DESIGN OF GAMMA IRRADIATOR SIMULATOR CATEGORY IV USING ARDUINO MEGA's

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Abstract. DESIGN OF GAMMA IRRADIATOR SIMULATOR CATEGORY IV USING ARDUINO MEGA's. Irradiation technology is increasingly developing in Indonesia. With the increase in irradiator facilities in Indonesia, it is hoped that irradiator control system technology can be applied in the construction and maintenance of irradiator facilities. This study aims to design and test the reliability of motion system irradiator facilities in category IV. The Irradiator Simulator was designed using 5 conveyors and a source motion system, to control the motion system of the irradiator facility, the Arduino Mega 2560 was used. The simulator that was made had dimensions of 550 mm × 650 mm. The simulator test results obtained the reliability coefficient of 0.62, which means that the irradiator simulator made has a high level of reliability.

Keywords: Irradiator, Simulator, Arduino Mega

1. Introduction

Irradiator is one of the nuclear installations that is used to modify physical, chemical and biological properties through ionizing radiation. Currently irradiators are applied in various fields such as sterilization of health equipment including medicines, preserving food and agricultural products, and modifying materials such as polymerization. The radiation source used can be in the form of gamma ray or electron radiation sources.

Irradiation technology in Indonesia is growing. In November 2017 the Red and White Irradiator was inaugurated in the Puspiptek Area, Serpong, South Tangerang, Indonesia. Previously, Indonesia had a commercial scale Irradiator in the Cibitung area. With the increase in Irradiator facilities in Indonesia it is hoped that graduates of the Electrical Engineering Study Program STTN-BATAN will be able to become involved in the development and maintenance of existing Irradiators. To equip students before being directly involved in the world of work, students need a basic introduction to irradiators. So to support the students of Electro Mechanics in understanding the working principle of irradiators, an irradiator simulator and motion system that can be controlled need to be made.

2. Theory

2.1. Simulator
Simulator is a technique of imitating or demonstrating the activities of various processes or facilities that exist in the real world. These facilities or processes are called systems, which in science are used to make assumptions about how the system works. Simulation is a system model in which its components are represented by arithmetic and logic processes that are run by computers to proclaim the dynamic properties of the system.

2.2. Irradiator category IV
Category IV irradiators are human-controlled irradiators where the radiation source (gamma radiation) will be completely stored and protected in a pool of water when not in use. When irradiated, the source of gamma radiation will be taken out of the pool of water and into the radiation chamber which is maintained and cannot be accessed during operation.

2.3. Arduino Mega 2560
Arduino board is an electronic system microcontroller module with a minimalist size but reliable and fast. Various modules and the latest sensors can be installed on this board equipped with various demo codes that satisfy.

Arduino Mega 2560 is a microcontroller device using ATMega2560 is shown in Figure 1. This module has 54 digital inputs or outputs, of which 14 pins are used for PWM output and 16 pins are used as analog inputs, 4 pin UARTs, 16 MHz Crystal oscillators, a USB connection, ICSP header power jack, and a reset button. This module has everything needed to program the microcontroller such as a USB cable and power supply via an adapter or battery. All this is provided to support the use of Arduino, only connected to a computer with a USB cable or electricity with an adapter from AC to DC or a battery to start usage. Arduino Mega is compatible with shiled which is designed for Arduino Duemilanove, Decimila and UNO5.

![Figure 1. Arduino Mega 2560](image)

3. Research methods
3.1. Simulator design and control system
Simulator design that will be made includes mechanical design and control system design. The simulator design consists of 5 conveyors driven by dc motors with a gamma source placed in the middle (Figure 2). Whereas in Figure 3 a schematic control system is shown. The mechanical movements that will be designed include conveyor movement and source movement, both movements are controlled using Arduino. Inputs to control the movement of conveyors and sources include push buttons, keypads and infrared sensors, while the outputs are DC motors, servo motors and LCDs.
The conveyor is driven by 4 DC motors controlled by Arduino through the Adafruit Motor Shield driver. While the gamma source drive is driven by a servo motor directly by Arduino without additional drivers.

