Analysis of JKT01 Neutron Flux Detector Measurements In RSG-GAS Reactor Using LabVIEW

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Abstract. The RSG-GAS Reactor, one of the Indonesia research reactors and located in Serpong, is owned by the National Nuclear Energy Agency (BATAN). The RSG-GAS reactor has operated since 1987 and some instrumentation and control systems are considered to be degraded and ageing. It is therefore, necessary to evaluate the safety of all instrumentation and controls and one of the component systems to be evaluated is the performance of JKT01 neutron flux detector. Neutron Flux Detector JKT01 basically detects neutron fluxes in the reactor core and converts it into electrical signals. The electrical signal is then forwarded to the amplifier (Amplifier) to become the input of the reactor protection system. One output of it is transferred to the Main Control Room (RKU) showing on the analog meter as an indicator used by the reactor operator. To simulate all of this matter, a program to simulate the output of the JKT01 Neutron Flux Detector using LabVIEW was developed. The simulated data is estimated using a lot of equations also formulated in LabVIEW. The calculation results are also displayed on the interface using LabVIEW available in the PC. By using this simulation program, it is successful to perform anomaly detection experiments on the JKT01 detector of RSG-GAS Reactor. The simulation results showed that the anomaly JKT01 neutron flux using electrical-current-base are respectively, 1.5×, 1.7× and 2.0×.

1. Introduction
The regulation of the head of BAPETEN article 6 paragraph 1 point a, b, c, d states that the safety of the non-power reactor deals with the safety assessment during the operation phase including the design of the reactor, the current condition of the structure, system and component (SSC), equipment qualification and ageing [1]. The GA Siwabessy Multipurpose Reactor (RSG-GAS reactor) is a research reactor which had the first criticality in 1987 and achieved full power of 30 MW in 1992[2]. It is therefore needed to evaluate each SSC to ensure the safety of reactor operation for both operator and environmental safety.

The previous evaluation by the researchers showed that the reactor safety system appeared good performance and reliable so that when there is interruption or even failure of operation or disruption of reactor usage, reactor can be extinguished automatically by reactor protection system[3]. The occurrence of reactor operation occurs in the scale of zero and scale one where no radiological impact. In a study of secondary water coolant, a RSG-GAS reactor to operate until 2017 had the
quality of secondary water coolant at very good conditions in suppressing the growth of microbes [4]. Due to the existence of some disturbances in the operating cycle of 61-75, namely the power loss of 57 times due to electric trips from the state electricity company (PLN) and 7 times error occurred by the operator, RSG-GAS reactor remains reliable [5].

One of the important parameter in the nuclear reactor is the measurement of neutron flux. In RSG-GAS reactor the neutron flux measurements are divided into three measuring ranges, start up range (JKT01), intermediate range (JKT02) and power range (JKT03) [6]. The development of neutron flux monitoring system has been done, the result shown that the system is able to display the measurement result of neutron flux detector in RSG-GAS [7]. In previous research focused only on the way to collect digital data from the measurements of neutron flux detector and has not yet perform an analysis of neutron flux measurements.

The measurement of neutron flux is important, especially in start up condition. If the start up go too fast the reactor will automatic shutdown. To anticipate the failure measurement of neutron flux detector, need to be analitic. In this research, simulated the anomaly on the measurement neutron flux detector on start up range. The aim of the simulation is to predict and to show the deference between the normal condition and anomaly condition that occur on the neutron flux detector JKT01. To simulate the anomaly condition on neutron flux detector, did by used the LabVIEW software [8]. Using LabVIEW software we can enter the measurement data of neutron flux from RSG-GAS reactor to evaluate and also simulate it to the anomaly condition.

2. Theory
Flux neutrons in a reactor core are important information to monitor the measurement system including: shutdown, subcritical, reactor coolant, and start-up check and reactor operation in all spectrum loads. The neutron flux in the core has the following equations [9]:

$$\phi = nv$$

\[ \phi = \text{neutron flux (n/cm}^2\text{).} \]
\[ n = \text{amount of neutrons (n/cm}^3\text{).} \]
\[ v = \text{neutron speed in the core (cm/s).} \]

To measure the amount of neutron flux density in the core, required reliable instrumentation. The instrumentation that used to monitor the number of neutrons in the core is a neutron flux detector. The neutron flux detectors inside the RSG-GAS reactor core consist of JKT01, JKT02, JKT03 and JKT04, each detector have different roles in monitoring the number of neutron fluxes when the reactor operates. The number of neutron flux is monitored through electrical signals in the form of electric current in the order of milliampere (mA). The electrical signals are proportional to the reaction count per second (CPS) or the magnitude of the neutron flux. The accuracy of the number of neutron flux inside the reactor core depends on the quality of the electrical signals. If there is detector disturbance, it will result in electrical signals from the detector will experience anomaly.

Detector
The RSG-GAS Reactor detector consists of three types: JKT01, JKT02 and JKT03. JKT01 neutron flux detector acts as RSG-GAS reactor start-up and Fission Chamber (FC) type, schematics as shown in Figures 1a and 1b.
Figure 1a. Overall plan of Fission Chamber with fissile element [8]

Figure 1b. Simplified schema of cylindrical Fission Chamber [10]

**Linear Regression**

Linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be an explanatory variable, and the other is considered to be a dependent variable [11].

