# A NOVEL PXI-BASED DATA ACQUISITION AND CONTROL SYSTEM FOR SINGLE STRETCHED WIRE MAGNETIC MEASUREMENTS FOR THE LHC MAGNETS: AN OPERATION TEAM PROPOSAL

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*Abstract*

The SSW system developed by Fermilab, USA, has been the main device heavily used since 2004 at CERN for certain required measurements of all the LHC Quadrupole assemblies as well as certain measurements for the LHC Dipoles. All these structures also include various small and large corrector magnets. A novel system is proposed, based on three years of operational experience in testing the LHC Magnets on a round-the-clock basis. A single stretched wire system is based on the wire cutting the magnetic flux, producing the electrical potential signal. Presently this signal is integrated with a VME-based data acquisition system and is used to analyse the magnetic field. The acquisition and control is currently done via a SUN workstation communicating between different devices with different buses and using different protocols. The new system would use a PXI based data acquisition system with an embedded controller; the different devices are replaced by PXI-based data acquisition and control cards using a single bus protocol and on one chassis. The use of windows based application software would enhance the user friendliness, with overall costs of the order of 10 KCHF.

## INTRODUCTION

The fundamental concept underlying the Single Stretched Wire (SSW) Magnetic Measurements is that the quality of a magnetic field can be assessed by measuring the potential developed across a wire cutting the flux. SSW measurements can broadly be classified into two types – cold testing, where the wire is moved in a static (DC) magnetic field, and warm testing, where the wire is kept stationary in a fluctuating (AC) magnetic field. Both these techniques are widely employed in testing of cryomagnets for LHC for measuring their magnetic axis with respect to the cryostat fiducials (XY), field direction with respect to gravity (roll angle), integral field (field strength) at different currents etc.

## EXISTING SSW SYSTEM

The SSW system used in SM18 during the intensive LHC magnet tests (2004 – 2007) in cold and warm tests is a Fermilab (FNAL, USA) product. It consists of a two “stage” installation (stage A mounted on CFB (magnet connection) side and stage B mounted on MRB side) with independent precise XY movement capability [1]. These stages that carry the wire support and movement and tensioning systems are mounted on the test bench. Alignment fiducials are mounted directly on these devices. Level sensors are mounted on both the stages. The wire support and tensioning system has wear resistant wire guides made of hardened ceramic ($Al_2O_3$) balls and have been located to better than 10 µm to the fiducials. To control sag effects, a tensioning system with a stepping motor on one stage and a tension gauge on the other, allows for measurements at several tensions, which can then be extrapolated to an infinite tension.

## EXISTING SSW SYSTEM HARDWARE

Fig. 1 shows a block diagram schematic of the existing system architecture [2],[3]. The SSW electronics rack contains several instruments communicating with the SUN workstation for data transfer and command signals through different buses obeying different protocols. A trigger generator card is used to synchronise the communication between these individual equipments.

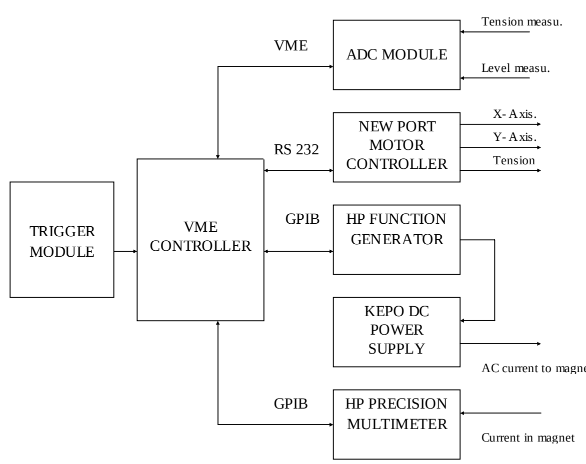


Figure 1: Block diagram of SSW hardware architecture.

For SSW measurement during cold testing, stepping motors driven by a Newport motor controller handle the movement of the wire at both ends of the magnet. The same controller also ensures adequate tension in the wire through another stepping motor. This controller is connected to the SUN station through an RS232 link. An HP precision voltmeter connected to the SUM station via a GPIB bus is used for precise monitoring of the current in the magnet. Signals corresponding to the levels of the stages at both ends of the magnet and the tension of the wire measured by the tension gauge are converted with ADCs and transferred to the SUN through a GPIB bus. During the warm testing a function generator along with a Kepo power supply feeds a modulated signal to the magnet.

## EXISTING SSW SOFTWARE

Existing SSW software works in a Solaris Unix platform on SUN based workstations. It contains various applications invoked through appropriate commands to handle different activities. For example, r*eadTension* command reads the tension in the wire in order to manually adjust the initial tension until its value reaches 800g. To check that the wire is in the centre of the aperture, the wire is moved in a particular sequence to all the extremities using *moveStages* command and contact resistance is checked, to ensure that the wire does not touch the anti-cryostat during actual measurement. To initialise the motor controller position and reset other devices *deviceInit* command is used [4].

