Special software design for data acquisition and experimental database management of electromagnetic launch system

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Abstract. Electromagnetic launching system is composed of the Electromagnetic Railgun (EMRG) and the large-scale Pulse Power System (PPS). According to the different test requirements of PPS and EMRG, the special master-slave distributed data acquisition software for electromagnetic launching system is designed by using LabVIEW graphic language. The test host and the sub-machines are multi-channel transient data acquisition systems based on PXI bus. The host PXI is used to measure the comprehensive parameters of the EMRG in multi-physical field. All sub-PXIs are used to diagnose the discharge current signals of each Pulse Forming Unit (PFU). The database management software uses C# programming language to design a friendly human-computer interaction interface, and uses SQL Server software to establish and manage the database, which realizes the comprehensive management of experimental data, tasks and resources involved in the EMRG experiments. The experimental information and experimental data are classified and filed, and the experimental data can be queried, and the experimental results can be analyzed and compared. The data acquisition and experimental database management software has perfect functions, friendly user interface, convenient operation, good versatility, and can also be used in other experimental occasions.

1. Introduction

The electromagnetic launch system of Science and Technology on Transient Physics Laboratory of NJUST is composed of the large-scale high-power Pulse Power System (PPS) and the Electromagnetic Railgun (EMRG). The PPS and the EMRG have different testing requirements for data acquisition (DAQ) system [1-2]. The PPS must measure the discharge current of each Pulse Forming Unit (PFU), the charge and discharge voltage of the Pulse Power System Rack (PPSR), and the discharge current of the PPSR combiner. The PFU discharge current is used to diagnose the working state of the PFU, the PPSR charging voltage is used to monitor the whole charging process in real time, and the PPSR combiner discharge current represents the current output performance of the PPSR. The EMRG should measure many kinds of physical parameters reflecting its launching performance, such as muzzle voltage, breech voltage, input current, magnetic field at each position of the barrel, muzzle velocity and so on. Therefore, we choose PXI bus DAQ system to design and build a special master-slave distributed DAQ system for EMRG, and use LabVIEW graphics language to design the special acquisition software.

In the EMRG experiment, the experimental data and experimental information are massive and complex. In order to effectively manage experimental data and improve the efficiency of experimental
information management, a special Experimental Data Management Platform (EDMP) is designed and developed. The main functions of the EDMP are as follows: 1) manage the EMRG's experimental data, such as: query, modify and delete experimental data; 2) classify, count and manage the experimental documents, experimental equipment, researchers and experimenters information; 3) establish PPS fault data base, classify and analyze all PPS faults, and provide reference data for PPS online diagnosis system.

2. Design of master-slave distributed DAQ system
The composition diagram of the PPS system and EMRG diagnosis system is shown in figure 1, including the following main sensors and instrument equipment: Rogowski coil, B-probe, high-voltage probe, optical fiber isolator and PXI data acquisition system.

![Composition diagram of the PPS and EMRG diagnosis system](image)

**Figure 1.** Composition diagram of the PPS and EMRG diagnosis system.

The DAQ system adopts PXI bus structure and master-slave distributed architecture design, which is composed of 1 test host and 6 test sub-machines. The test host measures the performance parameters of the EMRG, such as input current, muzzle and breech voltage, magnetic field at B-dot probe, muzzle
velocity, and the PPSR discharge current and charge discharge voltage signal of the PPSR. Six test sub-machines measure the discharge current of each PFU of the PPS. Optical fiber network is used for communication between test host and test sub-machines. The test host accesses and controls the operation of 6 sub-machines through remote desktop, as shown in figure 2. Based on the graphic programming platform of LabVIEW [3-5], a special data acquisition and processing test software is designed and developed, which includes the host test software, the sub-machine test software and the data processing software.

