J Fusion Energ (2016) 35:470–481
DOI 10.1007/s10894-015-0054-x

ORIGINAL RESEARCH

LabVIEW-Based Radiation Monitoring System of EAST

Guangzhu Liu[1] · LiQun Hu[1] · GuoQiang Zhong[1] · Kai Li[1] · RuiJie Zhou[1] · Neng Pu[1]

Published online: 12 January 2016

Abstract This paper focus on discussion and design of the LabVIEW-based radiation monitoring system of the Experimental Advanced Superconducting Tokamak (EAST). This monitoring system based on LabVIEW software can get and monitor the environment's real-time nuclear radiation around EAST. EAST is a fully superconducting Tokamak, it has played an important role of nuclear fusion research and plasma physics experiments. During EAST's pulse discharge, there will be some radiation produced in the EAST's hall and environment, so radiation monitoring and control are necessary. Firstly this paper reviews EAST and radiation. Then this paper briefly presents the structure of the monitoring system. Thirdly, the design of the monitoring system based on LabVIEW is presented. The LabVIEW-based radiation monitoring system mainly includes: the definition of serial port, the definition of data request, the definition of data rewrite, the definition of data cutting, the definition of data saving and displaying. This monitoring system can work well.

Keywords EAST · Radiation · Neutrons (n) detector · Gamma rays (γ) detector · LabVIEW · Counting rate · Dose rate

✉ Guangzhu Liu
gzliu@ipp.ac.cn

[1] Institute of Plasma Physics, Chinese Academy of Science, Hefei, Anhui, China

Introduction

To solve the future energy problem, many countries around the world have devoted manpower and wealth to the nuclear fusion research, and Tokamak has been adopted to study the nuclear fusion. The Experimental Advanced Superconducting Tokamak (EAST) which has played an important role on the fusion's research and the study of plasma physics is the first non-round section fully superconducting tokamak in the world [1]. In the past years, the EAST has achieved a long pulse discharge up to 400 s. During the EAST plasma discharge, [1–3] some radioactive particles and rays will be emitted around the environment, such as Neutrons (n), Gamma rays (γ), and others. But Neutrons (n) and Gamma rays (γ) are the main ingredients. Although most of the radiation will be shielded by concrete barrier shield, some radioactive particles and rays will escape from the EAST's hall and may hurt to people who work long time in the EAST's surrounding environment. Therefore, nuclear radiation monitoring and protection are very important for safety, also the measurement values of radiation doses are key control signals to decide whether the gates of the EAST's hall can be safely opened or not after the EAST plasma discharge. To get the radiation doses in real-time, the radiation monitoring system has been successfully constructed [2, 3]. This paper is main on the introduction of the monitoring system based on LabVIEW which is a graphical programming language [4, 5].

The paper is arranged as follows: in part 2, the radiation monitoring system will be briefly introduced. In part 3, LabVIEW-based monitoring software is well studied and designed. In part 4, the whole logic diagram of the designed monitoring system and the whole front panel of the designed monitoring system are presented, also example of the running system and data are presented. At last, the summary of this paper is presented.

Radiation Monitoring System

Brief Introduction of Monitoring System

An excellent radiation monitoring system should include a perfect hardware system and fine software [6]. So, in this EAST radiation monitoring system, hardware and software are designed carefully. To well monitor the environment's real-time nuclear radiation (neutrons and gamma rays) around EAST, Fig. 1 shows the layout of detectors.

In this monitoring system, as shown in Fig. 1, there are thirteen fixed monitoring sites which will provide the monitoring information for other studies and one movable monitoring site which will give real-time monitoring information in the environment around the EAST. At each monitoring site, a Neutron (n) detector and a Gamma ray (γ) detector are set.

Especially, Neutrons (n) detectors and Gamma rays (γ) detectors which are adopted in this monitoring system include two types: Area (N1, G1, N2, G2, N3, G3 and N14, G14, just as shown in Fig. 1) and environment (other detectors). Neutrons (n) detectors of area type are based on ^{3}He, and Neutrons (n) detectors of environment type are based on BF_3. Gamma rays (n) detectors of area type and environment type are based on Ar.

Tables 1 and 2 present the key parameters of neutrons detectors. Tables 3 and Table 4 present the key parameters of gamma rays detectors.

Since the long distance between each detector and the control room (where PC has been set) is different from each other, so in this monitoring system, RS-485 as a differential communication mode is introduced to overcome the disturbance of noise signals [7, 8].

As shown in Fig. 2, the hardware framework of the monitoring system is presented. This monitoring system includes four parts: AC (Alternating Current) supply, 28 Detectors, Transforming and Processing, PC and CP-118EL (CP-118EL is a smart Express PCI multi serial card which has 8 Ports to realize signals' transformation between RS232 and RS485 [9]). AC supply module provides voltage interfaces for detectors and other circuit modules. In this monitoring system, there are 28 detectors (fourteen Neutrons (n) detectors and fourteen Gamma rays (γ) detectors). Each detector works under high voltage will output voltage pulses which are correspond with numbers of Neutrons (n) or Gamma rays (γ) [10].

Transforming and processing module which plays an important role in this monitoring system will get voltage pulses and detectors' parameters from detectors, just as shown in Fig. 3 [11]. Then information will be transmitted

