EMBEDDED BASED DATA ACQUISITION SYSTEM FOR CORE TEMPERATURE MONITORING OF FUTURE SODIUM COOLED FAST REACTOR USING LOW COST MICROCONTROLLER

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ABSTRACT

The sodium cooled fast reactor is currently under construction at Kalpakkam, India. A Data Acquisition System is designed for core Temperature monitoring of adequate core cooling system and protects the reactor against Design basis events. Here the triplicated real-time computer system and hardwired system is used for monitoring subassembly outlet sodium temperature and reactor inlet temperature. This paper describes the microcontroller based data Acquisition system for core temperature monitoring of sodium cooled fast reactor.

Key words: *Electronics, Temperature monitoring, Data logging, Embedded control, Buzzer Indicating Alarm.*

1. INTRODUCTION

In sodium cooled fast reactors the mixed uranium-plutonium oxide is used as an fuel for the fission process this is the second stage of the Indian nuclear power generation process. The fast test reactor at kalpakkam represents the commencement of the second stage. Construction of the 500 MW (electric power) prototype fast reactor has commenced already. here liquid sodium is used as an coolant, which transfer heat from the nuclear reactor to the heat exchanger unit, which is presence depends on the type of reactor arrangement in the loop type reactor arrangement the construction of heat exchange is present outside the nuclear reactor building, where as the pool type reactor arrangement has the heat exchanger unit inside the reactor floor. And through the secondary sodium circulation the unit the heat is transferred to stream generator and finally the stream is supplied to the generator the power is generated.

In this system the microcontroller based data acquisition is designed due to compact design circuit and also the economical method of acquiring the data of the core temperature of the sodium cooled fast reactor .by proper design of the data acquisition card the card unit is kept under the high temperature of the reactor inside constructed AC compartment in order to reduce cablings.

2. CORE TEMPERATURE MONITORING OF SODIUM COOLED FAST REACTOR

For monitoring the adequate core cooling, temperature at the outlet of all Fuel subassemblies (FSA), and the inlet of the core are measured. These temperature signals are used for detecting of core anomalies like,

- Plugging of FSA,
- Error in core loading,
- Fuel enrichment error and
- Fuel orifice error.

In facilitates design validations of reactor physics and thermal hydraulics and burn up management. It provides signals for protection the reactor from various incidents like;

- SA flow blockage ,
- Primary pump speed reduction,
- Transient over power at low power and
- Power failure lead to generation of enormous amount of heat, this heavy heat causes more damage in the environment.

In order to protect the heavy heat libration in the core these safety actions prevent the coolant, clad and fuel temperatures from reaching the design safety limits. And hence protecting the reactor when the fuel temperature raises the safety limit.

The function of the system is to process the signal and derive parameters such as the mean core outlet temperature, mean temperature rise in the core and the derived in individual subassembly sodium outlet temperature over the expected value. And to produce the SCRAM signals to the reactor safety logics when the core inlet temperature, central sub assembly temperature, raises the safety limits.

The prevention is made to monitor temperature at the outlets of 211 core subassemblies. There are three thermocouple are present for each subassembly in this system and the increases in thermocouple per subassembly increases the efficiency of measurement. Core temperature monitoring consists of three systems, they are;

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1. Real –time computer (RTC)- base system
2. CSA outlet temperature monitoring system
3. Reactor inlet temperature monitoring system.

2.1 THERMOCOUPLE

Chromal-Alumel thermocouples are selected for core temperature monitoring since they have very good radiation resistance, almost linear temperature – millivolt characteristics over the required range of measurement, and proven operating experience in all the fast reactors. Mineral-insulated, stainless steel-sheathed, undergrounded junction thermocouples of overall diameter 1 mm are used.

In this design the three thermocouples are used for single core subassembly.so from the present system the proposed system design for temperature measurement accuracy is improved.

3. PRESENT ARRANGEMENT IN PROTOTYPE FAST BREEDER REACTOR CONTROL DESIGN

In the present design VME bus based real time computer are used to acquire the temperature reading and initiating safety actions. These system are located in air conditioning environment. This involves lot of cablings and disconnects able connectors. In the design adopted for PFBR the signal are routed to the local control center (LCC) from inside reactor containment building (RCB).

Thermocouples emerging from reactor vessel through control 1 plug are connected through the cables to the signal conducting modules in LCC of RCB. Two connectors are provided between the sensor and SCM at the interface of SRP/LRP and LRP/roof slab.