2.1. Software design of the test host
The test host measures the comprehensive parameters related to the EMRG, and its software interface is mainly composed of three parts: "Setting page tab", "Page parameter setting" and "Acquisition and status display area", as shown in figure 3(a) red rectangular box. The five page tabs of "Channel setting", "Acquisition setting", "Current and voltage acquisition", "B-dot probe acquisition" and "Velocity measurement acquisition" are used to set various parameters. Click different page tabs, and the content of page parameter setting will change accordingly. From left to right, the "Acquisition and status display" area includes "6133 status" indicator box, "5105 status" indicator box, "Acquisition" button and "Exit" button. Below it is the information display of the test process, as shown in figure 3(d). The function of "Channel setting" page shown in figure 3(a) is to set parameters of 6133 and 5105 data acquisition cards, including setting test channel, channel range, sampling rate, sampling record length, etc. The "Acquisition setting" page in figure 3(b) includes selecting triggering mode, setting triggering channel, selecting triggering edge, saving file path, etc. The "Current and voltage acquisition" page in figure 3(c) is used to input the sensitivity coefficient and other parameters of each channel's respective sensor. The functions of the "B-dot probe acquisition" and "Velocity measurement acquisition" pages are similar to this page. The main working process of "Acquisition and status display area" in figure 3 (d) is: (1) After checking that all parameters are set correctly, the user clicks the "Acquisition" button; (2) DAQ system enters the acquisition waiting for trigger signal state; (3) DAQ system collects data after receiving trigger signal; (4) After acquisition, DAQ system pops up "Data acquisition completed, do you want to save?" Dialog box prompts to save the experiment data.

![Diagram](image)
2.2. Software design of the test sub-machine

The test sub-machine is used to measure the discharge current signal of each PFU of the PPS rack. The design structure of the software interface is similar to that of the test host, and it also includes three parts: "Setting page tab", "Page parameter setting" and "Acquisition and status display area", as shown in figure 4(a) red rectangular box. The test sub-machine is only equipped with PXI-6133 acquisition card, so the "Setup page tab" only has three pages of "Channel setup", "Acquisition setup" and "PXI-6133 acquisition", as shown in figure 4(a), (b) and (c). The content of setting parameters of these three pages is similar to that of test host software. The analysis of the discharge current waveform of each PFU can quickly locate the faulty PFU, and preliminarily diagnose which power component is faulty according to the measured waveform characteristics.

2.3. Data processing software design

As shown in figure 5, the data processing software is mainly composed of six functional areas: (1) data file search, display and loading area; (2) loading data information display area; (3) processing command area; (4) curve editing area; (5) loading curve list area; (6) curve display area.

(1) Data file search, display and loading area: the data file is input and displayed in the data file list, and the selected data file is loaded into the data processing software for viewing, analysis, processing,
modification, export and other operations.

(2) Loading data information display area: Click to view the data information through the drop-down list of test result information, and the selected information will be displayed in the two property page box lists of "Test information display" and "Test result display". The "Test information display" page displays the DAQ system related setting information about this experiment, and the "Test result display" shows the test results of the data collected in this experiment.

(3) The processing command area consists of eight function keys: "Save modified test results", "Export data curve (CSV format)", "Export test results (Excel file)", "Reset magnification", "Reset discharge timing", "Recalculate test results", "Save modified test results", "Exit". The exported " . csv" files and ". xlsx" files can be processed with third-party software such as Origin and Excel.

(4) The curve editing area includes two functions: "Curve denoising" and "Cursor display list". When the "Curve denoising" option is selected, the corresponding denoising curve will be displayed in the curve display area according to the adjusted denoising "Coefficient" value. In the "Cursor display area", the values (x, y) and differences (Δx, Δy) of the two cursors in the curve display area are displayed. The user can also double-click the list to modify the values of the cursors.

(5) The curve list area lists all the loaded data curves, and multiple curves can be selected for display. The color of the "Status" column in the curve list is the color of its curve display.

(6) The curve display area is used to display the selected data curves.

3. Design of the EMRG experimental database management platform
In the EMRG experiment, there are massive experimental data that need to be analyzed, processed and archived, and a variety of experimental information and resources need to be optimized and integrated. According to the requirement of efficient management of EMRG experiment, the special EDMP for EMRG is designed and developed based on the object-oriented programming idea. It is mainly used to manage all data and information related to EMRG experiments, such as all experimental data (including video, image, etc.), all PFUs parameter information of PPS, experimental project information, researchers and experimenters, equipment information, etc. In particular, the detailed recording of the failure information of the PFU, instrument and equipment in the process of experiment, including failure phenomenon, failure reason and solution, is helpful for the rational
allocation of PPS, instrument and equipment and other experimental resources, and prolonging their service life; it is also convenient for later equipment maintenance and experimental data query, analysis and summary, and provides data support for experimental scheme decision.
The EDMP is designed with three-tier C/S architecture. Based on Microsoft .Net framework, the human-computer interface is designed with C# programming language [6-7] on the visual studio development platform. SQL Server [8-10] builds a back-end database to store all experimental information. According to the requirements of EMRG experimental information management, four main function management areas are designed: "PPS management", "Experimental project management", "Experimental resource management" and "System security management", as the main menu of the operation interface, as shown in figure 6 (a) and (b).

