Preliminary Development of Online Remote Multipurpose Reactor Monitoring System

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Abstract. RSG-GAS is the largest research reactor owned by Indonesia which has been operating for 31 years since August 18, 1987. RSG-GAS has employed the Simatic S7-400 Siemens PLC. However, the PLC system has not been optimized for remote online monitoring reactor purposes. Therefore this paper aims to design a wireless reactor monitoring system using LabVIEW. LabVIEW software is selected due to the flexibility and reliability for the software and hardware integration. Monitoring is carried out for the parameters of temperature, pressure and flow rate. The research covers the design interface on LabVIEW, wireless communication analysis, the verification process and validation of the monitoring system. The results obtained from this study are monitoring systems of RSG-GAS process diagram, verification of data communication and the analysis of the correctness the received data. The full paper will show that the RSG-GAS monitoring system using LabVIEW can applied in the RSG-GAS monitoring system.

1. Introduction

Energy is a necessity for every country, especially electricity in Indonesia which is a developing country, the need for electrical energy is increasing every year, from the electrical energy needs of households, industries, factories and others. To meet electricity needs, the government has built power generation centers in various regions, however, it remains inefficient compared to developing countries that have used nuclear reactors.

Multipurpose Reactor - G.A. Siwabessy (RSG-GAS) is the largest research reactor owned by Indonesia, has been operating for 31 years since August 18, 1987 [1], Indonesia's multi-purpose nuclear reactor was made by international interatom with a capacity of 30 MW. This multipurpose reactor is located in Serpong, Banten province, operated by the National Atomic Energy Agency (BATAN).

To improve multipurpose reactor performance, efficiency and safety in the operation of RSG-GAS, and the occurrence of aging in reactor components, then a monitor system is needed to observe the performance of reactor components [2], monitor systems will be very useful in RSG-GAS operations,
especially in solving problems, and maintenance of mechanical, electrical and instrumentation systems, monitor systems not only work when conditions operate, however, it can be activated when conditions are not operating. Some examples of things that can be monitored in RSG-GAS are: reactor control rods, pump motors on the cooling system, reactor radiation, reactor protection, and others.

In this research, the monitoring system will be designed with the title. "Preliminary Development Of Online Remote Multipurpose Reactor Monitoring System", for monitoring RSG-GAS, hardware is needed to be able to monitor data changes in RSG-GAS, then it will be integrated with software, to monitor in real-time, in this research the implemented hardware and software are PLC LabVIEW respectively. LabVIEW software can process and visualize data in the fields of data acquisition, instrumentation control, and industrial automation [3].

1.1. Description Of RSG-GAS

Multipurpose Reactor G. A. Siwabessy (RSG-GAS) is a research reactor with MTR (Material Testing Reactor) type, with a power of 30 MW, RSG-GAS fuel element plate type. The RSG-GAS reactor has a water-cooled (H2O) beryllium reflector. On the RSG-GAS core contains 40 fuel elements and 8 control elements. Each fuel element consists of 21 U3Si2-Al fuel plates, with enrichment of 19.75%, while the control element is the same dimensions as fuel, with 15 U3Si2-Al fuel plates, 3 plates on the left, and 3 plates on the right, control elements are emptied for the entry of absorbent material. Absorbent material that functions as a control rod, a control rod like a fork, a control rod made of AgInCd material, and will fill a vacant position on the control element to control fission products[4].

The RSG-GAS reactor produces neutron source, with average neutron flux of $2 \times 10^{14}$ n / cm$^2$/s. The operation of the reactor can be used by the user for other activities. For example utilization for research purposes and radioisotope production. In the operation of the reactor is expected by the user of the reactor, the reactor is able to run stably without experiencing technical problems because interference can affect the existing utilization activities. Stable reactor operation and no interference is an excellent manifestation of the performance, structure, system, and components of the reactor which includes: cooling systems, verification systems, ventilation systems, radiation protection systems, and reactor protection systems (RPS), operating in the range price of the specified operating system limit. Abnormal events and operating disruptions can occur when the performance of the structure, system, and components, when the reactor does not operate at the specified operating system limit value [5].