The amplified signal is routed through leak tight penetration to outside RCB. Signals are triplicated in CB LCC and processed by three real time computers (RTC) located in three LCCs of CB. Thermocouple to be handled by each RTC are 420 thermocouples.

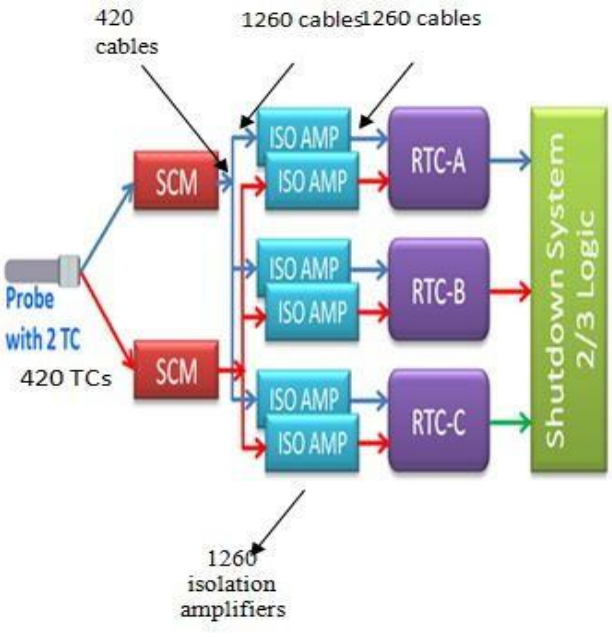

Fig.1 presents Arrangement in PFBR

There are three RTC`s the RTC input is from the iso-amplifier the function of RTC is to compare the character of the temperature and with the responding output voltage this was programmed in the RTC and also it will compare the output of temperature in form of emf with the present output and the limited range if it excides the limit the AND gate operation in the 2/3 logic will be used to give output to shut down system of the reactor. This project is used to display the temperature range in form of digital signal in the control building (CB).

In the present design there are six units are placed in various locations depends on the reactor structure and the each units consists of 35 thermocouples for each thermocouple there are two leads of terminals and for the six units there are 211 thermocouples ,for total device output of dual channel is tripilicated to the real time units so the cablings also tripilicated so the for the six units total channel present in the Lcc environment is 1260 channels.

This is the main drawback of this system in order to overcome this problem in the present system the data acquisition systemcard is designed to reduce the channels in the Lcc environment and also the designed data acquisition systemwill be kept inside the reactor building of the control area arrangement for card with particular temperature by creating ac compartment for the semi conductor devices.

4. EMBEDDED BASED DATA ACQUISITION SYSTEM

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems typically convert analog waveforms into digital values for processing. The components of data acquisition systems include:

- ✓ Sensors that convert physical parameters to electrical signals.
- ✓ Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
- ✓ Analog-to-digital converters, which convert conditioned sensor signals to digital values.

Data acquisition applications are controlled by software programs developed using various general purpose programming languages such as Embedded c, etc...; Stand-alone data acquisition systems are often called data loggers.

A Data Acquisition System is a collection of software and hardware that lets you measure or control physical characteristics of something in the real world. A complete data acquisition system consists of DAQ hardware, sensors signal conditioning hardware, and a computer running DAQ software. A sensor, which is a type of transducer, is a device that converts a physical property into a corresponding electrical signal. An

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acquisition system to measure different properties depends on the sensors that are suited to detect those properties.

Signal conditioning may be necessary if the signal from the transducer is not suitable for the DAQ hardware being used. The signal may need to be filtered or amplified in most cases.

DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc.). Usually the space on the back of a PCI card is too small for all the connections needed, so an external breakout box is required. The cable between this box and the PC can be expensive due to the many wires, and the required shielding.