3.1. PPS management
PPS is composed of hundreds of PFUs in parallel. Although the scale is huge, the composition of each PFU is basically consistent with the topology circuit, with the characteristics of modularization and integration. The matrix arrangement with PPSR as row and PFU as column is adopted, and each PPSR has 20 PFUs. PPS management mainly includes PFU management and PPS fault management.

3.1.1. PFU management. PFU management is to manage all parameter information of 20 PFUs in each PPSR. As shown in figure 7, click "PPS management" in the main interface to display the pull-down menu options of each PPSR. For example, after selecting PPSR9, the submenu "PFU parameters of PPSR9" will pop up. This submenu is to manage the basic information of each PFU in the selected PPSR, including PFU identification number, Capacitor nominal value, Inductor nominal value, Resistance value, Thyristor parameter, Diode parameter, Current transformer parameter, etc. Enter the PFU number in the "PFU query" function area, and click the "Query" button to quickly obtain all parameter information of the PFU. Click the "Export data to excel" button to export all parameters of the selected PFU to the excel table.

![Figure 7. PPS management menu and PFU parameter submenu of PPSR.](image)

3.1.2. PPS fault management. PPS fault can be divided into four types: trigger control fault, power component fault, test system fault and charging system fault. The design of fault information table mainly includes fault type, fault number, fault name, fault components, fault location, fault phenomenon, fault reason, troubleshooting method, fault time, etc. The operation of PPS fault management mainly includes query, addition, modification and deletion of fault information, as shown in figure 8 (a) is the operation of selecting "Fault type" in the "Fault information query" function area, and figure 8 (b) is the "add fault information" dialog box.
3.2. Experimental project management

Experimental project management is to manage and archive all project information, experimental data and experimental documents related to the EMRG experiment, which is convenient for future reference and invocation. It consists of three submenus: project information management, experimental data management and experimental document management. When the experiment data
is input, the experiment number and the experiment date are synchronously updated to the project information table through the stored procedure. Similarly, when the modification and deletion operations are carried out, they are also updated in real time. At the same time, the relevant documents such as the experimental task book and the experimental outline should also be entered into the management platform.

3.2.1. Project information management. Click the "Add experiment task book" and "Add experiment outline" buttons in figure 9 to enter the relevant information of the experiment project. Only the correctly formatted documents can be successfully entered into the system. In the "Experiment document query" area, enter the experiment date, and click the "Query" button to obtain all the experiment documents under the experiment date.

3.2.2. Experimental data management. As an important part of experimental project management, experimental data management records all experimental data of the EMRG experiment. The experiment number is the only identification of the experiment information. The contents recorded in the experiment data information table also include the experiment name, charging voltage, PFUs participating in the experiment, timing setting, PFU discharge state, experiment unit, experiment date, working mode (EMRG or simulated load device), experimental results and other important information. As shown in figure 10, the "Query" button, the "add experimental data" button, the "Modify experimental data" button and the "Delete experimental data" button are designed to manage the experimental data.

3.2.3. Experimental document management. The experimental document management arranges and archives all the experimental reports, experimental records, experimental logs and other document related to the EMRG experiment, and stores them in the designated location.
3.3. Experimental resource management

Compared with the traditional gun, the EMRG experiment has many links and complex experimental process. Reasonable arrangement of test equipment and deployment of experimental personnel is helpful to improve the experimental efficiency. Experimental resource management consists of Researchers and experimenters management, experimental equipment management and experimental knowledge library.