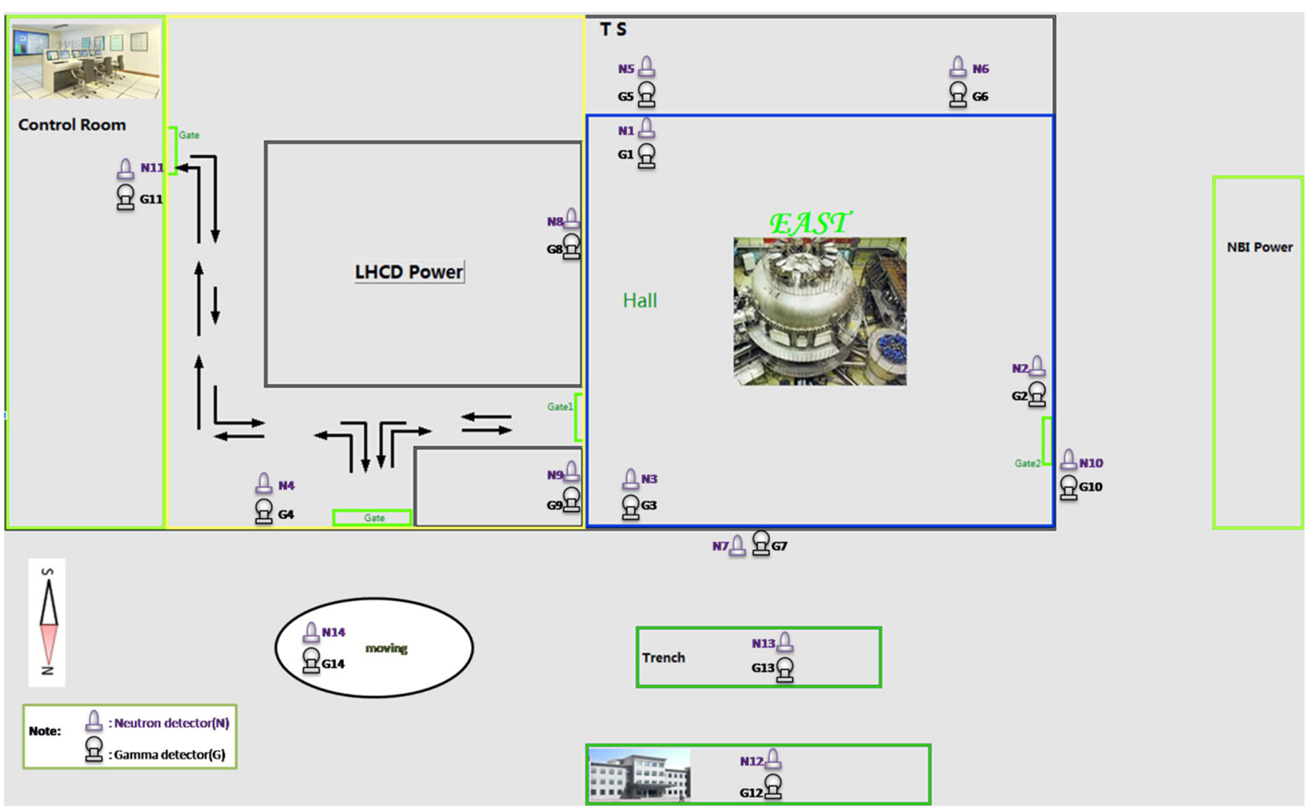


Fig. 1 Layout of detectors

Table 1 Key parameters of area neutrons detectors (^{3}He)

No.	Parameters	Values
1	Sensitivity	≥15 cps/(μSv/h)
2	Measuring range	0.5×10^{-3}–1000 μSv/h
3	Energy response	0.025 eV–16 MeV

Table 2 Key parameters of environment neutrons detectors (BF_3)

No.	Parameters	Values
1	Sensitivity	15 cps/(μSv/h)
2	Measuring range	1.0×10^{-3}–1000 μSv/h
3	Energy response	0.025 eV–16 MeV

Table 3 Key parameters of area Gamma rays detectors (Ar)

No.	Parameters	Values
1	Sensitivity	0.250 nSv/p
2	Measuring range	0.1 μSv/–100,000 μSv/h
3	Energy response	50 keV–3 MeV
4	Ar pressure	2.03 MPa

Table 4 Key parameters of environment Gamma rays detectors (Ar)

No.	Parameters	Values
1	Sensitivity	2.65×10^{-3} A/(μSv/h)
2	Measuring range	10 nSv/h–100 mSv/h
3	Energy response	60 keV–3 MeV
4	Ar pressure	2.5 MPa

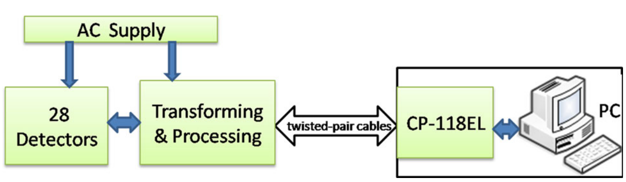


Fig. 2 Framework of the monitoring system

between this module and PC as TTL (Transistor–Transistor Logic) signals in RS-485 [7]. Since PC cannot recognize signals in differential mode (RS-485 mode), so a convertor which can convert signals between RS-485 mode and RS-232 mode has to be adopted, in this system, Moxa's CP-118EL is introduced as a convertor.

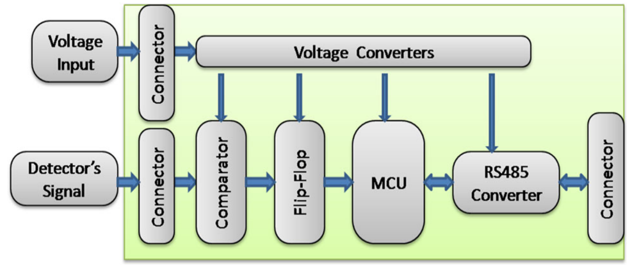


Fig. 3 Framework of transforming and processing module

This paper is focus on the design and introduction of the radiation monitoring system software, so the hardware of the radiation monitoring system will not be thoroughly introduced in the following.

Framework of Radiation Monitoring Software

Without loss of generality, in this radiation monitoring system, the hardware will firstly obtain the radiation information and detectors' parameters, and then a proper subsequent processing software should have to be introduced to process there information and parameters for saving and displaying in PC. Since LabVIEW is graphical programming software which has great differences from other software languages, such as VC, VB [4, 5], so in this monitoring system, LabVIEW is adopted to design the monitoring software.

According to the introduction of the monitoring system's hardware in the preceding section and the requirement of displaying the radiation values in real-time, the software's framework of the monitoring system is carefully designed, just as shown in Fig. 4.

Roughly speaking, the software of this monitoring system includes six function modules which are module of request, module of writing, module of VISA, module of reading, module of display and module of saving.

Module of VISA is an interface module which includes the definitions of communication port, reading port and writing port. By this interface module, the communication between MCU and PC can be carried out accurately.

Module of request is an important part of this monitoring software, because this module will decide the requested information's displaying and saving.

Module of writing is also used as a rewriting module by which some parameters can be written and changed

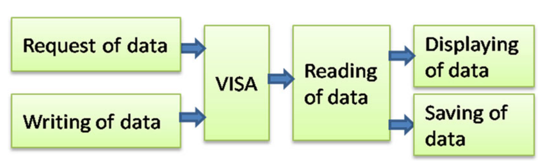


Fig. 4 Framework of the monitoring software

according to the requirement. If the monitoring detectors are adopted the first time, some detectors' parameters have to be written, the module is used as 'module of writing'. However, if the environment's conditions and system's requirements are changed, the module will be used as 'module of rewriting' to change some parameters of the detectors.

Module of reading reads some parameters according to some commands which are decided by module of request and module of writing.

Some parameters (such as neutrons' or gamma rays' counting rates and dose rates) come from module of reading have to be displayed and saved, so modules of displaying and saving are indispensable.

In the following part, these modules will be introduced in detail.

Software Based on LabVIEW

Serial Port Definition

Serial communication is a universal mode in the transmission technology, and this mode should have different baud rate for different data equipments. So, we have to define a proper baud rate in the system's software according to the requirement of the data' s transmission. LabVIEW has a packaged serial port module which is one part of VISA's module, as shown in Fig. 5.

To have a communication between the PC and the detectors, the serial port module is adopted in the monitoring system based on LabVIEW. In this radiation monitoring system, as shown in Fig. 5, the uniform serial port's parameters are defined as shown in Table 5.

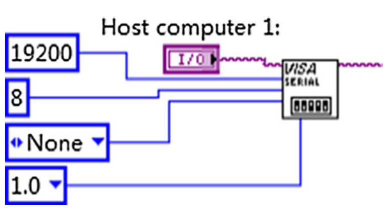


Fig. 5 The definition of serial port

Table 5 The definition of serial port

No.	Name	Code or Function
1	COM port	
2	Baud rate	19200
3	Data bit	8
4	Even–odd check	None
5	Stop bit of the serial port	1.0

This module's function is the definition of serial port's parameters. Firstly, COM (Component Object Mode) port can be selected by the input port (such as, the symbol in Table 5, in the first row of column Code or Function). Then the serial port baud rate can be set by a probable constant.

