

Fig 5: Mode selection form to choose particular working and control mode of nuclear reactor systems.

C. Manual Mode

In this mode, a user is provided with four halves of computer software system. First is nuclear reactor-1 with its coolant and heating controls, second is nuclear reactor-2 with its coolant and heating controls, third is nuclear reactor-3 with its coolant and heating controls and fourth is nuclear reactor-4 with its coolant and heating controls. The whole control of system's activities is in user's hands. By using this mode, user himself monitors the temperature of reactor and can control the heating and coolant activities of reactor manually. In this mode, software intelligence will not work. It can only get in the temperature but the automation and control operations will be only performed by user.

- There are thermometers at four sides which show the current temperature of particular reactor in progressive way.
- Space at four sides to display current temperature in per °C values.
- A timing control in form of slider at each side which allows user to control coolant resources in timely manner i.e. for how much time that coolant will pass to reactor. It is fascinating way to save valuable coolant resources.
- Check boxes and radio buttons at each side for manual control of system.
- Bar graph displays at each side to plot the relative uplifts and downfalls.
- Prediction display space at each side.

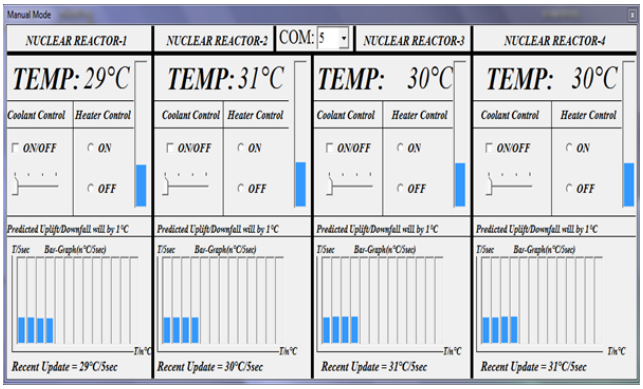

Fig 6: Manual operating mode form to monitor and control the activities of four nuclear reactors manually.

D. Semi-Auto Mode

In this mode, a user is again provided with four halves of computer software system. First is nuclear reactor-1 with its coolant and heating controls, second is nuclear reactor-2 with its coolant and heating controls, third is nuclear reactor-3 with its coolant and heating controls and fourth is nuclear reactor-4 with its coolant and heating controls. By using this mode, user only instructs the operating mode by giving instructions with respect to coolant and heating limits which will be further used by AI as threshold to work upon. AI of system controls the heating and coolant activities of reactor system by matching those entered limits against incoming readings from MCU.

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- There are thermometers at four sides which show the current temperature of particular reactor in progressive way.
- Space at four sides to display current temperature in per °C values.
- A timing control in form of slider at each side which allows user to control coolant resources in timely manner i.e. for how much time that coolant will pass to reactor. It is fascinating way to save valuable coolant resources.
- Bar graph displays at each side to plot the relative uplifts and downfalls.
- Prediction display space at each side.
- Slider controls at each sides of heater control to set the up and down limit for AI to decide about control of system and scanning current temperature with respect to up limit and down limit slider.

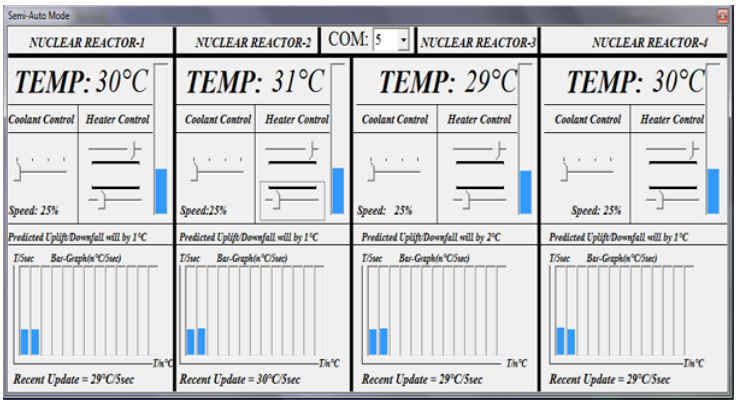

Fig 7: Semi-Auto operating mode form to monitor and control the activities of four nuclear reactors by instructing the software only once and then AI works under FL.

