Construction of operation parameters data acquisition system for 300 keV/20 mA *EBM BATAN yogyakarta*

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Abstract. Construction of components operating system and operation data parameters acquisition system for 300 keV/20 mA EBM PSTA-BATAN Yogyakarta has been done. The system is used for operating and monitoring of operation data parameters of 300 keV/20 mA EBM such as input oscillator power voltage, high voltage, high voltage current, coloumn current, regulated voltage of electron gun, electron beam current and vacuum pressure. The system consists of a hardware and a software. The hardware consisted of the SuperPLC FX2424 Module, L-Relay 51 module, voltage power supply, while the software as created using the LabVIEW version 2018 and i-TRiLOGI programs version 7.01. The construction of the system was started with the making of an operating program at i-TRiLOGI, making PLC and LabVIEW communications, programming the operating system in LabVIEW, making a data acquisition system in LabVIEW. The system was functioned to operate will operate EBM components via a computer device by pressing the operation buttons on the computer screen, while the operating parameters was displayed in the form of continuous graphics, digital tables and numbers. The system was equipped with operating data storage facilities that can be opened or printed at any time. The test results of communication testing between SuperPLC and LabVIEW was done with serial communication. The operation of the LabVIEW software was able to operate the programming function on PLC FX2424. From the ADC PLC test the linear graph results showed with a correlation value of 1. In the data appearance testing in HMI LabVIEW it was appropriate and the data presentation function could be performed in the form of tables and graphs and the data could be displayed in Ms. Excel for data tables and in Ms. format Word for graphical data.

1. Introduction

Several research of data acquisition systems had been developed in accelerator machines [1 -3], either for monitoring or controlling. The electron accelerating machine which is often called the Electron Beam Machine (EBM) is a new type of technology that was developed two decades ago as a source of ionizing radiation (energized electrons) in the irradiation process of an industrial product [4]. The electron beam machine (EBM) is a device that functions to speed up the electron beam to a certain level of energy used for a material or target irradiation process [5]. One important part of an EBM is the instrumentation and control system (ICS) which functions as the operating system, monitoring and controlling the parameters of the MBE operation [6]. EBM can be operated using PLC FX2424.

The SuperPLC FX2424 is a new F-series PLC family that features an ethernet port that can be connected directly to a network router, switch, or hub for access to a LAN or to the Internet. The basic FX2424 consists of 8 analog inputs having 12-bit, (0-5) V_{DC}, and 4 analog outputs having 10-bit, (0-5) V_{DC}, and also 24 digital inputs and 24 digital outputs [7]. PLC FX 2424 has been used for data acquisition.

Data acquisition is the process of changing data from a sensor into electrical signals which are then converted into digital forms for processing and analysis by computers. A data acquisition system consists of sensors, signal processing units, data acquisition hardware, and computer units [8]. Data acquisition is used to retrieve, collect and prepare data that is running, then the data is further processed in a computer for certain purposes [9].

At present, the operation of the MBE 300 keV/20 mA still uses the HPI 8255 interface module using parallel data communication and ADC 0808 and the Atmega 8535 microcontroller which results in limited operating distance and data acquisition. The aim of the research is to build the MBE component operating system and the acquisition of MBE parameter data to facilitate operator work in operating and acquiring MBE data parameters. Therefore, it is necessary to establish a module to facilitate the operation and data acquisition. The system is expected to later become an Internet Accelerator Laboratory device that can be accessed through the internet.

2. Basic Theory

2.1. *Electron Beam Machine (EBM)*

The Electron Beam Machine (EBM) is a nuclear device that functions to speed up the electron beam. The amount of generated energy and electron beam current can be adjusted to the MBE specification, including radiation energy and electron beam currents. Radiation energy determines the depth of penetration of the beam into the irradiated material, while the beam current determines the radiation dose. The parameters of the irradiated material include the phase and shape of the material. The higher the electron beam energy, the deeper the penetration of the electron beam. Accelerated electrons will decrease their energy after penetrating the material at a certain depth. Radiation penetration is influenced by the density of the material. The higher the density of the material the lower the electron penetration, and vice versa.

EBM operations can only be carried out through several stages of activities in sequence, namely preparation, check or check list, vacuum system conditioning, optical system (focus, driver and payer), high voltage source (accelerator) and electron source. After conditioning, it is continued with the operation of the electron beam machine, namely by setting the high voltage source as the accelerator voltage and regulating the source power of the electron. Besides that, the operation of the conveyor speed must also be related to the desired dosage in operation. To set the required irradiation dose is done by adjusting the electron beam flow and conveyor speed. All these settings can be done by adjusting the operating parameters through the operation panel on the control panel. The operating parameters of each stage must be recorded because related to the operation of the next stage, the data of this operation stage is very necessary for the next operating reference and for identification of damage in the maintenance of electron beam machines [5].