![Simulator design](image)

**Figure 2.** Simulator design

![Schematic control system](image)

**Figure 3.** Schematic control system

3.2. *Arduino Programming*
The Arduino program is needed to move the conveyor and adjust the timer according to the length of irradiation needed, and move the gamma source to go up and down using a servo motor. The program to control the simulator refers to the pseudo code and the program flow diagram created as Figure 4.

Arduino Programming using Arduino IDE Software. The Arduino program will control the input and output of the electrical system. To control input and output into one system such as Figure 4, program writing is done in stages. There are 3 stages of the program that were made before all programs were combined.

3.2.1. The number input program uses the membrane keypad and displays it on the LCD. Create a library initialization program and declare the variables used. The library used is LCD and Keypad.
3.2.2. **The on-off program uses a push button with pseudo code**. This program initializes the library and declares the variables used. The library used is Continuous Servo, with 2 push button inputs and output servo motors and LEDs.

3.2.3. **The DC motor control program uses an infrared sensor with a pseudocode**. This program initializes the library and declares the variables used. The library used is the Adafruit Motor Shield driver, with infrared sensor input and 4 DC motor outputs that are PWM regulated.

3.3. **Assembling**.
At this stage, all mechanical components in the simulator are arranged in such a way according to their respective functions, including assembling infrared sensors, LCD, push buttons, and a keypad as well as the power supply and USB port. Components are assembled with the help of PCBs and sockets that function to connect inputs and outputs to Arduino.

3.4. **Installing programs**.
Install / upload the program that was created in the Arduino IDE software to the Arduino board according to the steps as follows:
1. Open the program file that has been created.
2. Setting the board type and port on the Arduino IDE by selecting the Tools → Board menubar. The Arduino board used by Arduino Mega 2560 with com port 10 as shown in Figure 5.

![Figure 5. Board and Port Settings](image)

3. Upload the program to Arduino by pressing upload.

3.5. **Testing**.
Tests carried out to determine the success of the simulator is the testing of irradiation time and reliability testing.

4. **Results and Discussion**
4.1. Results

The results achieved were the construction of an iradiator simulator controlled by Arduino Mega 2560. The iradiator simulator has dimensions of 550 mm × 650 mm, consisting of a sample carrier component consisting of five conveyors and gamma source drive components as well as the control components inside the control panel. The results of the iradiator simulator that have been made can be seen in Figure 6.

![Image of the iradiator simulator](image)

**Figure 6.** Results of Category IV Iradiator Simulator

4.2. Testing the sample travel time around the gamma source

This test is carried out to determine the time taken for the sample to surround the source. 10 experiments were carried out by putting the sample from one conveyor (in) until the sample returned through conveyor five (out), the length of time the sample was calculated using a stopwatch. Each motor is regulated by a different PWM depending on the length of the conveyor path. The first motor is 95, the second motor is 85, the third motor is 99, the fourth motor is 99, and the fifth motor is 95.

Table 1 shows the results of testing the sample travel time.

| trial | time |
|-------|------|
| 1     | 7.41 |
| 2     | 7.47 |
| 3     | 7.29 |
| 4     | 8.69 |
| 5     | 7.53 |
| 6     | 7.47 |
| 7     | 9.17 |
| 8     | 7.55 |
| 9     | 8.31 |
| 10    | 7.82 |

The average result obtained was 7.871 seconds. This value will be entered in the Arduino program to adjust the exposure delay while the conveyor stops. The following is the program that has entered the value, so that the sample will stop 4 times each through the infrared sensor.

Delay (((wi-7.871) / 4) * 1000)); // adjusted for the length of the motor must stop.

4.3. Reliability testing
Reliability tests are carried out to determine the consistency of the irradiator simulator that has been made. The fairness test is carried out 10 times following the instructions for use. In this test, let's say source activity of 200 kCi, with source distance to the sample 0.175 m, gamma factor 1.3 and conversion factor 0.877. It will irradiate 30 samples that require irradiation doses ranging from 160 Gy to 450 Gy.

\[ D = \frac{\Gamma \cdot A}{r^2} \]

\[ \hat{D} = 0.877 \cdot \frac{1,3200 \cdot 10^3}{0.175^2} \]

\[ \hat{D} = 7445551,02 \text{ Rad/hour} = 74455,5102 \text{ Gy/hour} \]

**Irradiation time** = \[ \frac{160 \text{ Gy}}{74455,5102 \text{ Gy/hour}} \]

**Irradiation time** = 0.002148934 hour = 7.736163 second

From the calculation then for a dose of 160 Gy irradiation time is needed for 7.736163 seconds. Because it can only enter integers for input irradiation time, the calculation results above will be rounded up to 8 seconds.

