

RELATIONAL DATABASE DESIGN FOR THE TEST OF THE KSTAR SUPERCONDUCTING MAGNET SYSTEM

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Abstract

The Korea Superconducting Tokamak Advanced Research (KSTAR) superconducting magnet system consists of 16 TF (Toroidal Field) and 14 PF (Poloidal Field) coils. Both of TF and PF coils use internally-cooled conductors. In order to validate the design of the KSTAR TF coil, a full-scale prototype TF coil, TF00, is developed. For the test of TF00, a large scale superconducting magnet and conductor test facility, SSTF (Samsung Superconductor Test Facility), has been constructed. The data acquisition and control system for SSTF is based on Linux system and Experimental Physics and Industrial Control System (EPICS) is used for the acquisition and distribution of experimental data. A relational database management system is used for the configuration of the EPICS record data. Calculation routines, which convert a measured voltage to a physical value, are added to the EPICS IOC (Input-Output Controller) application, which is ported to an i386 PC with the Real-Time Executive for Multiprocessor Systems (RTEMS).

INTRODUCTION

The KSTAR device is a tokamak with a fully superconducting magnet system, which enables an advanced quasi-steady-state operation. The major radius of the tokamak is 1.8 m and the minor radius is 0.5 m with the elongation of 2. The superconducting magnet system consists of 16 TF coils and 14 PF coils. Both of the TF and PF coil system uses internally cooled superconductors [1][2][3].

In order to confirm the TF coil performance, TF00 is fabricated. The major objective of the TF00 test is to validate the engineering issues in the coil design and to measure performance. SSTF is constructed in order to test superconducting strands, conductors, and magnets. It consists of a vacuum cryostat system, a cryogenic cooling system, a background magnetic field generation system, a power supply system and a data acquisition and control system. Large Vacuum Cryostat (LVC) with the diameter of 6 m and the height of 7.9 m is located in a pit of 9 m x 9 m x 6 m. It is connected to cold boxes, such as Helium flow control box, and current lead box. The cryogenic cooling system has two 200-watt Helium refrigerators and one 1000-watt Helium refrigerator. The power supply system consists of a 40 kA-25V DC power supply, a 20 kA-1000V bipolar power supply, a 10 kA-300V Bipolar power supply, a 50 kA superconducting transformer type power supply and others.

Main purposes of using EPICS are to provide an unified interface to data acquisition and control, and to provide an operator interface to all control system

parameters. In order to provide the unified interface, EPICS requires the configuration data for the DAC (Data Acquisition and Control) system, which is stored in the EPICS database. A set of field values for a single test parameter is described in a record and a set of records forms the EPICS database. The EPICS database is generated using RDB (Relational Database) and loaded into IOC. Records defined in EPICS database are accessed by EPICS client software using logical field names[4][5].

In this work, the structure of DAC system for the TF00 test is described and the use of RDB in the EPICS database generation, the monitoring system, and the database system for measured data. An IOC application for data conversion is also described.

TF00 TEST DATA ACQUISITION SYSTEM OVERVIEW

The schematic of the DAC system is shown in Fig. 1. EPICS is adopted as the basic communication software of the DAC system, which is based on Linux and UNIX system. Both of VxWorks and RTEMS is used for the real-time operating system. A voltage signal from sensor is collected by VME system and the raw signal is converted to a physical value by the RTEMS workstation in real-time. Data from independent devices such as Helium liquefier, RGA (Residual Gas Analyser), and stain gauge controller are also collected by the RTEMS workstation using EPICS CA (Channel Access) Routine.

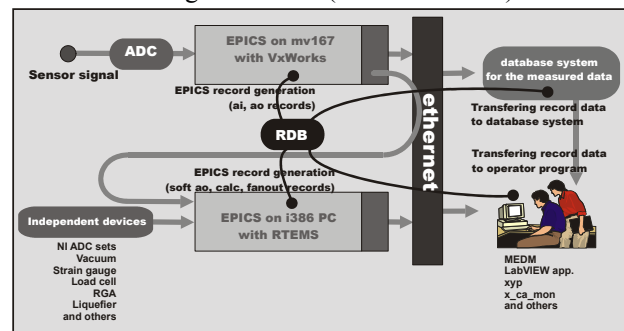


Fig 1. Schematic of SSTF DAC System

The measurement data is stored in a database server. A Linux workstation is used for an in-house developed database system, which is designed for the archiving of measured data.