E. **Intelligent Mode**

In this mode, a user is again provided with four halves of computer software system. First is nuclear reactor-1, second is nuclear reactor-2, third is nuclear reactor-3 with its coolant and heating controls and fourth is nuclear reactor-4 with its coolant and heating controls. But there is not any control for user is given here to interact with the software system. Functionality of this mode is totally independent from user's interaction and is totally dependent in AI using fuzzy logic.

- There are thermometers at four sides which show the current temperature of particular reactor in progressive way.
- Space at four sides to display current temperature in per °C values.
- Bar graph displays at each side to plot the relative uplifts and downfalls.
- Prediction display space at each side.
- Operation of this mode is totally handled by AI.

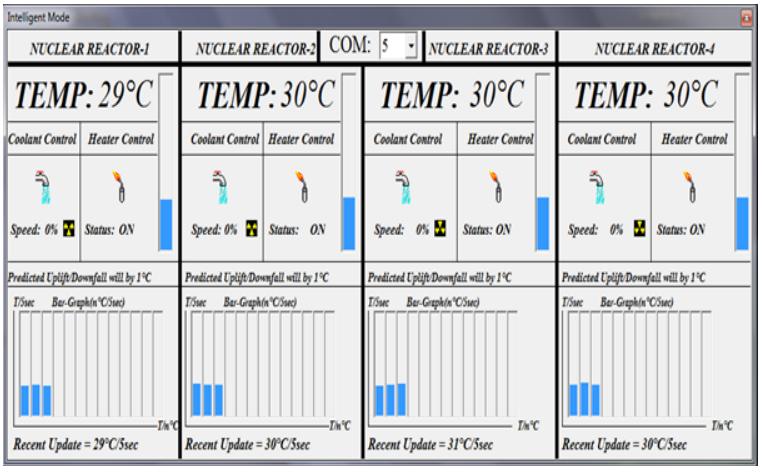

Fig 8: Intelligent operating mode form to monitor and control the activities ofour nuclear reactors totally from software's intelligence by AI under FL by sensing incoming readings.

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F. Features of proposed system

- Precision degree centigrade sensors are used.
- Intelligence in monitoring and control.
- Eight bit high-speed processor.
- Fuzzy logic is used as controller.
- Temperature is displayed, processed and controlled in computer software.
- Automatic shutdown is used to turn off associated controls.
- Three operating modes are used.
- Temperature prediction is used to predict uplifts and downfalls.
- Bar-graphs are used to plot relative statistics of particular reactor.
- It can be used to get readings of temperature of reactor and controls accordingly.
- It can be installed not only in nuclear reactor plants but also at a site where control is needed according to temperature.
- Ability to sense heating limit before reaching at peak.
- Wireless control of nuclear reactors.
- Able to control four nuclear reactors at a time.
- Cost-effective as hardware cost cut down and wireless.
- Easy to install and relocate.
- Communication range increases

VII. RESULTS AND DISCUSSIONS

The performance of proposed system is compared with the previous research which was lacking in developing low cost monitoring and controlling heating and coolant activities of more than two nuclear reactors automatically with wireless communication medium. The main aim of this research is to develop low cost monitoring and controlling heating and coolant activities of four nuclear reactors automatically and to improve the communication medium between transmitting and receiving end in the nuclear power plant. The following figure shows the practical of proposed work:

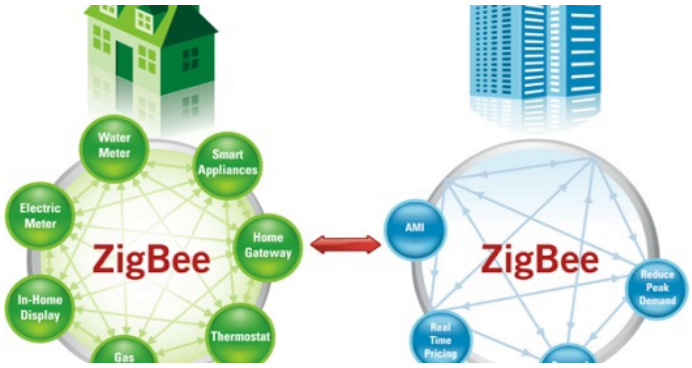

Fig 9: ZigBee based transmitter end.