Serial Port's Protocol

Data Request

Definition of this module is in accordance with the firmware of the transforming and processing module which has been introduced in part 2.2. To illustrate this module, an example of this module's data format is presented, as shown in Table 6.

First of all, in this software protocol, each data request module has a Beginning Character which is defined as ':'. To get one detector's parameters, in the following, one given Device Number which is correspond to one special detector is selected, in this example (as shown in Table 6), '01' is one detector's Device Number. Then, Function Code is set to present what this module's function is. In this example, '41' is a Function Code which says that this module will request information and parameters from the transforming and processing module. And Data Segment follows the Function Code is given. Data Segment contains Data segment identifier, Parameter Code and End of Data which are '#' '80A1' ';' in this example. At last, Longitudinal Redundancy Check (LRC) Code and Terminator Code are essential to this module, and in this example, the two codes are '02' and '<CR><LF>' as shown in Table 6. By the way, all the codes in this software protocol are ASCII. According to this introduction, this data request module's codes can be given as ':0141#80A1;02<CR><LF>'. But, in this module, there may be more than one Parameter Code which will be added in Data Segment, for example, if 80A2 and 80A3 are also needed to be added, the data request module's codes can be given as ':0141#80A1#80A2#80A3;05<CR><LF>'. Especially, Longitudinal

Table 6 Format of data's request

No.	Data name	Code
1	Beginning character	:
2	Device number	01
3	Function code	41
4	Data segment identifier	#
5	Parameter code	80A1
6	End of data	;
7	Longitudinal redundancy check (LRC)	02
8	Terminator code	<CR><LF>

Redundancy Check (LRC) Code has to be calculated by rule of LRC which can be calculated as follows: begin from Device Number end at Device Number, every consecutive 8 bits Byte is added together by the way of addition without carry. Then radix complement of this addition's result is calculated, and LRC is got.

In this radiation monitoring system, data request module designed by LabVIEW just as shown in Fig. 6. Firstly, by Concatenate Strings VI, from Device Number ('01') to End of Data (';'), all the respective ASCII codes are formed as one ASCII string. Then, LRC Code is calculated by the rule of LRC. At last all the ASCII codes formed as string are written to VSIA Writing module of LabVIEW.

Parameters Rewriting

As have been introduced in part 2.2, module of writing is also used as a rewriting module which is very important in this monitoring system. For example, originally, the parameters of some detectors (i.e. Low value alarm threshold of neutron is '20 μSv/h', the second level alarm threshold of neutron is '40 μSv/h') have been written for the EAST fusion plasma discharge modes of high neutron radiation doses since the radiation monitoring system were set up. However, after these discharging modes, to give radiation doses alarm properly and timely, some parameters have to be changed (i.e. Low value alarm threshold of neutron is changed to '5 μSv/h', The second level alarm threshold of neutron is changed to '10 μSv/h'). Here, the module of data rewriting (writing) will complete the changing of parameters. And in this monitoring system, IEEE 754 single precision floating-point standard is adopted to be a data format. For example, the decimal number '10' is expressed as sixteen hexadecimal number is '4120 0000'.

This module of rewriting just as data request has a definite format of data, but has little difference. Especially in this module, Function Code is '43' which represents rewriting (writing) function complies with the firmware of the transforming and processing module. An example of parameters rewriting based on LabVIEW is shown in Fig. 7.

First of all, as shown in Fig. 7, string input modules are adopted. Then all the data codes are formed as a string to get Longitudinal Redundancy Check (LRC) Code and formed a whole ASCII string code which will be written to VSIA Writing module of LabVIEW. By this module, some parameters of detectors and other information can be easily rewritten. One example of rewriting's format is presented in Table 7.

As presented in Table 7, Low value alarm threshold (LVAT) whose parameter code is '10B6' is changed to be '5 μSv/h' (40A00000), Level alarm threshold (LAT) whose parameter code is '10B3' is changed to be '7 μSv/h' (40E00000) and The second level alarm threshold

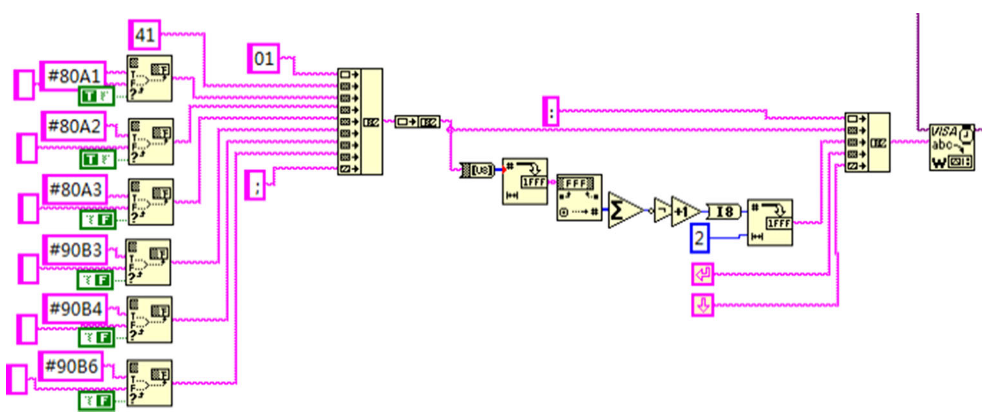


Fig. 6 The definition of data request

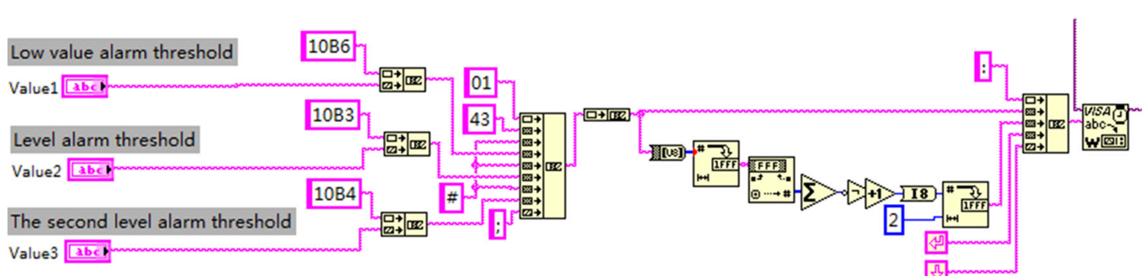


Fig. 7 The definition of parameters rewriting

(TSLAT) whose parameter code is '10B4' is changed to be '10 μSv/h' (41200000). As shown in Fig. 6, the rewriting (or writing) module's codes will be given to detectors are ':0143#10B640A00000#10B340E00000#10B441200000;36 <CR><LF>'. And then by this way, the parameters can be successfully rewriting (writing) for some conditions and requirements.

Data Reading

Data come from the transforming and processing module of this monitoring system has a definite format. This format is in accord with the module of data request and the firmware of the transforming and processing module. Table 8 shows an example of this format.