X-window based programs and Labview application programs are developed for the real-time monitoring using EPICS CA library. Various kind of programs including GUI (Graphical User Interface) programs are

also developed for the archiving and monitoring of the measured data from database server.

RDB AND IOC APPLICATION

Data Conversion Methods and RDB

The conversion of raw data into physical values is implemented using four different kinds of conversion methods, which is graphically summarized in Fig. 2.

The first kind is using EPICS calculation records. The RDB table for EPICS database has information, which includes the polynomial coefficients for the EPICS calculation record.

The second one is the internal data conversion using IOC application programs. Sometimes, a complicated mathematical calculation is required for the conversion of the measured value from a sensor to a physical value. Those real-time conversions are accomplished by specially developed IOC application programs, which include calculation routines for Ga-Al-As temperature sensor, Cernox temperature sensor, TVO (Teollisuuden Voima Oy) temperature sensor, pressure sensor, Helium level sensor and etc. The RDB table includes the information describing the type of the sensor and manufacturer's serial number (MSN) for each channel.

The third type is the external data conversion using CA client application. This method is used for the conversion routine requiring special data such as physical properties of materials or complicated mathematical functions. The record of the third type is linked with various EPICS record types such as AI (Analogue Input) record, AO (Analogue Output) record, CALC (CALCulation) record, and fanout record. The RDB table includes the information about the record link structure.

In the last type, the data conversion is accomplished by the independent device and the converted data is written to a soft analogue output channel. Sometimes the converted data is further processed using first three types of conversion methods.

The key concept of RDB - joining tables by the use of significant relations - is well matched with the concept of the link among EPICS record field attributes. EPICS database files are easily generated by the execution of RDB report scripts. End-users can also share RDB data via database connection protocols such as ODBC (Object DataBase Connection) and JDBC (Java DataBase Connection).

EPICS IOC Application

The EPICS base has data conversion routines in the form of linear and thermocouple conversion routines in the AI record definition. The CALC record can also be used for simple data conversion. This is the first method described in the previous section.

However, the optional data conversion routine of the second type described in the previous section is required to be developed for the efficient operation of the DAC system. The data conversion routine is added as a sub-

1 Basic calculation supported by EPICS

x is analogue input record value and coefficients set is decided by msn .

$$y = C_0 + C_1x + C_2x^2 + C_3x^3 + C_4x^4 + C_5x^5 = C(x)$$

2 Internal data conversion through developed IOC application

by sensor type

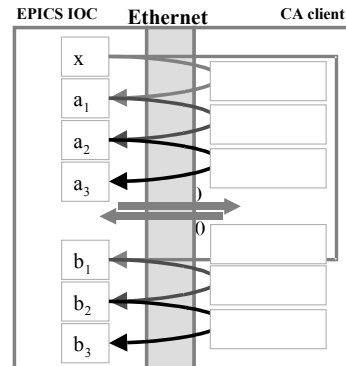
$$y = \text{calc_pc_epics}(C(x), msn) \dots \text{for absolute pressure sensor}$$

$$\text{or } y = \text{calc_tg_epics}(C(x), msn) \dots \text{for Ga-Al-As diode sensor}$$

$$\text{or } y = \text{calc_tx_epics}(C(x), msn) \dots \text{for Cernox temperature sensor}$$

$$\text{or } y = \text{calc_tt_epics}(C(x), msn) \dots \text{for TVO temperature sensor}$$

3 External data conversion using CA client application



4 Data conversion for the local devices

x is soft analogue output record value from local devices.