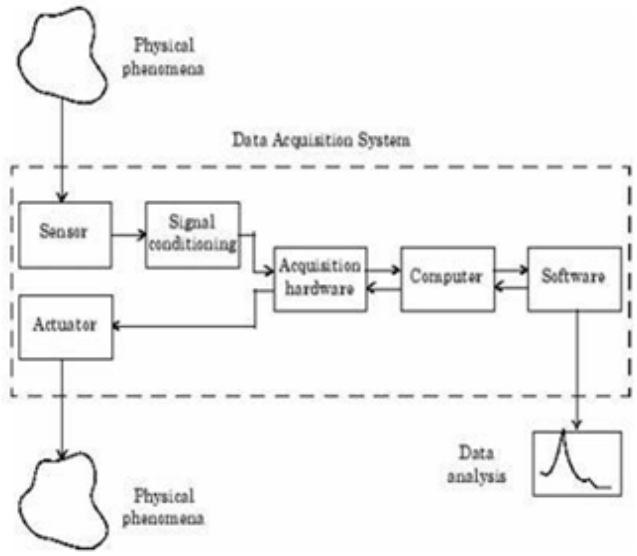

Fig.2 Data Acquisition System

DAQ device drivers are needed in order for the DAQ hardware to work with a PC. The device driver performs low-level register writes and reads on the hardware, while exposing API for developing User applications in a variety of programming environments.

Basically the output from the temperature sensor is low level signal in order to control and monitor the temperature, the received output low level signal is take as input to the data acquisition card it receives the low level signal from the sensor and process the low level signal to the high level signal by using the amplifier design its or single sensor input. But in our system we are using n sensor input in order to read the n sensor inputs the switching device which is also called as multiplexer is used to get n sensor inputs, now the sensor value which we have converted is an analog signal, because the sensor output is an analog signal.

So in order to read the analog signal corresponds temperature signal the analog signal is converted to digital signal by using the analog to digital converter then the converted digital signal is processed by using the micro controller and the output is transmitted to the communication channel.

The Data acquisition system design unit based on the design of a signal conducting unit construction so it consists of Amplifier, Multiplexer, Analog to Digital Converter, Microcontroller.

The proposed system design of the core temperature monitoring of the sodium cooled fast reactor,Three thermocouples (A,B,C)are emerging out of reactor vessel for each FSA. Each thermocouple will have a signal conditioning module (SCM) which will carry out the isolation, cold junction compensation and amplification. Amplified output of the SCM corresponding 32 thermocouple output come out through the one opening in control plug will be processed by one RTC and so on.

It is proposed to locate the signal conditionings g units and RTC on the top of the roof slab, close to the point where it is emerging from reactor vessel. This will avoid the connectors and routing of large volume of cables on the top of roof slab. Temperature at that location is around 65degree C temperature. Data acquisition system can be designed to withstand the field temperature of 65degree C. The RTC pertaining to A group of thermocouples will be networked.

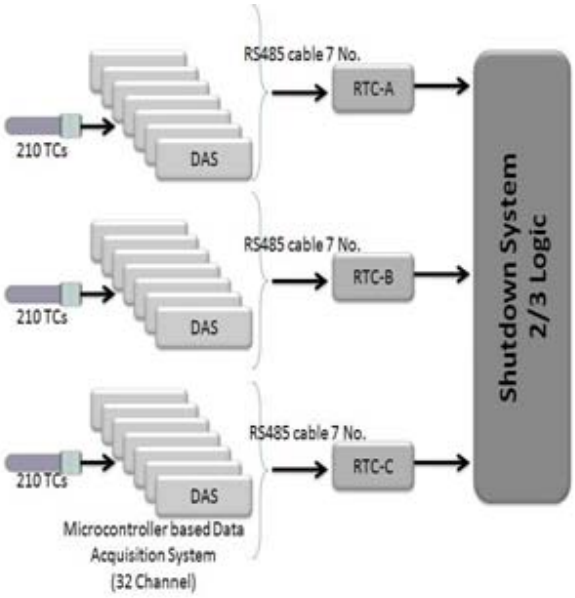

Fig. 3 Proposed Arrangement in PFBR

Similarly for the thermocouples of B and C groups. And the group A ,B,C each carry individual signals to all RTC`s then they each signals is compared in the RTC. The single unit thermocouple is readied by data acquisition system card by the presence of multiplexer inside the DAS and the each output will be amplified in the amplifier and the output will be given to the analog to digital converter this converted digital signal is processed by the micro controller.