The principle of MBE work is generally the electron beam produced by the source of electrons inserted into the accelerator tube to be accelerated to the desired energy according to the ability of the accelerator system. To accelerate this electron beam, a high voltage source is needed as an accelerator voltage mounted on the accelerator electrode. These electron beams are then focused, directed and paid for by an optical system (focusing system, driver and payer) then released through a window (window) towards the irradiated target. During operation, the trajectory of electron beams in the electron beam machine (MBE) must be empty, that is, at the level of emptiness around mbar so that there is no electron beam resistance from the electron source to the window. The higher the level of emptiness, the better for electron beam machine operations because the smaller obstacles that occur. After exiting through the window, electron beams are used to irradiate targets placed after the window at atmospheric pressure, so the irradiated target is brought close to the window taking into account the gusts that occur by window cooling air. Figure 1 provides the scheme of MBE 300 keV/20 mA instrumentation & control system [5].

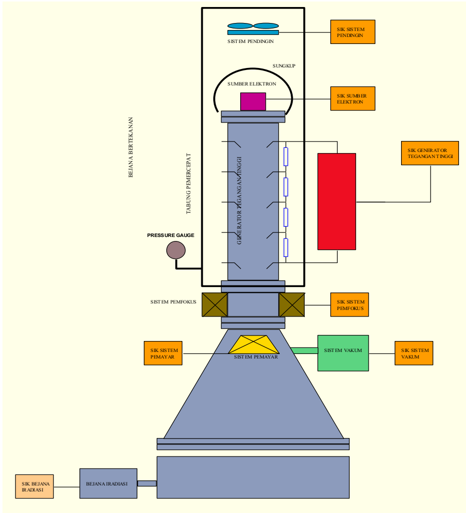

Figure 1. MBE 300 keV / 20 mA instrumentation & control system diagram scheme [5]

2.2. *Programmable Logic Controller*

The Trilogy FX2424 PLC is the first member of the new F-series PLC family to feature an ethernet port that can be connected directly to a network router, switch, or hub for access to a LAN or to the Internet. The Ethernet port supports FServer (for remote programming or monitoring) and modbus / TCP servers (for access by third party devices) with up to 6 simultaneous connections [7]. The basic FX2424 unit consists of 8 analog inputs (12-bit, 0-5VDC), 4 analog outputs (10-bit, 0-5V DC), 24 digital inputs, and 24 digital outputs. Figure 2 shows the PLC FX2424 scheme.

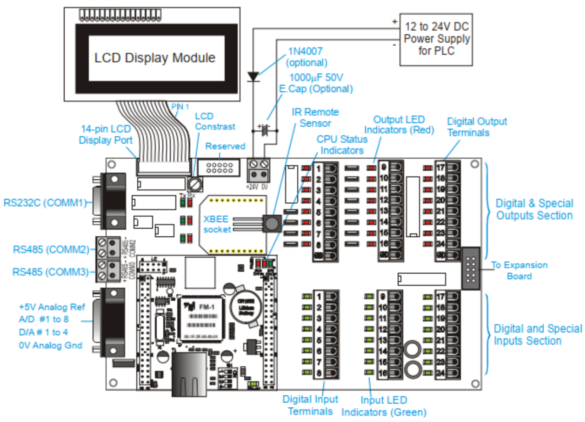

Figure 2. Scheme of PLC FX2424

2.3. RS-232 serial communication mode

Communication mode is an illustration of the communication process that shows the connection between one of communication component with other ones, namely between HMI (Human Machine Interface) and master with slave [10]. The RS-232 serial communication is an asynchronous protocol, which means the clock path is not separate from the data path so that both points must know the communication speed known as the baud rate. RS-232 has 2 data lines, namely Tx (Transmitter) and Rx (Receiver) because the paths are separate, so sending and receiving data can be done simultaneously, making this system full duplex. In addition to the Tx and Rx lines there is also a ground line. [10]

2.4. L-Relay-51 module

The L-Relay-51 module is a module that has 8 DC 12V relays that can be programmed to ON or OFF via a computer device [11]. Figure 3 shows the L-Relay 51 scheme.