In this example, just like the protocol of data's request, first of all, this data's output has Beginning Character which is defined as ':'. In the following, Device Number is '01'. Then, Function Code is set to present what this module's function is. In this example, '42' is a Function Code which says that this module will output information and parameters from the transforming and processing module. Data Segment contains Data segment identifier, Parameter Code, Parameter Value and End of Data which are '#' '80A1' '3E063B75' ';'in this example. At last, Longitudinal Redundancy Check (LRC) Code and Terminator Code are essential to this module, and in this example, the two codes are '42' and '<CR><LF>' as shown in Table 8. Especially, the calculation of Longitudinal Redundancy Check (LRC) Code is the same as the rule in the previous introduction. According to this introduction, this data output module's codes can be given as ':0142#80A13E063B75;42<CR><LF>'.

Table 7 Format of data's rewriting

No.	Data name	Code
1	Beginning character	:
2	Device number	01
3	Function code	43
4	Data segment identifier	#
5	Parameter code	10B6
6	Parameter value	40A00000
7	Data segment identifier	#
8	Parameter code	10B3
9	Parameter value	40E00000
10	Data segment identifier	#
11	Parameter code	10B4
12	Parameter value	41200000
13	End of data	;
14	Longitudinal redundancy check (LRC)	36
15	Terminator code	<CR><LF>

Table 8 Format of data's output

No.	Data name	Code
1	Beginning character	:
2	Device number	01
3	Function code	42
4	Data segment identifier	#
5	Parameter code	80A1
6	Parameter value	3E063B75
7	End of data	;
8	Longitudinal redundancy check (LRC)	42
9	Terminator code	<CR><LF>

Cutting and Saving of Parameters

Cutting of Parameters

Detector's parameters and information which are formed in the Transforming and Processing module are only ASCII string codes. If communication is established between PC and the slave monitoring system, by the software's request, parameters and information will be transmitted by serial port. In this radiation monitoring system, VSIA Reading module of LabVIEW is introduced to read parameters and information from serial port, just as an example is shown in Fig. 8.

To clearly get information, these ASCII string codes have to be separately cut. So, in the following of VSIA Reading module, some modules of parse string VI are added, as shown in Fig. 8, by modules of parse string VI, each key parameter can be separated for saving and displaying.

For example, the output codes are ':0142#80A13E063B75; 42<CR><LF>'. To get the parameter value, the beginning code is '3' which has 10 offset in these codes. So in Fig. 8, the starting location of data cutting is 10, and the length is 8. Then the parameter value is '3E063B75'. If there are more than one parameter values has to be cut, more modules of parse string VI should have to be added to get the parameter values.

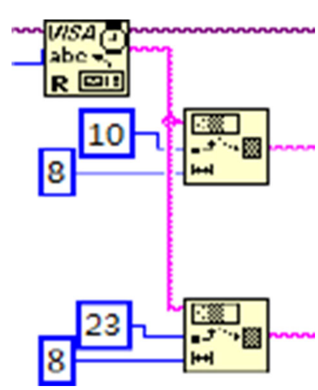


Fig. 8 The definition of data cutting

Saving and Displaying of Parameters

In this radiation monitoring system, some key parameters have to be displayed and saved, such as Neutrons (n) counting rates, Gamma rays (γ) counting rates, radiation dose rates, and so on. So, after some key parameters are separated by modules of parse string VI, data saving based on LabVIEW is introduced to save these parameters, just as shown in Fig. 9. At first, file name is definite by module of Creating Path, as shown in Fig. 9, the file will be saved as '.mysql' format for subsequent database processing. Then, module of Write to Text File VI is added to create file and write data to file and a file handle is created. Especially, in this system, to save files by a proper time interval which will be good for checking data, new-files will be automatically created and saved in a certain time interval which will be decided by the 'Reading Time' module and the constant number (86400) (for example, if the Reading Time is 500 ms, 'i' will increase one in the time interval of 500 ms, then the time interval of creating new files will be 12 h That is, if 'i' increases to the integral multiple of 86400, the remainder of 'i/86400' will be '0' which compares with '0', then logic '1' will be obtained and the condition module will be 'True', new files will be created, as shown in Fig. 9a. If 'i' is note the integral multiple of 86400, the remainder of 'i/86400' will not be '0', the condition module will be 'False', new files will not be created and the parameters will be still saved to the original files by 'Circular Shift Register' module until the condition is 'True', as shown in Fig. 9b).

After file and the handle of file are created, the needed key parameters (which are in string, just like '3E063B75') come from modules of parse string VI will be written in a certain format. But, usually, these parameters will be saved and displayed by the form of floating point number, so module of type casting is introduced, as shown in Fig. 10.

Firstly, the string has been cut by modules of parse string VI is scanned and changed into hexadecimal form. Then a module of type casting is added to complete the type casting by a specified type (Usually, this type is decimal type). By this type casting, ASCII codes will be the wanted floating-points parameters which is displayed by a module of displaying. After that, to save the parameters into a file (.mysql), a module which will convert the decimal type to decimal string is introduced.

Then, By Concatenate Strings VI, the given format data string will be written to the object file which has been created by module of Write to Text File VI, just as shown in Fig. 10. The data format includes device number, parameter's value, parameter's unit, department, group, date and time, and in each line of parameters, between every component of the parameter, a space is set to clearly display the parameter's content. For example, the counting rate of gamma ray comes from G1 (Gamma rays' detector at monitoring site 1, as shown in Fig. 1) is saved as "C-rate2-G1 0.796608 Hz 6 H-6 2014/8/16 16:18:14" in a row. By this way, some parameters can be check conveniently in future.