The micro controller process the ADC input the equivalent milli volt function by conversion of milli volt signal to equivalent temperature signal to display in the RTC unit. For the conversion process the equivalent coding is processed in the micro controller. This type of arrangement in the control monitoring the pool type reactor , the thermocouple , signal conditioning unit and the RTC are in built in to the sodium cooled reactor building (Reactor containment

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building). The RTC transfer the communication signal to the air environment control room in some distance through the serial communication channel .The proposed arrangements are show in the Fig. 3

4.1 DATA ACQUISITION SYSTEM

Data acquisition system is designed to acquisition the data of the physical signal which is generated by the sensor is taken input to the data acquisition system. Where the sensor signals of small level signals which is acquired and amplified to the required level of the input signal to the ADC.

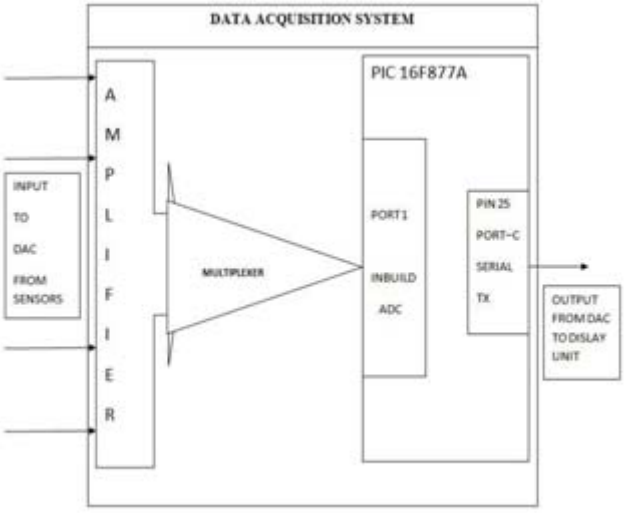

Fig.4 Data acquisition system

Here tripilicated thermocouple channels are connected to the input o f the DAS of the required amount per multiplexers through the amplifier and the output of the multiplexer is connected to the input of the microcontroller after the analog to digital conversion process. The amplifier gain selection process depends up on the resolution of the ADC which is selected. But in the PIC Microcontroller has the ADC inbuilt the resolution determined by;

Resolution (x)= 2^n*V ref / (V in)

After the analog to digital conversion process the milli voltage signal is converted to the temperature signal through the method of step wise linearization, that the millivoltage to temperature conversion the below given formula is written;

t=((t2-t1)/(v2-v1)*(v-v1)+t1)

Where; t= output temperature in degree c

t1= initial temperature of step linearization limit

t2= final temperature of step linearization limit

V= input voltage from ADC

V1= initial temperature corresponding volt of step linearization limit

V2= final temperature corresponding volt of step linearization limit

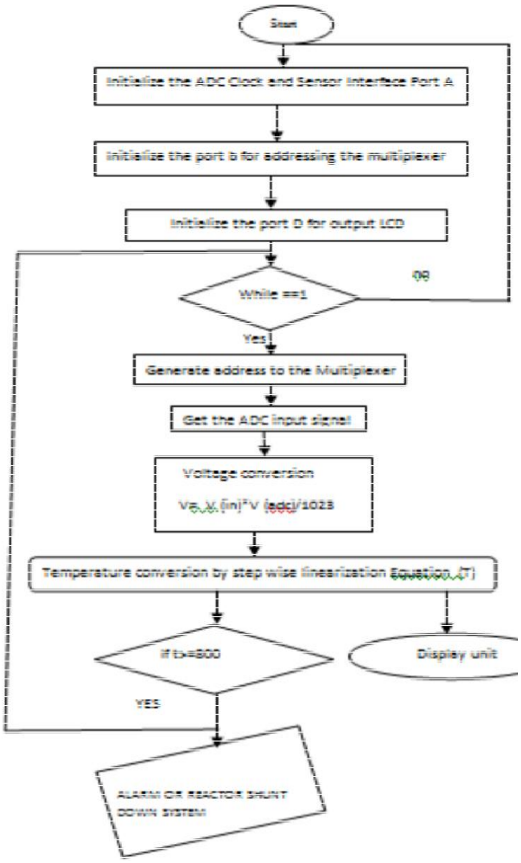

Fig. 5 Flow chart

The PIC16F877A controller is programmed by the pic compiler which has the following flow chart functionality.

And the temperature signal which is from the serial transmission output of the microcontroller is connected to the serial communication channel which transmits the data to the real time computer unit which is present out of the reactor floor.