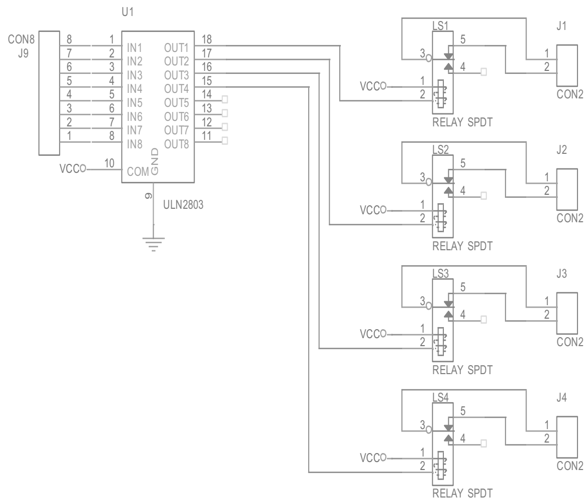

Figure 3. The scheme of L-Relay 51

2.5. LabVIEW

LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is computer software for data processing in the field of data acquisition and is an instrumentation control and industrial automation. LabVIEW itself uses images or graphics as a function of the Graphical Programming Language or Visual Programming Language. LabVIEW uses a programming language that can interpret data with a graphic as a function. LabVIEW is also called Virtual Instrument (VI) because there are several views and operations on LabVIEW programs that resemble instruments such as oscilloscopes and multimeters. Each Virtual Instrument (VI) uses many functions that manipulate input from the user interface or other sources and display information or move that information to other files or computers [12].

2.6. Data acquisition

A data acquisition system or commonly known Data Acquisition System (DAS) is an electronic instrumentation system consisting of a number of elements which together aim to measure, store and process measurement results. The actual watershed is an interface between environments analogous to the digital environment. Analog environments include transducers and signal conditioning with all their features, while digital environments include analog to digital converter (ADC) and then digital processing is carried out by microprocessors or microprocessor-based systems [13].

3. Research methods

3.1. Tools and materials

The tools used are laptops, computer operator LabVIEW software and i-TRiLOGI software and TLserver. Whereas the materials used in this research are Super PLC FX2424, 24V DC power supply, SIK MBE module box, L- Relay 51, and regulated DC power supply.

3.2. Initial data collection

In this initial data collection aims to determine each parameter (input/output) to be controlled. In addition, at this stage it will produce a user requirement document, or it can be said as data relating to the wishes of the user (operator) in designing the system for the operation of the MBE 300 keV / 20 mA. Tables 1 and 2 show system requirements.

Table 1. The need to operate MBE components

Input/*Output*	Pin *input* PLC	Pin *output* PLC
Aktivasi STT SE	Pin 5	-
Up STT	Pin 1	Pin 10
Down STT	Pin 2	Pin 11
Reset STT	Pin 4	Pin 12
Up SE	Pin 6	Pin 13
Down SE	Pin 7	Pin 14
Reset SE	Pin 9	Pin 15
Aktivasi Modul	Pin 11	Pin 9
Reset Mikro	Pin 14	Pin 17
Reset Alarm	Pin 15	Pin 18
Off Modul	Pin 12	Pin 9
Off Up STT	Pin 24	Pin 10
Off Down STT	Pin 25	Pin 11
Off Up SE	Pin 26	Pin 13
Off Down SE	Pin 27	Pin 14
Off Reset STT	Pin 28	Pin 12
Off Reset SE	Pin 29	Pin 15
Off Emergency	Pin 30	Pin 16
Off Mikro	Pin 31	Pin 17
Off Reset Alarm	Pin 32	Pin 18

Table 2. Trip signal requirements

Input/*Output*	unite	Interface	Pin ADC PLC
HV	kV	ADC	PIN 1
STTcurrent	mA	ADC	PIN 3
Coloumn current	mA	ADC	PIN 4
Beam current	mA	ADC	PIN 6
Vaccuum	Torr	ADC	PIN 7
Input voltage from high voltage source	Volt	ADC	PIN 2
Input voltage from electron source	Volt	ADC	PIN 5

3.3. System planning
System design consists of hardware design and software design. In hardware design is done by designing a connection between the input and output of the Pin Super PLC FX2424 which is connected to the computer module SIK MBE hardware module box and also connected to the operator's computer. On the connection between the PLC FX2424 and the operator computer using RS-232 cable serial communication. Figure 4 shows the block diagram.