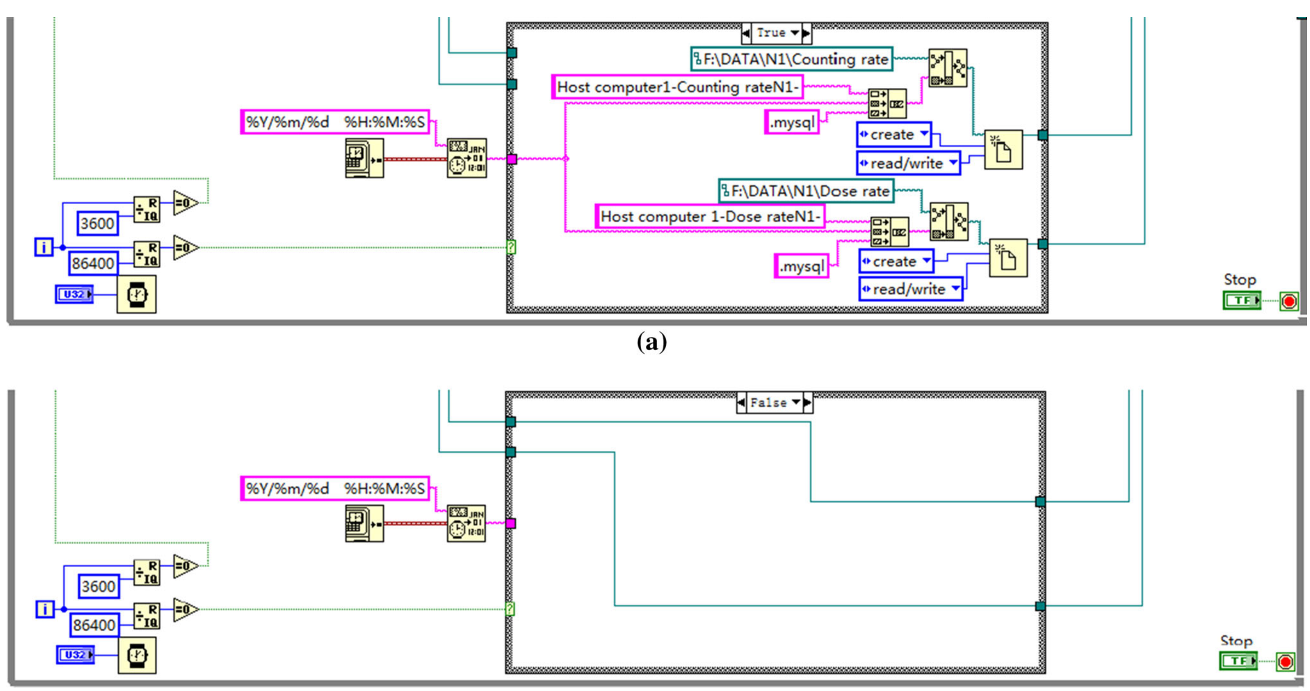


Fig. 9 The definition of file creating

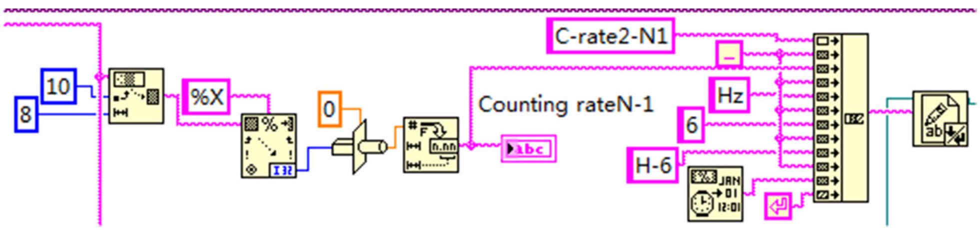


Fig. 10 The definition of type casting

Result of the Designed Monitoring System

The Whole Logic Diagram

Based on the previous introduction of the designed parts of this monitoring system, the basic function and objective of the software system are very clear. So, all these modules designed by LabVIEW produce the monitoring software system, Here, a part of this software is presented (This example is one detector's radiation monitoring software, others' are same as this design.), as shown in Figs. 11 and 12.

In Figs. 11 and 12, firstly, serial port and file name are defined. Then, a module of bytes calculation is added to judge whether string codes are valid or not (A Boole indicator is used to display this result). And a Boole button ('start') decides data request or parameters rewriting. (If 'start' is 'True', data request will be executed, if 'start' is 'False', parameters rewriting will be executed.) At last, data from serial port will be displayed and saved by a proper format which can be set randomly and handily. Especially, as shown in Figs. 11 and 12, every detector's counting rates and dose rates will be saved and displayed in real time. And the accumulated doses of each detector are calculated by a shifting register, then, the accumulated doses will be displayed and saved in a certain time interval.

The Whole Front Panel of the Monitoring System

The front panel of the monitoring system mainly includes two parts: Real-time dose rate and Accumulate Dose, as shown in Figs. 14 and 15.