![Figure 1. RSG-GAS](image)

**Table 1. RSG-GAS Specifications**

| Parameter          | Value     |
|--------------------|-----------|
| Thermal Power      | 30 MW     |
| Flux Neutrons      | $10^{12}$ n/cm$^2$/s |
| Reactor Type       | Multipurpose                      |
|-------------------|----------------------------------|
| Nuclear Fuel Element Material | $\text{U}_2\text{Si}_2\text{Al, MTR}$ |
| Uranium-235 enrichment | 19.75 %                          |
| Shape of Nuclear Fuel Elements | $\text{Plat 1},30x70,75x625 \text{ mm}$ |
| Material Cladding  | $\text{AlMg}$                    |
| Reactor Coolant    | $\text{H}_2\text{O}$             |
| Flow Speed         | 800 Kg/s                         |

On the RSG-GAS reactor core which contains fuel elements and control elements, has 4 central irradiation positions, and some irradiation positions around the fuel, and in the position of the beryllium reflector. The position of irradiation is used for irradiation of research materials and can produce radioisotopes. Various radioisotopes for the health sector can be produced by RSG-GAS: Iodine-125, Tc-99, Co-60, and Mo-99 [6]. The most needed radioisotope now is Mo-99, Mo-99 is used as a $99\text{mTc}$ Generator. Mo-99 radioisotope is produced by irradiating LEU targets on the reactor core. Mo-99 is a fission product from U-235, U-235 is an element of the LEU target. Mo-99 activity is a function of reactor power, or neutron flux in the position of the LEU target, irradiation time, and mass of the U-235 contained in the LEU target. The amount of Mo-99 radioisotope needs reaches 300 Ci per week. This need is met by irradiation of the LEU target on the RSG-GAS reactor core [6].

1.2. Reactor Cooling System

There are two RSG-GAS cooling systems, primary and secondary cooling systems. The primary cooling system serves to move heat, the heat results from the reactor core operation. Heat removal is carried out by flowing cooling water through the fuel gap, heat is transferred to the secondary cooling system through the heat exchanger system, then the heat is discharged into the atmosphere through the cooling tower. So the function of the secondary cooling system, which is to take and throw heat out of the environment through the cooling water tower. The RSG-GAS cooling system is designed to be able to move heat by 30 MW [7].

The primary cooling system has 3 pumps, during normal operation 2 pumps operate, and 1 pump as a backup. Water flows through the reactor core from top to bottom, then into the delay chamber, then water passes through the heat exchanger, and returns to the reactor pool. The delay chamber is used to slow down the flow rate, so that the N-16 isotope activity can be reduced. The flow time in the delay chamber is 50 seconds, the volume delay chamber is 80 m$^3$. Another important part of the reactor is the pumps and heat exchangers. There are 2 shell and tube type heat exchangers, each with a capacity of 50%. heat exchanger is installed vertically.
Cooling water in the secondary cooling system, water passes through small tubes / pipes, while in the primary cooling system the water passes through the room outside the small pipes / shell. to maintain the cleanliness of the interior of the small pipes, the heat exchanger is passed sponge balls, with the PAH01 sponge ball-system unit on the secondary cooling system. In the primary cooling system there are measuring tools for flow rate, temperature, pressure and the motor speed rotation indicator. Some parameters on the primary cooling system are the RPS parameters:

- Flow rate control (JEO1 CF811 / 821/83 1)
- Temperature control (JEO1 CT811 / 821/831)
- Pressure control (JEO1 CP811 / 821/831)
- Valve position control (JEO1 CG811 / 821/831)

In the secondary cooling system, the system takes heat carried by the primary cooling system, uses a heat exchanger then heat is discharged, heat is discharged into the environment using 6 cooling towers. Secondary cooling system consists of 2 parallel lines, where each line serves 1 heat exchanger. Each secondary cooling line consists of a heat exchanger pump, pipes and 3 cooling towers. Secondary cooling system flow rate + 1950 m$^3$/h. on secondary cooling systems mounted measuring instruments:

- Flow rate control (PA01 / 02CF01 / 02/03)
- Pressure control (PA01 / 02 CPO1 / 02/03/04)
- Temperature control (PAO 1/02 CTOI / 02)
- Motor rotation speed (PAO1 / 02/03 CS01)
- Water quality control (PAO1CQ01 = conductivity, PA01 CQ02 = pH)
- Water level control (PA04 CL01; PA04 CL02)

In the secondary system mounted radiation control (PAO 1/02 CR002), radiation control is mounted on the press side of each secondary path. If PAO1 / 02 CR001 passes through the specified limit price (5 x 10$^{-6}$ Ci / m$^3$), then, secondary isolation valves (PA01 AA14 / AA16; PA02 A A14 / AA 1 (j)) will close automatically. this is done to prevent water that is active (contaminated) from outside the environment [9].