Table 2 is the result of reliability testing with input time varies according to the desired dose of 30 trials.

| Number | Dose (Gy) | Input Time (seconds) | Process | Travel time |
|--------|-----------|----------------------|---------|-------------|
|        |           |                      | 1  2  3  4  5  6   |          |
| 1      | 160       | 8                    | 0  1  0  1  1  1   | 16.58    |
| 2      | 170       | 8                    | 0  1  1  0  1  1   | 13.61    |
| 3      | 180       | 9                    | 1  1  1  0  0  1   | 10       |
| 4      | 190       | 9                    | 0  1  0  1  1  1   | 14.65    |
| 5      | 200       | 10                   | 0  1  1  0  0  1   | 23.65    |
| 6      | 210       | 10                   | 1  1  1  1  1  1   | 10.83    |
| 7      | 220       | 11                   | 1  1  0  0  0  1   | 10       |
| 8      | 230       | 11                   | 1  1  0  1  1  1   | 14.42    |
| 9      | 240       | 12                   | 0  1  1  0  1  1   | 11.96    |
| 10     | 250       | 12                   | 1  1  0  1  1  1   | 15.24    |
| 11     | 260       | 13                   | 1  1  0  1  1  1   | 18.14    |
| 12     | 270       | 13                   | 0  1  0  1  1  1   | 14.49    |
| 13     | 280       | 14                   | 1  1  0  1  0  1   | 14.94    |
| 14     | 290       | 14                   | 1  1  0  1  1  1   | 16.56    |
| 15     | 300       | 15                   | 0  1  0  0  1  1   | 19.98    |
The results from Table 2 if the process goes well are symbolized by 1 and if it fails to be symbolized 0. 6 processes are observed in each simulator operation. The first process is after inputting the irradiation time then pressing the start button so that the gamma source is raised and the entire conveyor is running. The second process is the sample passing through conveyors 1 and 2 then stops at the infrared sensor 1 for a certain delay. The third process of the sample moves back through conveyor 2 and conveyor 3 then stops on the infrared sensor 2. The fourth process of the sample moves back through conveyor 3 and conveyor 4 then stops on the infrared sensor 3. The fifth process is the sample moves back through conveyor 4 and conveyor 5 then stops on the infrared sensor 4. The final process is the sample exits through conveyor 5 and when the stop button is pressed then the entire conveyor will stop and the gamma source goes down to the pool.

The input time entered should be in accordance with the length of the irradiation process, but in 30 samples only 4 had the same input and output. This is because during the experiment there were several obstacles that caused the sample to be too long in the conveyor, namely conveyors 3 and 4 which were stuck when the conveyor returned to run after a delay for irradiation. In addition, there are a number of unsuccessful experiments due to samples that fell from the conveyor as happened in experiments 3, 7, and 18, so no travel time was recorded because it did not complete the entire process. While that causes the sample irradiation time to be faster than the input time entered, this is because the infrared sensor does not respond when the sample passes through the conveyor so that the conveyor does not stop.

Of the 30 sample tests, there were several trials that failed and there were successful experiments. The reliability test of the irradiator simulator obtained the results of the calculation of the reliability coefficient of 0.620427881. Because the reliability results obtained are more than 0.601, it can be said that the irradiator simulator has a high level of reliability.

5. Conclusion

Category IV gamma irradiator simulator has been made with dimensions of 550 mm × 650 mm, consisting of a sample carrier component consisting of five conveyors and source drive components, and controlled using Arduino Mega 2560. Based on reliability testing obtained reliability coefficient of 0.620427881 so that the irradiator simulator has a high level of reliability.
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