The equation has the form[12]:

\[ y = a + bx \]  

where \( y \) is the dependent variable (that’s the variable that goes on the y axis), \( x \) is the independent variable (i.e. it is plotted on the x axis), \( b \) is the slope of the line and \( a \) is the y-intercept.

\[ b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \]  \hspace{1cm} (3a)

\[ a = \frac{\sum y \sum x^2 - \sum x \sum xy}{n \sum x^2 - (\sum x)^2} \]  \hspace{1cm} (3b)

Correlation coefficient of linear regression[13]:

\[ r = \frac{n \sum xy - \sum x \sum y}{\sqrt{(n \sum x^2 - (\sum x)^2)(n \sum y^2 - (\sum y)^2)}} \]  \hspace{1cm} (4)

The value of \( r \) is such that \(-1 \leq r \leq +1\). The + and – signs are used for positive linear correlations and negative linear correlations, respectively [14]. A correlation greater than 0.8 is generally described as
strong, whereas a correlation less than 0.5 is generally described as weak and similar on negative linear correlations.

3. Methodology
To research begin with take data form the instrumentation system in the reactor. The diagram block of instrumentation system on neutron flux detector is shown in Figure 2 below.

![Diagram block of instrumentation system on neutron flux detector](image)

Figure 2. Diagram block of instrumentation system on neutron flux detector

Neutron flux detector JKT01 detects neutron flux in the reactor core and converts it into electrical signals. The electrical signal is forwarded to the amplifier to become the input of the Reactor Protection System (RPS). Output from the RPS forwarded to the Main Control Room (RKU) to display in the analog meter as an indicator that used by the operator to monitor and control the reactor condition. Analog signal from the analog meter become input for the Programable Logic Controller (PLC). PLC convert analog data to digital data so that can be read by computer. LabVIEW is used to display digital data of neutron flux which has been processed by PLC. Neutron flux measurement data is saved on the computer so that the data can be analyz, even the reactor is not on operation.

Data that has been save on computer can be called using LabVIEW programming. Labview can be used to process data and perform mathematical calculations. So that LabVIEW can simulate for the anomal measurement data. In this research anomal data set to $1.5\times$, $1.7\times$ and $2.0\times$ from the original data. The value is set on that condition because it will see how the system response when the anomaly occur on a fairly minor error. In this research the anomal is set on the JKT01 CX811. Using the multiple program in LabVIEW, it can manipulate the original measurement data from JKT01 to the $1.5\times$, $1.7\times$, and $2.0\times$

4. The Results and Discussions
Table 1 shown the results of neutron flux value (CPS) versus current (mA) on JKT01CX811. From the Table 1 can be know that the pattern of increasing the neutron flux on the reactor is logarithmic. Base on this data, it can be found the equation.
**Tabel 1.** Neutron Flux Value (CPS) Versus Current (mA) on JKT01CX811

| No. | Current (mA) | CPS       |
|-----|--------------|-----------|
| 1.  | 0            | 0         |
| 2.  | 0.52         | 10E-1     |
| 3.  | 2.86         | 10E+0     |
| 4.  | 5.72         | 10E+1     |
| 5.  | 8.56         | 10E+2     |
| 6.  | 11.42        | 10E+3     |
| 7.  | 14.28        | 10E+4     |
| 8.  | 17.14        | 10E+5     |
| 9.  | 20           | 10E+6     |

The data calculation are formulated using equation (2) and (3) and those are then obtained by linear regression equation and the correlation and its graph are shown in Figure 3.

**Figure 3.** Graph of logarithmic of current (I) vs of CPS

Based on the data seen in Table 1 and developed using regression equations, simulations of anomalous electrical current are 1.5×, 1.7× and 2.0× respectively. The results of the normal electric current can be seen in Figures 4, 5, and 6 as follows:
Figure 4 show the simulation of anomali that ocure on JKT01 CX811 neutron flux measurement. The output current on JKT01 CX811 get simulate multiply 1.5 time than normal condition. The measurement results show a drift signal on the appointment of JKT01CX811 compared to JKT01 CX821. In line with the increase in current, the drift signal is greater than the normal signal.

Figure 5 show the simulation of anomali that ocure on JKT01 CX811 neutron flux measurement. The output current on JKT01CX811 get simulate multiply 1.7 time than normal condition. The measurement results show a drift signal on the appointment of JKT01CX811 compared to JKT01 CX821. At first of the measurement, the difference is not visible. But in line with the increment of input current, the drift signal is greater than the normal signal.
Figure 6. Simulation on 2.0 by normal current

Figure 6 show the simulation of anomali that ocure on JKT01CX811 neutron flux measurement. The output current on JKT01CX811 get simulate multiply 2.0 time than normal condition. The measurement results show a drift signal on the appointment of JKT01CX811 compared to JKT01 CX821. At this simulation the drift signal is visible from the begining of measurement. It cause the multiply of the signal is double than the normal. The drift signal is getting bigger when the input current is increase her paragraphs are indented (Body text Indented style).

5. Conclusions
The measurement of neutron fluxes in RSG-GAS reactor core through the detector JKT01 CX811 and CX821 has been done in this work. A program to simulate the output of the JKT01 neutron flux detector using LabVIEW was developed. The simulated data is estimated using a lot of equations also formulated in LabVIEW. The calculation results are also displayed on the interface using LabVIEW available in the PC.
Using this simulation program, it is successful to perform anomaly detection experiments on the JKT01 detector of RSG-GAS Reactor. The simulation results showed that the anomaly JKT01 neutron fluxes using electrical-current-base are respectively, 1.5×, 1.7× and 2.0×.

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