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E. Gorskaya, V. Samoilov, A. Raimondo*, A. Rijllart*

THE LHC DIPOLE TEST CONTROL ARCHITECTURE

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*CERN, Geneva

1. INTRODUCTION

The next large accelerator project at CERN is the Large Hadron Collider (LHC) [1], which is foreseen to be installed in the existing LEP tunnel, and scheduled to be commissioned in 2007. For this project 1200 15–metre long dipole magnets need to be tested at CERN in warm and cold conditions on dedicated test benches that are under development. Fig. 1 shows the general view of Magnet Test Hall at CERN.

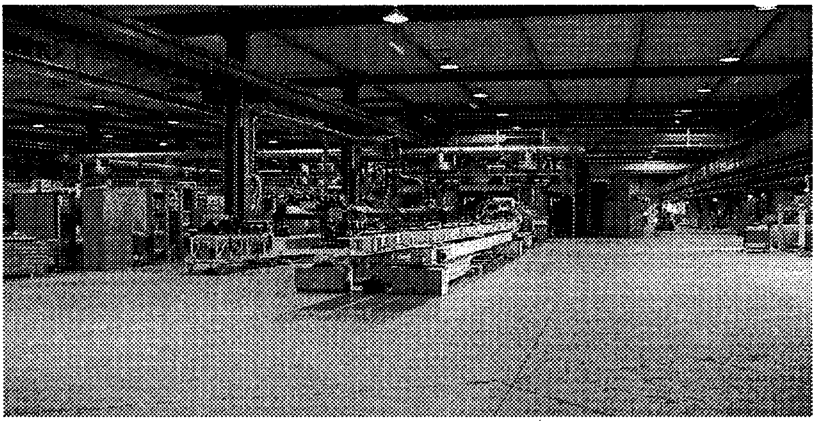

Fig. 1: View of Magnet Test Hall

An important part of the test procedure is the magnetic field mapping. Dedicated software has been developed to perform this measurement in the LHC magnets by means of the rotating coil method [2].

Rotating coils, mounted on a shaft driven by a motor, deliver signals proportional to the magnetic field and the rotation speed. The coil signals are integrated by digital integrators, which are triggered by an angular encoder. The integrators, on a VME bus, are configured and read-out by a computer through a VME interface. Fig. 2 shows a sketch of the measurement system.

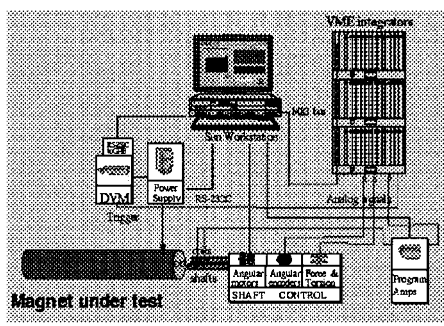

Fig. 2: The magnetic field mapping system

From the raw data the software computes the main field, the main field direction, the higher order harmonics and the magnetic axis coordinates. To perform these measurements the computer controls motors, power supplies and measurement devices, and reads-out the acquired data. Finally, it analyses online the raw data and stores it for later offline treatment.

The ratio of measurement time versus preparation time allows a de-phasing of the tests without limiting the total throughput where the largest and most expensive resources, such as cryogenics and power supplies, can be shared into clusters of two benches for a total of 6 clusters.

The control architecture is organized in two levels, where the TMs are at the bottom level, driving the measurement for the clusters, and requesting the booking of required equipment to the RM at the top level.

To orchestrate the measurements a Test Master (TM) is needed to organize the tests per cluster and a Resource Manager (RM) to centralize the booking of the resources.

Each TM drives two VME based measurement systems controlling the magnet test electronics. The first is a turnkey industrial DAQ system for magnet power tests and the second is an in-house developed magnetic measurement system based on industrially produced components [3]. The TM's user interface has been designed to allow non-specialist operators to execute predefined tests.

2. THE CONTROL ARCHITECTURE

An offered two–levels control architecture [4] includes:

- the Test Master layer which drives the test for a cluster;
- the Resource Manager layer that allocates common devices and central resources.