A. Comparison with respect to software enhancement & more Nuclear Reactors support

Proposed work was initiated by taking the aims of developing low cost monitoring and controlling heating and coolant activities automatically using wireless technology with the software enhancement and more nuclear reactors support. In the previous research, the software is enable to handle only two nuclear reactors automatically at a time. But in this research, the software is able to handle four nuclear reactors automatically at a time.

Previous research was able to monitor and control the heating and coolant activities automatically with wires as a communication medium between transmitter and receiver end. In the proposed system, communication medium is improved to monitor and

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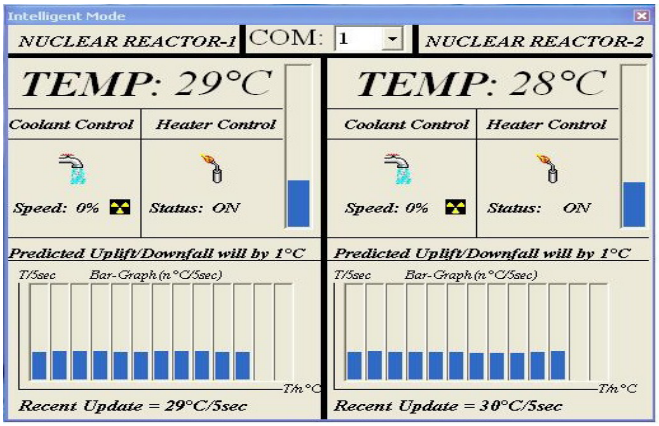
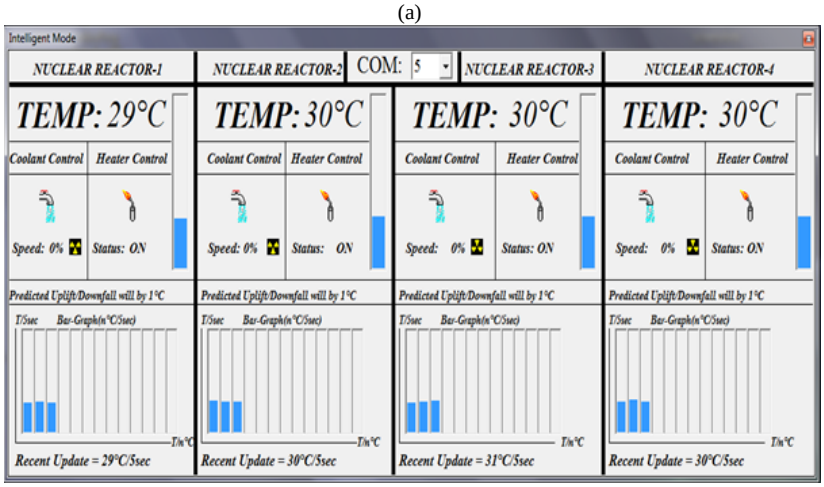
control the heater and coolant activities automatically using ZigBee wireless technology. Following are the comparison between two software as per software enhancement and nuclear reactors support. We are comparing only one mode i.e. intelligent mode as the design of three modes are same.



(a)



(b)

Fig 10: (a) shows working of previous research and (b) shows working of proposed software

As it can be observed from above comparison that the previous research can only handle or support two reactors automatically at a time. This research can handle or support four reactors automatically at a time. And software functionality is enhanced from handling two reactors at a time to four reactors at a time.

VIII. CONCLUSION

The proposed system is carried out using different devices, modules and by adding some new features like wireless communication i.e. easy to install, support more number of nuclear reactors, low cost. This system is designed to monitor and control the heating and coolant activities of four nuclear reactors at a time. PIC microcontroller avoids the use of separate ADC's thus cut down the cost. The communication is based on ZigBee wireless Technology. Two ZigBee devices are used: one at transmitter side and the other at receiver side. Wireless communication provides security, better performance, easy to install, relocate and reliable communication. The proposed work can not only be used in nuclear power plant for monitoring and controlling the temperature but can also be used in any field where monitoring and controlling of temperature activities are required.

IX. FUTURE SCOPE

Work done in this thesis can be extended in future with little variations. Some of the directions to this work for future are:

- Use of neural network with proposed work.
- Use of PIC18 microcontroller support USB that make system portable to use and easy to use.
- You can control the nuclear reactors with your mobile by installing android application in your phone and installing Bluetooth device in your system.

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