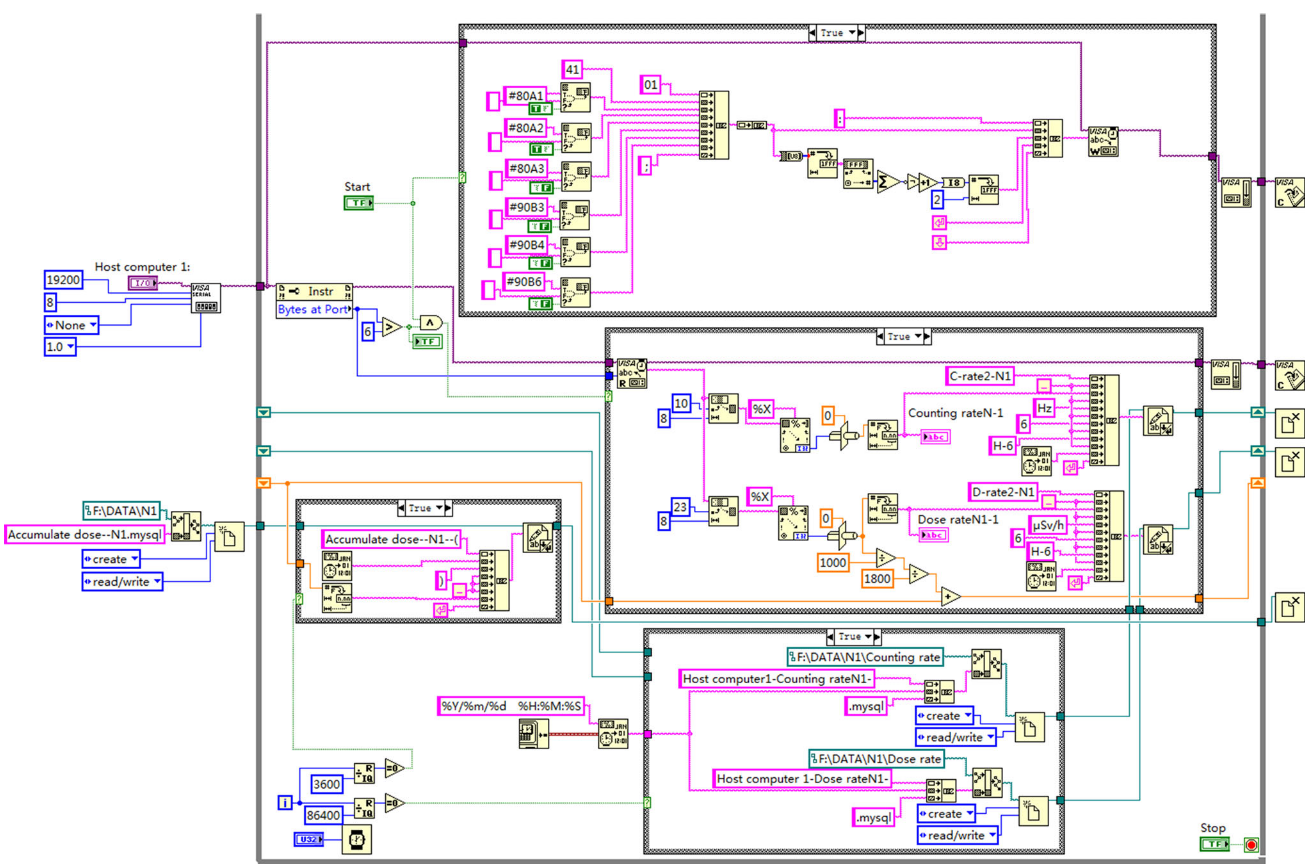


Fig. 11 The definition of data request and saving

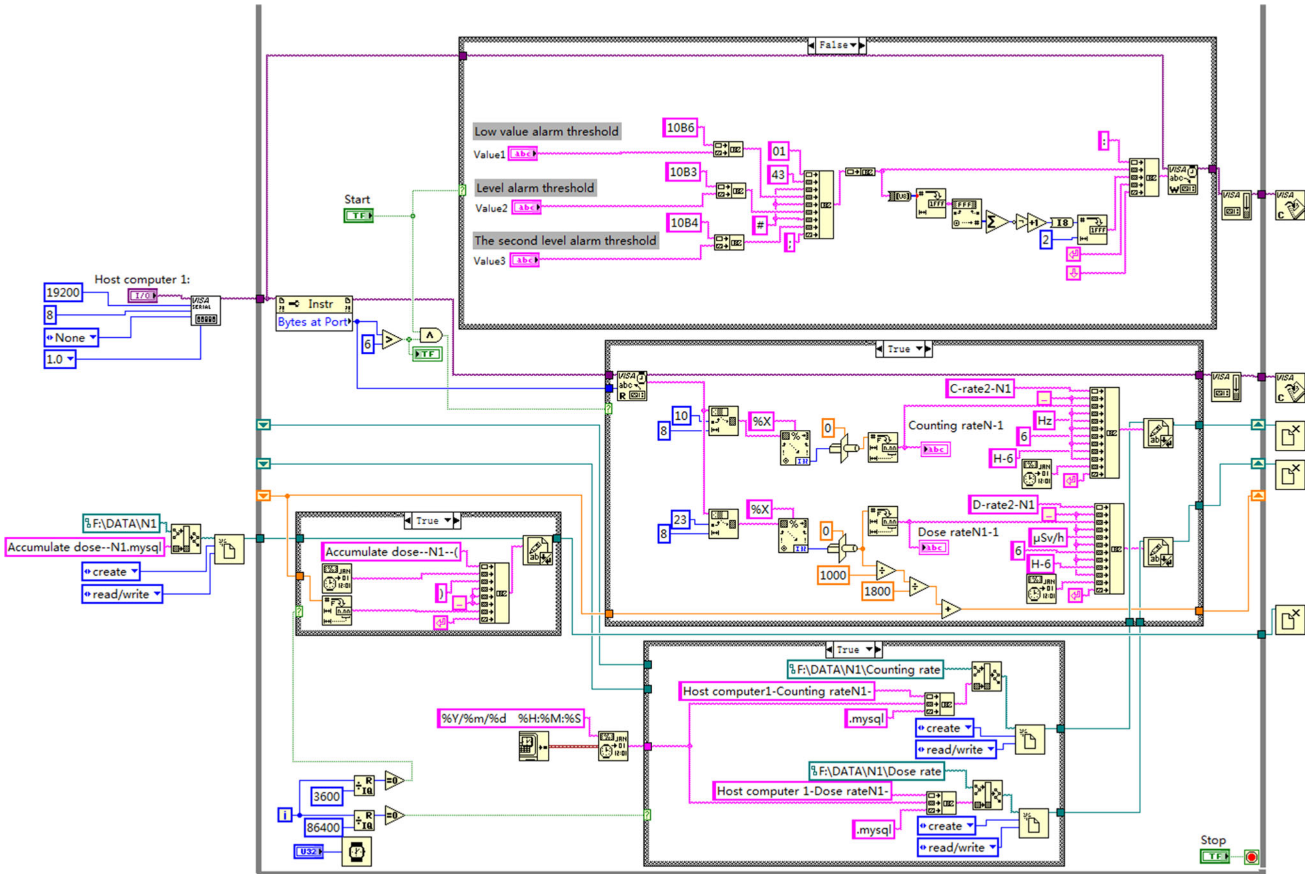


Fig. 12 The definition of parameters rewriting (writing)

The panel of Real-time dose rate is the displaying of the real-time parameters and dose rates around the EAST, also some parameters can be rewritten at any time. In general, the panel of Real-time dose rate mainly includes five parts which are: 'Port', 'Displaying', 'Rewriting', 'Data and time', 'Start and Stop' for twenty-eight detectors (N1–N14, and G1–G14), as shown in Fig. 13.

To each detector, Part of Port has twenty-eight COMs which are produced by four converters (Moxa's CP-118EL), so, each detector will have a serial port corresponds to one of the COMs; Part of Displaying contains four blocks which are 'State', 'Detector's number (D_Number)', 'Counting Rate (C_Rate)' and 'Dose rate', in this part, 'State' will indicate whether the serial port is transmitting data or not by a Bool logic indicator, and 'Detector's number (D_Number)' denotes the detector's name, 'Counting Rate (C_Rate)' and 'Dose rate' will display the real-time counting rate values and does rate values which are detected by detectors around the EAST and environment. Part of Rewriting contains three blocks which are 'LVAT (Low value alarm threshold)', 'LAT (Level alarm threshold)', 'TSLAT (The second level alarm threshold)', in this part, LVAT is used to set the detector's low value alarm threshold, LAT (Level alarm threshold) is used for changing the detector's level alarm threshold at any moment, and TSLAT (The second level alarm threshold) also is used to set the detector's desired second level alarm threshold; Part of Data and Time is the real time data's displaying of the monitoring system; Part of Start and Stop will control the system running or not. Especially the unit of dose rate is 'μSv/h' and the unit counting rate is 'Hz'.

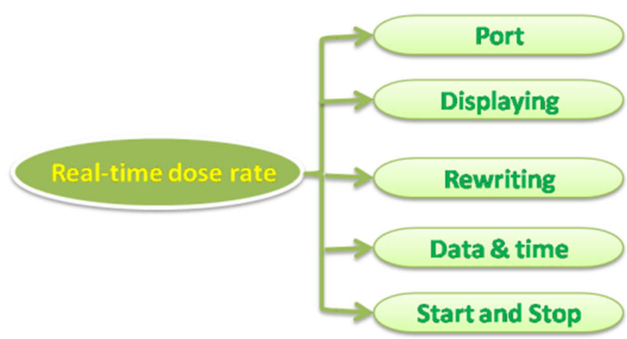


Fig. 13 Framework of the panel of Real-time dose rate

The panel of Accumulate Dose is the displaying of the accumulate doses around the EAST. In Fig. 15, 28 detectors' accumulate doses are visually displayed during the EAST's plasma discharge. As shown in Fig. 15, at each monitoring site which just as presented in Fig. 1, and here, green dot denotes neutron detector and oblique quadrilateral denotes gamma ray detector. Especially the unit of the accumulated dose is 'mSV'.