2. Methodology
In accordance with the research objectives described, the objects of this research are: pool reactor, reactor core, delay chamber and heat exchanger tank as shown in Figure 1.

This research includes:

1. Designing a reactor monitoring system interface using LabVIEW.
2. Testing by simulation of RSG-GAS wireless monitoring system using LabVIEW.
3. Verification and validation of monitoring system data using LabVIEW.

With the parameters to be monitored: temperature, flow rate, neutron flux and pressure.

In research, tools and materials are needed to support activities, and as a method of system design, testing, and data retrieval. Tools and materials used to carry out design and research activities are:

1. PLC (Programmable Logic Controller) Simatic Siemens
2. LabVIEW 2014
3. OPC (OLE For Process Control)
4. Antena TL-ANT2412D
5. Router D-Link Dir-619L

![Figure 3. Block Diagram]

RSG-GAS monitoring system design using LabVIEW is shown in Figure 4, where the process starts from the reactor that will give a signal, then the sensor will read the signal that will be forwarded through the PLC hardware, and received by the PC Server, the data will be sent wirelessly to the PC Client then the data will be displayed using LabVIEW software in the form of graphs, waves, and also indicators that resemble reactors to facilitate monitoring, the data obtained can also be recorded by LabVIEW and stored on a PC.
The first monitoring system start. Then, choose one of the simulations or realtime on the LabVIEW interface. If you choose simulation, LabVIEW on the PC client will read the data from row by row, then LabVIEW will sort the data. then the data is displayed on the interface. and then, if the stop process ends, if it's not the process repeats again. If you choose real time, LabVIEW on the PC server reads data from the PLC, and then, sending data row by row using TCP/IP, the data will be received by the PC client. then LabVIEW on the PC client will sort the data. then the data is displayed on the interface. and then, if the stop process ends, if it's not the process repeats again.

3. Results And Discussion

The result of this research is an interface design and program in LabVIEW, with a wireless communication system for RSG-GAS monitoring. The system consists of blocks of senders and receivers.
Figure 5. Transmitter Diagram Block

Figure 6. is a block diagram on the transmitter system, this block diagram is on the PC Server. The process starts with reading data from a file, for real work the data will be obtained from sensors via OPC. Data that is read is then sent in string form, in one transmission containing 26 channel data. Examples of sent strings can be seen in Figure 7.

Figure 7. An example of a string sent by a transmitter diagram block, in one transmission containing 26 channel data.

Figure 6. Example of String Data

Figure 7. Receiver Diagram Block
Figure 8. is the receiver system block diagram on the PC Client. The process starts from receiving data, because data is received in string form. So, the data must be changed to array form so that it can be sorted, then the data is sorted by channel to display on the interface.

For research, there needs to be a system that can work offline. So, the system simulation is designed, the simulation system block diagram is on the PC Client, this system can work without connecting to the PC Server.
Figure 10. is the final result of the interface design for wireless monitoring systems in RSG-GAS. Interface design is made based on flow chart from RSG-GAS. The interface is on PC Client and PC Server. The parameters taken from the RSG-GAS component are marked with color.

![Antenna TL-ANT2412D](image1)

**Figure 10. Antenna TL-ANT2412D**

To reach the distance of the RSG-GAS building using a router. Then, an antenna is needed. Antennas are mounted on the PC Client and PC server, the antenna is connected to the router.

![WDS Router Mode Settings](image2)

**Figure 11. WDS Router Mode Settings**

To be able to communicate both routers must be set. The mode used is the WDS mode. Some important things in the WDS router mode settings. On router 1 enter the MAC ID router 2. and on the router 2 enter the router MAC ID 1. Bridge security and the network key of both routers must be the same. Figure 11. is an example of a WDS mode router setting.
4. Conclusion

The results of this research are wireless data communication systems with very small errors. so, this system expects to be applied to the RSG-GAS monitoring system.

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