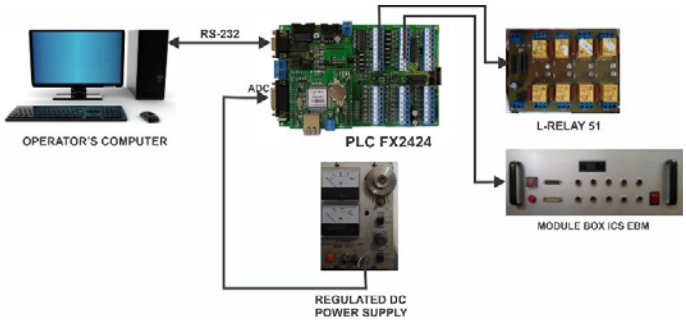

Figure 4. Block diagram

The design of this software consists of programming design on Super PLC FX2424 and programming in Labview for user interfaces and data acquisition of operating parameters.

3.4. Designing an operating program on the PLC
The program aims to make the MBE component operation program and its operating parameters. Figure 5 shows a PLC FX2424 programming flowchart.

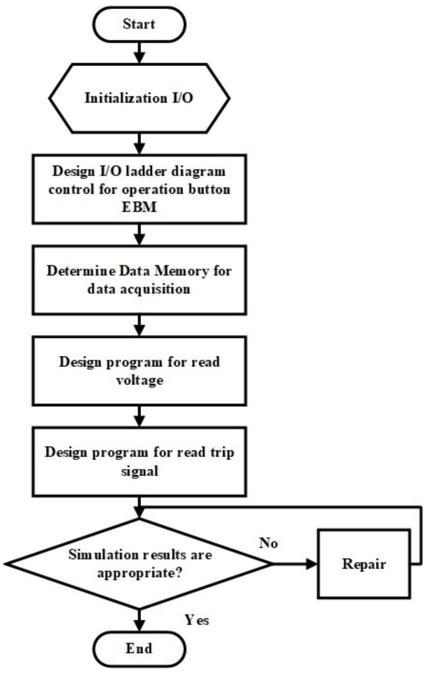

Figure 5. PLC FX2424 programming flowchart

3.5. System creation
Furthermore, the HMI program was created on LabVIEW to operate the MBE component via a computer which included PLC FX2424 I/O controls, MBE operation control buttons, MBE operation data viewer, and field data acquisition. The flowchart can be seen in figure 6.

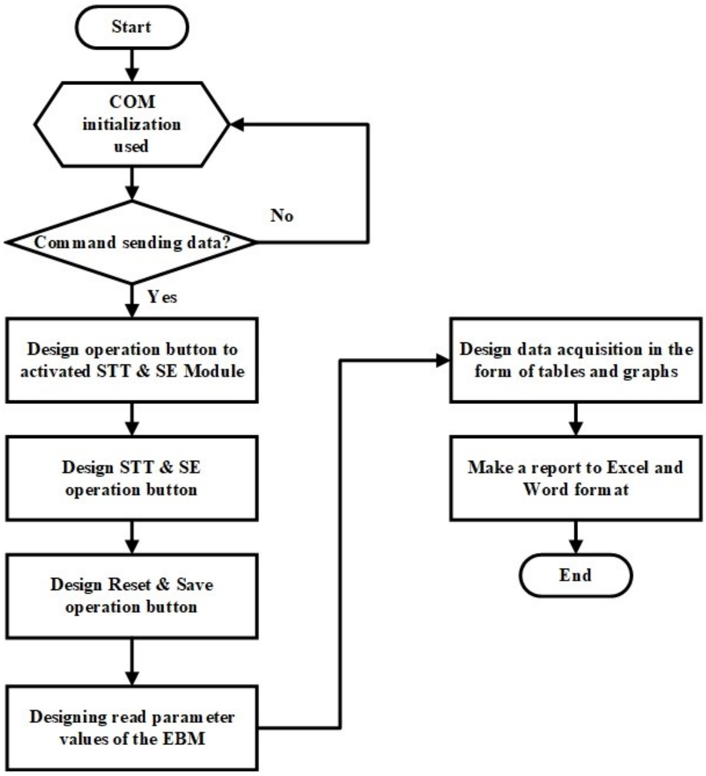

Figure 6. HMI programming flowchart

3.6. System testing
When the program has been completed, the next step is testing the system. System testing consists of several stages, namely are:
1. Testing system components (subsystem), carried out in order to find out that the components have worked correctly, which consists of (1) testing for PLC input output, (2) testing for L-Relay program 51, (3) testing for ADC, (4) testing for communication between PLC FX2424 and SIK MBE 300 keV/20 mA computerized system hardware module box, (5) testing for operation keys, (6) testing for trip digital input output signals, (7) testing for the appearance of operating data in LabVIEW, (8) testing for data acquisition.
2. Overall system testing, means carried out to test the overall system performance whether the operation has been working properly.