Examples

Just as shown in Figs. 14 and 15, the LabVIEW-based monitoring system is commendably running. By the real-time display of this front panel, the real-time counting rates, dose rates and accumulated doses can

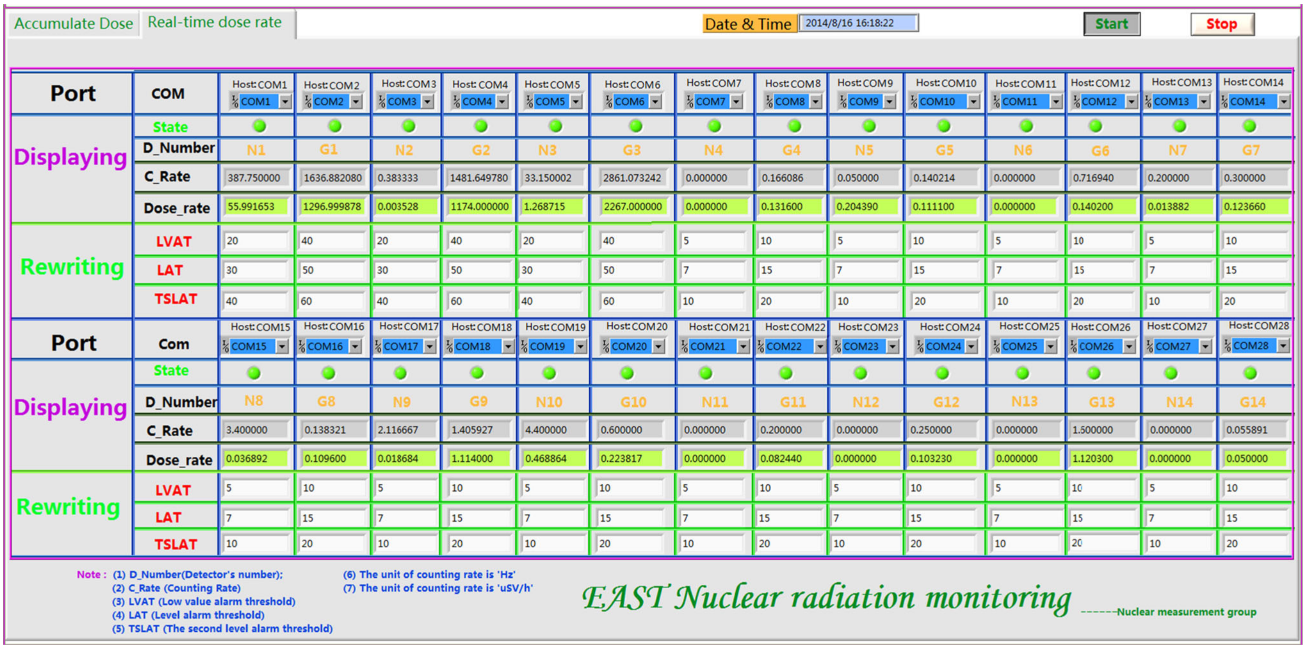


Fig. 14 The panel of Real-time dose rate

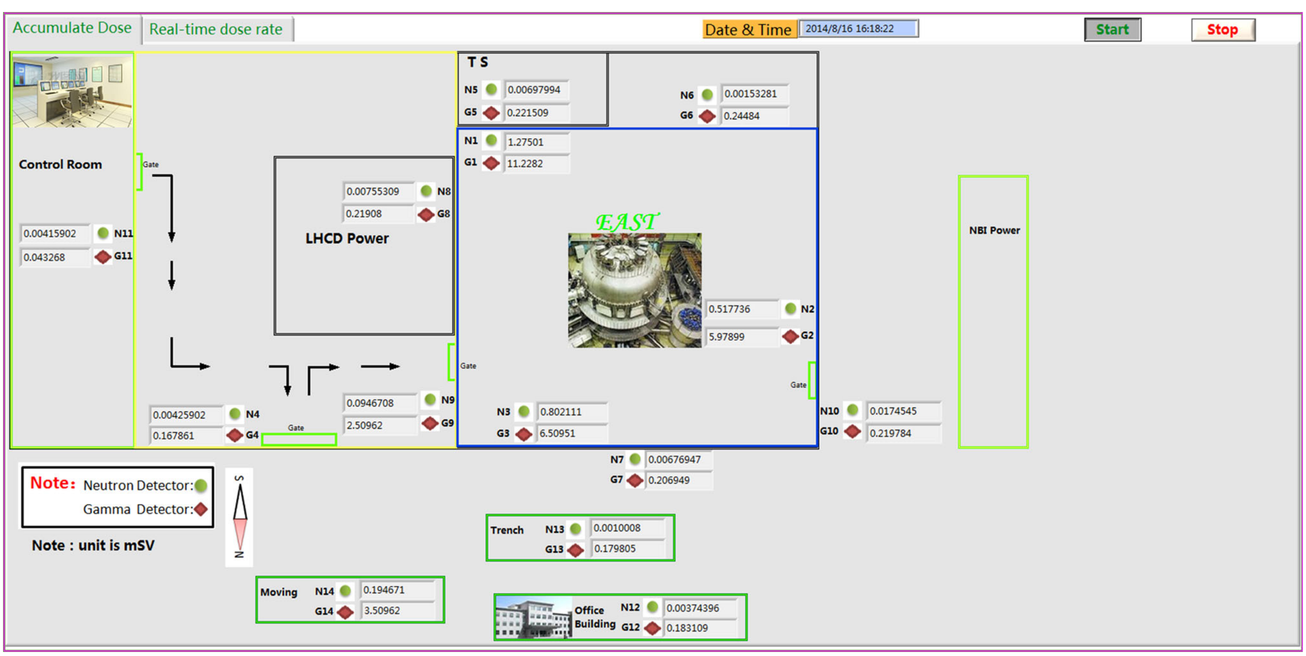
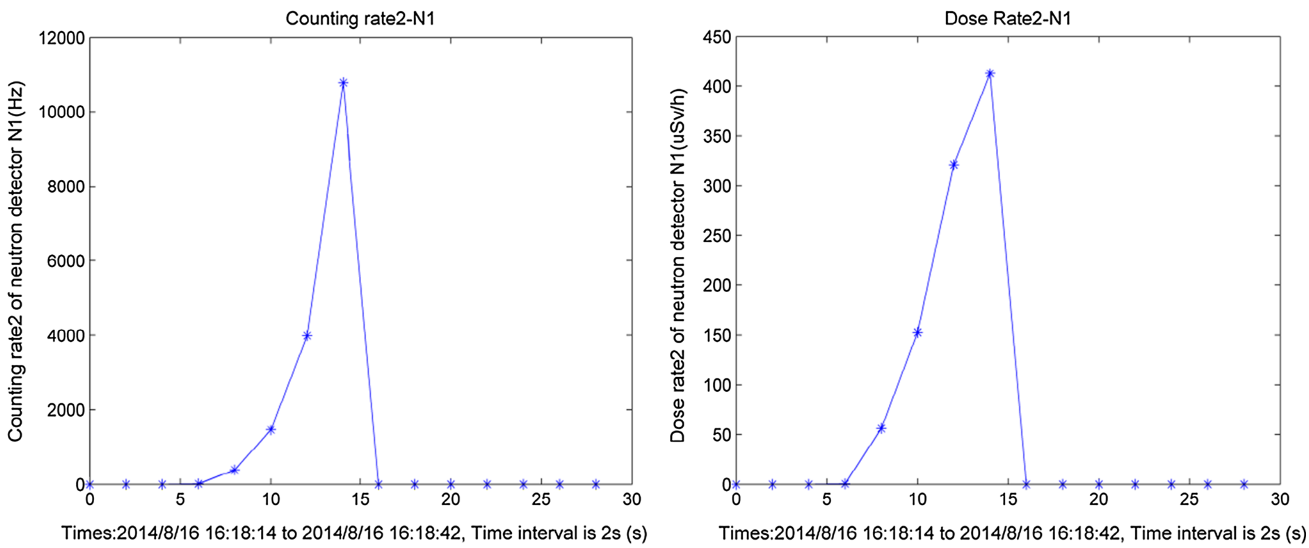