4.2 REAL TIME COMPUTER

This Real time computer system is also called as an RTC. Which is an display unit which collect the Data's of the n sensor through the single serial transmission cable and connecting to the display computer unit through RS-485 serial transmission cable to the display unit as well as the 2/3 logic circuit. and display the data's in the real time computer unit. in the present control room the CRT monitors are used to monitor the data's.

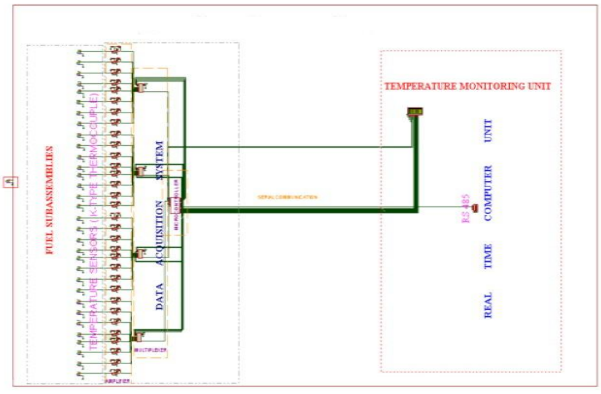

Fig. 6: PIC16F877A Based design control circuit

Here the basic design control circuit of the data acquisition system is designed by using the proteus $_{de}$sign software by using the control and processing .

4.3 ALARM

This RTC system generated the alarm pulse to the buzzer which will raise the sound or indication to the real time world to make an alert. When the temperature excess the safety limit.

5. EXPERIMENTAL VERIFICATION

Fig. 7: Hardware Fabrication Layout

The Data Acquisition card is designed for the thermocouple interface at the input side of the data acquisition card and the analog signal of the sensor's are converted to the digital and processed in the low cost micro controller unit and output is directly transmitted to the RTC real time unit through the serial communication channel are else it is displayed in the LCD by parallel communication unit for the testingpurpose through the port D of the microcontroller output.

6. CONCLUSION

The "Microcontroller Based Data Acquisition system for core temperature monitoring of Future Sodium Cooled Fast Reactor" the Data Acquisition system the DAS card is designed to reduce the cabling in between the reactor and the control room by creating the DAS is designed by using an simulation software and program complier for microcontroller programming .then the output of the DSA card is send to the real time computer unit in the control room by using the serial communication network and real time computer based system are used to display the data's. Then the system cost is reduced due to reduction in number of cablings from large amount to smaller number due to this proposed design.

REFERENCES

[1] M. Sakthivel* and K. Madhusoodanan "core temperature monitoring system for prototype fast breeder reactor" nuclear science and engineering: 170,290-293(2012) Indira Gandhi center for atomic research ,kalpakkam ,india.

[2] P.M.VIJAYAKUMARAN et al., "conceptual design of core temperature monitoring system," PFBR/63110/DN/1000, Indira Gandhi center for atomic research (apr.2004).

[3] D. KIRUBAKARAN M.E., Ph.D. prof/head of department in St.Joseph's institute of technology. He has done his research "Implementation of AC-AC converter for induction Heating using low cost embedded controller"in the year of 2000.

[4] An Intrnet-Based Interactive Embedded Data-Acquisition System for Real-Time Applications IEEE Transactions On Instrumentation And Measurement, VOL.58, NO. 3, MARCH 2009 Ali ZiyaAlkar, Member, IEEE, and Mehmet AtifKaraca

[5] Ms.Va ishaliDhawale*, Prof.S.M. Turkane** "Data Acquisition System (DAS) Based On ARM Embedded Web Server"Department of Electronics and Telecommunication, PREC, Loni, Pune University, Ahmednagar ISSN : 2248-9622, Vol. 4, Issue 1(Version 3), January 2014, pp.212-215.

[6] Bharathi ML and Kirubakaran . D. (2014) "PIC based implementation of ZV ZCS Interleaved Boost Converter ", Advanced Material Research Journal, Volume: Modern Achievements and Developments in Manufacturing and Industry 2014.

[7] Kirubakaran D. and Rama Reddy S (2010) , ' Embedded controlled Pulse Converter fed Induction heater', Journal of circuits, systems and Computers, Issue No. 3, Vol. 19.

[8] Kirubakaran D. and Rama Reddy S. (2009), 'Closed loop controlled AC-AC converter for induction heating', Journal of Industrial Technology, USA,Vol. 25, No.2, pp.01-05.

BIOGRAPHIES

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