3.3.1. Researchers and experimenters management. According to the requirements of the EMRG experiment, PPS group, control group, test group, EMRG assembly group, coordination support group and security group are respectively set up, and the leader of each group is responsible for the task arrangement of this experiment. The experiment number is also used as the unique identification, and the information of all the researchers and experimenters is recorded in detail in each experiment. As shown in figure 11, the "Query" button and "Edit the information of the Researchers and experimenters" button are designed in the Researchers and experimenters management submenu. Enter the correct format of the experiment date in the "Please input the experiment date" query box and click the "Query" button to quickly obtain the required information. Select the experiment number and click the "Edit Researchers and experimenter information" button to open the corresponding dialog box to modify the personnel information.

3.3.2. Experimental equipment management. There are many experimental equipment used in the EMRG experiment, such as Rogowski current transformer, high-voltage probe, digital optical fiber isolator, data acquisition system and other instruments used in PPS detection, and velocity measuring target, high-speed camera and other equipment used in muzzle velocity measurement. Experimental equipment management is the information statistics and use management of all equipment used in the EMRG experiment, mainly including equipment name, model, purpose, equipment working condition and other information. Equipment information is edited and managed by clicking "Add equipment
information" button, "Modify equipment information" button or "Delete equipment information" button. As shown in figure 12, click "Add equipment information" button to open the "Add equipment information" dialog box. Input the equipment name in the "Please input the equipment name" Query box to quickly query the specific functions, operating conditions and other information of the equipment in the experiment. The management of experimental equipment is convenient for users to know and master the performance of experimental equipment in time, to configure experimental equipment reasonably, and to ensure the smooth implementation of the EMRG experiment.

**Figure 11.** Researchers and experimenters management windows.

**Figure 12.** Add experimental device information dialog box.
3.3.3. Experimental knowledge library. The EMRG experiment involves many subjects, such as acoustics, optics, thermodynamics, mechanics, and electromagnetics and so on. Mastering the relevant knowledge of the EMRG experiment is helpful to fully understand the experiment and participate in the experiment. The experimental knowledge base is to classify and archive the EMRG related documents, and store them in the designated location of the computer. Users only need to click the entry of the directory list to link to the relevant path and read the relevant literature.

3.4. System information management
In order to ensure the information and data security of the EMRG experiment, the functions of "User access rights management" and "Backup and recovery of database files" are used to improve the security of the management platform.

3.4.1. User information management. According to the responsibilities of the experiment task, administrator level and ordinary user level permissions are set. Only users with permissions can log in to the EDMP. In the EDMP, the administrator has all the operation permissions, while ordinary users can only query and enter information, without modifying and deleting information permissions. User information management includes user name, login password, user type, gender, age, contact number, email address and other information. As shown in figure 13, enter the user to be queried in the "User name" query box in the lower left corner, click the "Query" button to quickly query the target user information; click "Add user information" to open the new user information entry dialog box; select a user name to modify or delete the user information.

![Figure 13. User information management.](image)

3.4.2. User login management. The management platform uses "System login" to restrict access to the management platform only for users with permission. The user login window is as shown in figure 14. After entering the username and user password, click the "Login" button, and the management platform immediately addresses the contents of the user information table in the database to check one by one. If the user name and password are not completely entered or the information does not match, the management platform will report an error and prompt for re-entry; otherwise, if the user's identity
information is verified to be consistent, the user can enter the EDMP window. The user log records the user's historical login information, which is convenient for the system administrator to understand the use of the EDMP. This table records the user name, user type, login time and exit time. When the user logs in, the current user information is displayed at the bottom of the EDMP window, as shown in figure 6(b) above.

Figure 14. User login management.

3.4.3. Data backup and recovery. The backup and recovery of database files is an important guarantee to ensure data security. Figure 15 shows the designed "Data backup and recovery" dialog box. The "Backup" tab is used to back up the database files to the specified path of the computer. In case of system failure, the "Recovery" tab can quickly recover the database to ensure the safety of experimental data.

Figure 15. Data backup and recovery dialog box.
4. Conclusion
The experimental application shows that the EMRG special DAQ software and EDMP software have perfect functions, friendly user interface, good stability and security, which meet the requirements of data acquisition, data analysis and data management of the EMRG experiment, and significantly improve the efficiency of EMRG experiment information management.

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