Fig. 15 The panel of accumulate dose

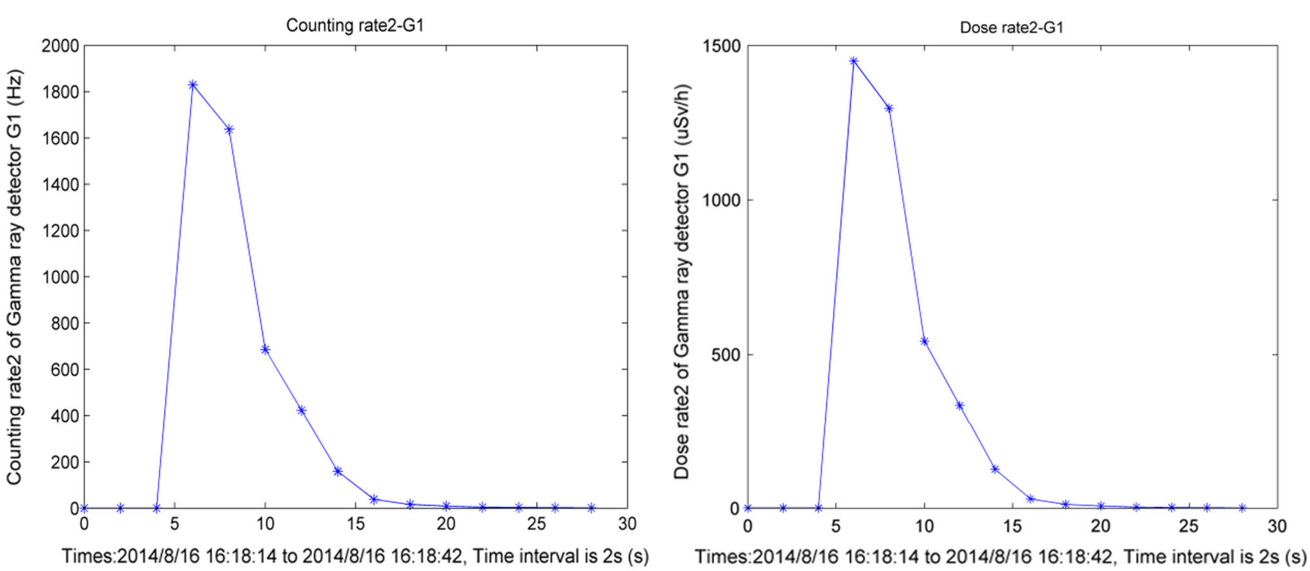
be clearly showed to check and appreciate. Also the state of each detector's communication port can be visually displayed to illustrate the normal or not of the monitoring system communication (BOOL logic indicator denotes normal, denotes abnormal). And the accumulated doses at monitoring sites also can be visually displayed in real-time, just as presented in Fig. 15.

Based on the LabVIEW-based monitoring system has introduced in previous part, the radiation counting rates and radiation dose rates can be easily obtained and saved. Here, the counting rates and dose rates which have been saved by the monitoring system at one monitoring site (Site 1 includes neutron detector N1 and gamma ray detector G1) during one time of EAST plasma discharge are introduced and plotted, just as shown in Figs. 16 and 17.



(a) Counting rates **(b)** Dose rates

Fig. 16 Counting rates and dose rates of detector N1 during one time of EAST plasma discharge. **a** Counting rates. **b** Dose rates



(a) Counting rates **(b)** Dose rates

Fig. 17 Counting rates and dose rates of detector G1 during one time of EAST plasma discharge. **a** Counting rates **b** Dose rates

Conclusion

Radiation monitoring system based on LabVIEW has been designed successfully, and this monitoring has exhibited high virtue on real-time information acquisition and monitoring of radiation.

The whole system's structure which denotes the whole monitoring system's constitution has been designed briefly, and the system software's framework which expresses the LabVIEW-based software's function also has been presented. The system's serial ports based on LabVIEW have been designed and these serial ports' parameters can be expediently changed according to the system's need. The system's protocols were introduced, and examples based on LabVIEW are designed and presented. The cutting and saving of parameters designed by LabVIEW, according to the protocol, parameters are cut separately, and the saving and displaying of parameters are designed. To one parameter, a new file will be automatically created and saved in a definite format and definite interval.

The results of designed the monitoring system based on LabVIEW are given. Firstly, the logic diagrams of the whole monitoring system are introduced. At last, the designed panels of the whole monitoring system and examples of counting rates, dose rates and real-time system front panel are presented. And this monitoring system can work finely.

References

1. X. Jianping, Nuclear radiation monitor based on single-chip microcomputer. Nucl. Electron. Detect. Technol. **19**(1), 63–65 (1999)
2. C. Zhu-xin, W. Yi-can, L. Bo-xue, High reliability radiation protection control system for fusion device EAST. Nucl. Electron. Detect. Technol. **25**(1) (2005)
3. C. Zhu-xin, W. Yi-can, H. Qun-ying, A radiation on monitoring system for nuclear fusion devices, Chin. J. Nucl. Sci. Eng. **25**(4) (2005)
4. National Instruments, "LabVIEW User Manual", National Instruments, 4/2003 Edition Part Number 320999E-01
5. Š. Koprda, M. Turčáni, Z. Balogh. Modelling, simulation and monitoring the use of LabVIEW. 978-1-4673-1740-5/12/2012 IEEE
6. T. Kozak, D. Makowski, A. Napieralski, FMC-based neutron and gamma radiation monitoring module for xTCA applications. in *MIXDES 2012, 19th International Conference "Mixed Design of Integrated Circuits and Systems"* (Warsaw, Poland, 2012), pp. 152–155
7. M.R. Jathar, RS-485 based multi axis motor controller. in *International Conference on Electronics Computer Technology*, vol 2 (IEEE, 2011) pp. 104–106
8. E. Talnishnikh, L. Paganini, J. Stegenga, H. Limburg, H. Wortche, Self-sustained operation of radiation detectors based on embedded signal processing. IEEE **2013** 1–6 (2013)
9. http://www.szpk.cn/MOXA/CP-118EL.htm (2014)
10. K. Arshak, D. Buckley, O. Korostynska, Development of a portable gamma radiation monitoring system. in *Proceedings of the 25th International Conference on Microelectronics (MIEL 2006)* (Belgrade, Serbia and Montenegro, 2006), pp. 248–251
11. G.Z. Liu, L.Q. Hu, G.Q. Zhong, J.P. Long, N. Pu, Monitoring System of EAST's Nuclear Radiation. J Fusion Energ **33**, 503–509 (2014). doi:10.1007/s10894-014-9702-9