Fig 2. Four Basic Categories of Data Conversion

function in the CALC record. By the choice of newly defined LINR field, the `convert()` routine links the equivalent conversion routine with the record. In order to identify the sensor for each channel, MSN field is also added to the CALC record definition. The data conversion routine requires calibration data for sensors. However, most of VME controllers used for IOC have relatively small RAM (Random Access Memory) and the EPICS IOC application is ported to a RTEMS workstation, which was a personal computer with PENTIUM CPU[6][7].

Interface Programs for the Operators

One of EPICS extensions, MEDM (Motif Editor and Display Manager) is utilized as a monitoring program for Linux workstations. X-window based GUI programs are also developed in order to satisfy end-users' needs for the Linux and UNIX system. For Windows operating system, LabVIEW application program is used. These application uses CA routines to obtain measured data. By obtaining the valid channel list from the RDB, the error occurred by requesting invalid channel data is reduced in operator interface programming.

In order to monitor the experimental status using web browsers, JCA (Java Channel Access) applications are also developed. These applications interactively obtain the channel information from the RDB using SQL (Structured Query Language).

POST PROCESSING

The measured data archived in the measurement database system requires post-processing for the analysis of the experimental result. The post-processing application package consists of data handling tools and data analysis tools. Data handling tools include data retrieval and archival programs and data management programs. Data analysis tools include graphics programs and mathematical analysis tools such as simple mathematical calculation programs, Fourier analysis program and linear equation solver. These analysis programs directly access the measurement database and the time required for preparing data is reduced.

DISCUSSION

Fig. 3 shows the installation of TF00 in SSTF. The TF00 test is successfully accomplished. During the test, TF00 was repeatedly charged and discharged with various scenarios. Fig. 4 shows the result of a TF00 operation, where the maximum current is 29 kA. The coil was operated well without any quench over 30 kA. The result of repeated current charge tests shows that TF00 is fabricated robustly and auxiliary systems, such the power supply system, the quench detection and quench protection system, are also designed and fabricated reliably[8].

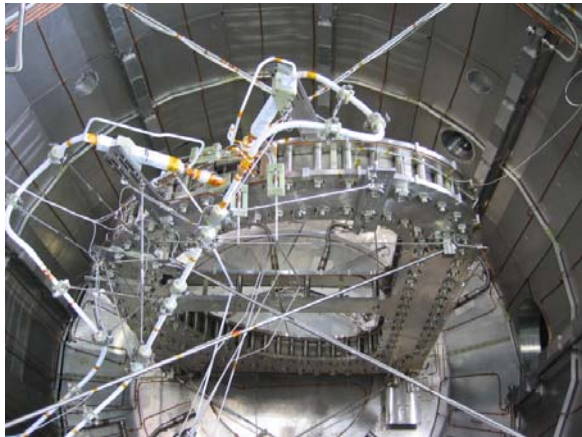


Fig 3. Installation of TF00 for the performance test

Since SSTF is a magnet test facility, the configuration of the system requires modification for every experiment. And the update of the system configuration should be accomplished with a little labor and time. RDBMS could be a good candidate for solving such problems.

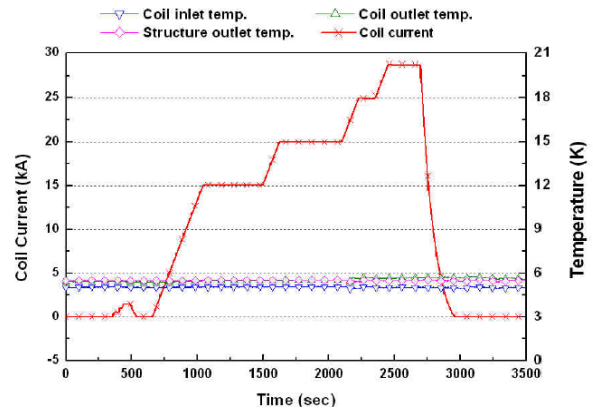


Fig 4. Current Ramping and Slow Discharge of TF00

The RDB provides the configuration data for the EPICS record data, sensor calibration information and the channel information for monitoring and archiving system.

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