4. Results and discussion
4.1. System creation results
The results of the operating system creation and acquisition of MBE 300 keV/20 mA operating data parameters using Super PLC FX2424 in the form of a Human Machine Interface (HMI) MBE operating system produced with LabVIEW software as shown in figure 7.

Figure 7 Display of the 300 keV/20 mA EBM HMI operating system

It can be seen on the display that there are operating buttons and data acquisition for MBE operations. The operation buttons are in the form of module activation, STT & SE activation, STT up, STT down, STT up, SE down, STT reset, SE reset, micro reset, alarm reset, and save. With data acquisition in the form of high voltage, STT power supply input voltage, STT current, column current, SE power supply input voltage, beam current, and vacuum pressure. Then a trip signal for the MBE operation is also displayed.

4.2. System Test Results

4.2.1. Testing Input PLC Output. It can be observed that when the ON button is pressed, then the output will be active, and so on. When the OFF button is pressed then the output will turn off, and so on. Figure 8 shows the results on the PLC.

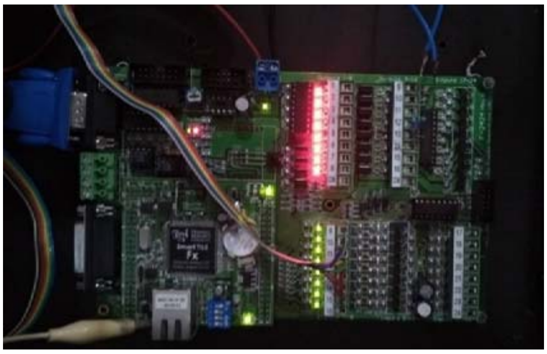
Figure 8. Results of PLC input output

4.2.2. 51 L-Relay Test Results. From the test, it is known that when L-Relay 51 gets active input action which means getting input voltage, the condition of L-Relay 51 which initially in normally open condition changes to normally close, which means L-Relay 51 output is active. And when given the input action that is off in the form of turning off the voltage for L-Relay 51, then the state of the L-Relay 51 which initially closed normally changes to normally open so that the output will turn off.

4.2.3. ADC Test Results. The ADC test aims to determine the characteristics of the ADC from Super PLC FX2424. This test is carried out with input from Regulated DC Power Supply. Figure 9 shows the results of the ADC test.

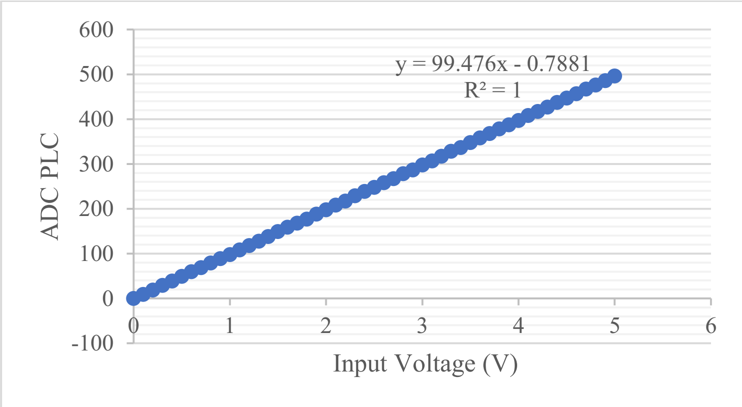

Figure 9 Test results for PLC ADC

Figure 9 shows the relationship between the voltage values of the Regulated DC Power Supply to the PLC ADC is linear, meaning that the higher the input voltage the ADC will produce a high value.

4.2.4. Communication Test Results between Super PLC and LabVIEW software. When the program is started and the COM port is used, then when pressed the ON button in the LabVIEW software the FX2424 Super PLC output is generated to be active. This proves that communication between Super PLC FX2424 and LabVIEW software has been successful.

4.2.5. Results of testing the MBE operating system through LabVIEW software. This test aims to be able to carry out the MBE operation through the Human Machine interface (HMI) that has been created in LabVIEW software. Testing is done by operating the operation button in LabVIEW software and seeing the response on the Super PLC FX2424 and the display results on the LabVIEW HMI itself. Can be seen in table 3.