In the next sections we describe the implementation of this architecture in the LabVIEW® environment.

2.1. THE TEST MASTER

The TM will be used to perform in an automatic way a predefined measurements cycle and should be a common interface for all the applications to be used in a cluster such as power supply control, magnetic measurements and energy loss measurements.

The aim is to simplify the way to perform the measurement allowing users with minimum experience to perform tests, and to minimise time and errors during test definition.

To do this, the TM displays a synoptic panel that describes the cluster that is being controlled. In this diagram, the lines represent the communication between TM and the low-level programs that are located in different computers. The colour of these lines describes the communication status. The boxes that can be seen represent the program status and indicate the computer they are installed in.

TM has several operating modes to configure the execution of measurements in a cluster.

The first mode (*install mode*) is used to select the computers of the cluster that we want to control. In this mode, TM gets also the names of the configuration files present in the remote computers, which will be used to create the test files in the next mode (*define test mode*). These tests are in fact a list of commands written in a text file replacing the same operations that the user would do in the low-level programs, which operate the hardware and make the data acquisition.

In one test, the TM sends several command files, using FTP, to the program that performs the measurement and to the programs that make the low frequency and high frequency data acquisitions. These two types of programs are located in different computers.

To define a new test or to modify existing tests, the TM offers a specific editor that proposes a list of predefined commands. After creating the necessary tests, the user can build a sequence with these tests in the *build sequence mode*. Finally, in the *run sequence mode* the user can launch a sequence of tests. Fig. 3 shows the *run sequence mode* cluster synoptic.

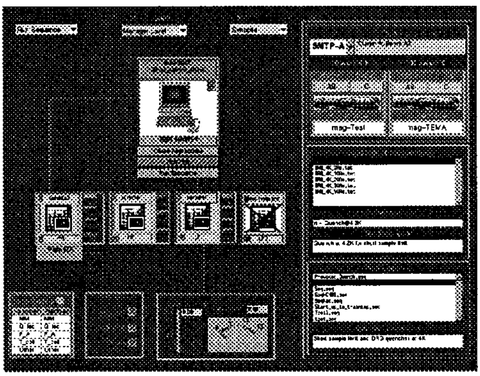

Fig.3: The run sequence mode synoptic

During a sequence execution, the status of each measurement is shown and a log is being kept. For each test in the sequence, the TM configures and runs several applications in parallel (magnetic field mapping, temperature data acquisition, etc.) and communicates with the RM for status information and resource allocation.

The information coming from the remote programs launched by TM is obtained through a UDP socket.

2.2. THE RESOURCE MANAGER

The RM monitors the activity of TMs and the total power consumption. It shows the status of each test bench and handles the resource allocation on request of the TMs. It can refuse the use of a power supply if the total power consumption approaches the limit.

The aim of the RM is to give an overview of all ongoing tests to the operators to help making decisions about the program in case it has to be changed depending on individual magnet test results. Normally a magnet will follow a standard program, but depending on results obtained during the test it may be necessary to shorten or extend the program. Such a change can influence the program on other clusters because of the common limited resources of cryogenics and electrical power.

2.3. SYSTEMS INTERACTIONS

When a measurement requires a particular power supply, the TM needs to reserve it and keeps control of it for the full time of the measurement. It is the RM that takes care of power supply reservation. The TM asks the RM if the needed device is available through a query on a UDP socket. The TM continues to send queries to the RM until an answer is received.
Through another UDP socket the RM sends the answer allowing or not the reservation. With the reservation each TM gives an estimate of the total booking time that is updated during the measurement.

The measurement can start once the power supply is available. At the end, the TM sends to the RM the information to deallocate the device through a system as before. If the power supply cannot be used the RM gives an estimate of how much is the waiting time. Then the TM allows the user to make a decision to wait or to change the test sequence. Fig. 4 shows the control architecture.