Table 3. Results of operating the HMI button

HMI operation button	Button operation	PLC Respons	HMI Respons
Modul activation	ON	ON	ON
STT & SE activation	ON	ON	ON
Up STT	ON	ON	ON
Down STT	ON	ON	ON
Up SE	ON	ON	ON
Down SE	ON	ON	ON
Reset STT	ON	ON	ON
Reset SE	ON	ON	ON
Reset Mikro	ON	ON	ON
Reset Alarm	ON	ON	ON
Save	ON	ON	ON

4.2.6. Digital Input Output test results for trip signals. The test results of the Trip Signal between the action on the switch button and the indicator information can be seen in table 4.

Table 4 Test results for trip signals

Switch button	Aksi	Indikator pada HMI
Cooler	ON	ON
Vacuum	ON	ON
Optic	ON	ON
STT	ON	ON
SE	ON	ON
B. Process	ON	ON
Emergency	ON	ON
Panel	ON	ON

Table 4 shows that the trip signal operation has been successfully carried out, with when given the On action giving the On output in the form of an illuminated LED also displayed on the HMI LabVIEW display.

4.2.7. Test Results for Operating Data Acquisition in LabVIEW. This test is done by looking at the response value displayed on the MBE operating system HMI display in LabVIEW software when given input to the Super PLC FX2424 ADC. Test results in figure 10.

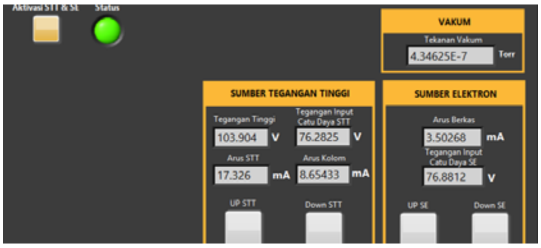

Figure 10 Display of HMI data acquisition

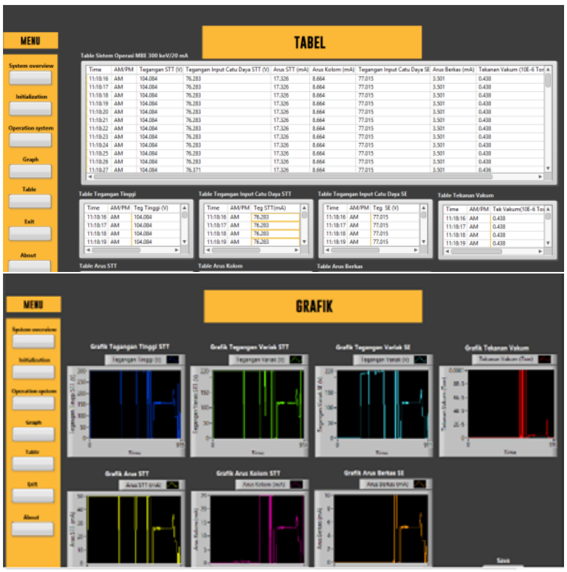

Figure 11. Update data

Based on the test it is known that the relationship between the value of the input voltage to the value of the LabVIEW HMI Display is linear, which is the same as the characteristics of the PLC ADC FX2424.

4.2.8. Update and Save Data Test Results. When sending and reading data, the MBE parameter data will be recorded automatically and real time on the LabVIEW front panel. For table data, it will be recorded on the "Table" tab of the LabVIEW front panel, and for graphical data will be recorded on the "Graph" tab of the LabVIEW front panel. Data recording is carried out every 1 second according to the settings in the program in the LabVIEW block diagram. The results of the data update test can be seen in figure 11.

When the save button is pressed, the parameter data will be displayed on Microsoft Excel for table data and at Microsoft Word for graph data.

5. Conclusion

Based on the results and discussion described earlier, the conclusions that can be taken are as follows:

1. An operating system and acquisition of parameter data of MBE 300 keV / 20 mA operation have been made which functions to operate the MBE components and monitor the parameters of the MBE operation.
2. This system consists of hardware in the form of FX2424 PLC and software in the form of LabVIEW and i-TRiLOGI using RS-232 serial communication with PLC baudrate default of 38400 bps for operator computer communication protocols.
3. The MBE operating system built is able to work in realtime with the operating parameter values updated continuously and with the storage of table data in Microsoft Excel format and graphical data in Microsoft Word format every 1 second.
4. This system has been successfully used to operate MBE components and monitor MBE parameters through computer devices and display them in continuous graphic form.

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