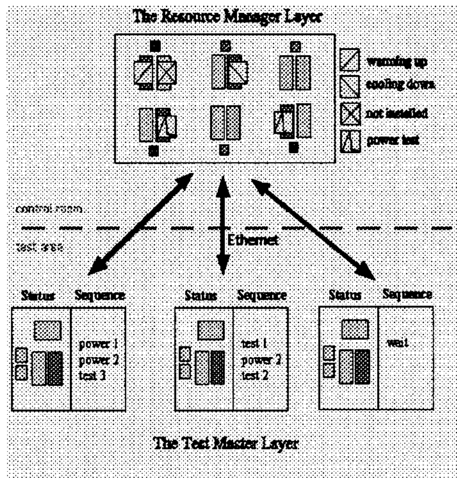

Fig. 4: The control architecture

The use of UDP sockets is preferred to TCP because it does not need a permanent connection between the processes: in this way, the TM can also run if the RM is not running or if there is no network communication with the RM. Only when needed, the communication takes place with a sort of simulation of TCP connection given that for every command sent the receipt is expected. During the measurement each bench sends status and usage information to the RM, which shows the full installation to a supervisor user.

3. CONCLUSIONS

For the LHC project 1200 15–metre long dipole magnets need to be tested at CERN in warm and cold conditions on 12 dedicated test benches. The resources are shared in clusters of two benches, because of a deliberate de-phasing of the tests between magnets. This makes an optimum use of the resources, such as cryogenics and power equipment, without limiting the test throughput.

All measurement operations within a cluster can be controlled by a measurement scheduler software called Test Master. The necessity of overall supervision software to share the total available electrical power is provided by the realization of a Resource Manager.

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Горская Е. и др. E10-2003-42
Архитектура управления испытанием дипольных магнитов
для проекта LHC

Ближайшим крупным проектом в области ускорителей в ЦЕРН является ускоритель LHC (Large Hadron Collider), который предполагается установить в существующем уже туннеле LEP и сдать в 2007 г. Для этого проекта 1200 15-метровых дипольных магнитов необходимо тестировать и испытывать в холодных и горячих условиях. Для этих целей разрабатываются специальные установки — так называемые бенчи. В окончательном виде тестово-измерительный комплекс будет состоять из 12 бенчей, сгруппированных в 6 кластеров (по 2 бенча в каждом), между которыми будет разделено наиболее крупное и дорогостоящее оборудование, используемое в тестовых измерениях. Это разделение возможно только при продуманном графике тестирования различных магнитов в противофазе, который обеспечит оптимальное использование ресурсов, таких как криогенное и силовое оборудование, без потери общей производительности. Предлагается двухуровневая архитектура управления: 1) тест «Мастер», который управляет тестированием внутри кластера; 2) ресурс «Менеджер», который распределяет общедоступные устройства и центральные ресурсы.

Разработка программного обеспечения этой системы выполнялась в среде LabVIEW®.

Работа выполнена в ЦЕРН, Женева, и Научном центре прикладных исследований ОИЯИ.

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Gorskaya E. et al. E10-2003-42
The LHC Dipole Test Control Architecture

The next large accelerator project at CERN is the Large Hadron Collider, which is foreseen to be installed in the existing LEP tunnel, and scheduled to be commissioned in 2007. For this project, 1200 15-metre long dipole magnets need to be tested at CERN in warm and cold conditions on dedicated test benches that are under development. The final LHC dipole series test set-up will consist of 12 benches organized in 6 clusters of two benches sharing the largest and most expensive devices. This sharing is made possible by a deliberate de-phasing of the tests among magnets, ensuring an optimum use of resources, such as cryogenics and power equipment, without limiting the total throughput. An offered two-level control architecture includes: 1) the Test «Master» that drives the test for a cluster; 2) the Resource «Manager» that allocates common devices and central resources.

The implementation of this architecture is done in the LabVIEW® environment.

The investigation has been performed at CERN, Geneva, and at the Scientific Center of Application Research, JINR.

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141980, г. Дубна, Московская обл., ул. Жолио-Кюри, 6.
E-mail: publish@pds.jinr.ru
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