After the initial set-up of the hardware, the measurement preparation program *sswtest* is launched. Fig. 2 shows the user interface of the *sswtest*. This program requires different input parameters (about 14) depending on the type of magnet and type of test to be conducted. Some of its inputs are in the form of text files (e.g. the ".z" file giving geometric details about magnet w.r.t. the SSW stages, the ".db" file giving details about type of measurement to be performed, and the calibration file giving details about the SSW equipment calibration).

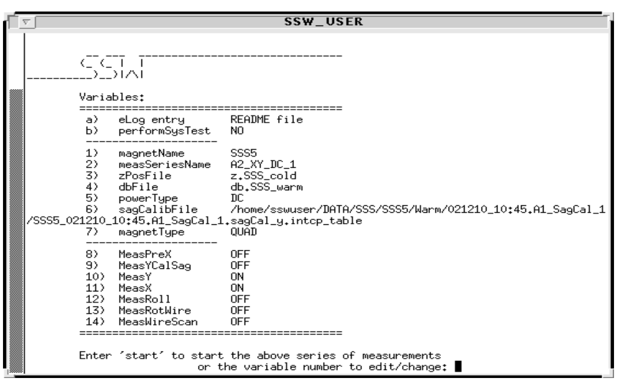


Figure 2: The User Interface of the sswtest application.

Once the test is launched using the *start* command, the program initially adjusts the wire tension to the specified value for the measurement. Then, depending of the type of test, the wire is moved in a sequence with the help of motors in both stages (or, in the case of a warm test, the magnet current is modulated) and the voltage produced in the wire in each step is measured. This synchronised signal is processed in the integrator card and captured in the SUN workstation for further processing and analysis. The operator can further validate the measurements by analysing the result file through the *sswtest* program.

## DRAWBACKS OF EXISTING SYSTEM

The electronics rack of the SSW system is very bulky and has many cables running between instruments and the SUN workstation, which makes the equipment handling rather difficult.

Software used in the system is based on a Solaris Unix platform which required a Unix-friendly person to operate it. Many programs written to do the specific tasks are also not integrated. This demanded the Operation Team to memorise the procedure to operate the equipment.

Even after doing much work in the levelling of stages and installation of the wire, there is no diagnostic procedure in the application software to verify the correctness of the wire contact resistance, stage levelling and the magnet current acquisition. This can only be known when one of the tests is completed and the result file shows the error, due to either a problem in the installation of the SSW system or due to a problem in the magnet. Hence, for the operators involved in LHC magnet tests, it becomes a trial and error procedure.

There is also no facility of system diagnostics to verify the correctness of the signals acquired by the system.

To make the situation worse, the SSW stages are very bulky and fragile; the system requires specialised, careful and patient handling for installation of the wire and it has complicated hardware and software. All these issues make the SSW system rather unfriendly for large scale usage and is difficult to operate in the production environment that LHC magnet tests demanded for tests of hundreds of magnets.

## PROPOSED SSW SYSTEM HARDWARE

In the present scenario where high speed and high buffer PXI based data acquisition cards are available, the issue of synchronization and high speed data capturing and control can be solved by using a common bus such as PXI (PCI Extended bus) with PXI based cards and their embedded processors. This, in combination with a windows base application, may enhance the operator's comfort and efficiency.

Thus, using the same instrumentation installed in the SSW stages, the hardware architecture could be modified as indicated in Fig. 3.

The new PXI based configuration has been derived from the SSW system requirements and the existing hardware used in the electronic rack.

- The SUN workstation should be replaced with a PXI chassis and its Pentium IV based embedded controller suitable for an industrial environment.
- The six axes Newport motor controller (Model ESP 7000) should be replaced with a PXI based 8 Axis Stepper/ servo motor controller (NI PXI-7358) and the Newport drive capable of driving the motors.
- The Hewlett Packard Multimeter (3457A) used to measure the tension in the wire, current in the magnet and level of the stages should be replaced with PXI based 24 bit Flexible resolution digitiser

(NI PXI-5922). This also replaces the integrator card and the trigger module in the MXI bus.

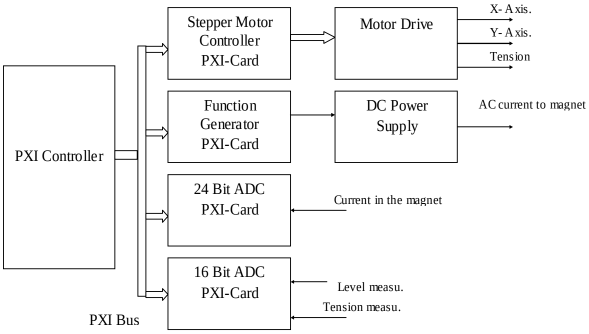


Figure 3: Proposed SSW hardware architecture.

- The Agilent Function Generator (33120A) used to generate AC frequency in the magnet during warm test should be replaced by PXI base 40 MHz Arbitrary Function Generator (NI PXI-5406)

PXI Chassis with an option of 12 cards is shown in Fig 4.

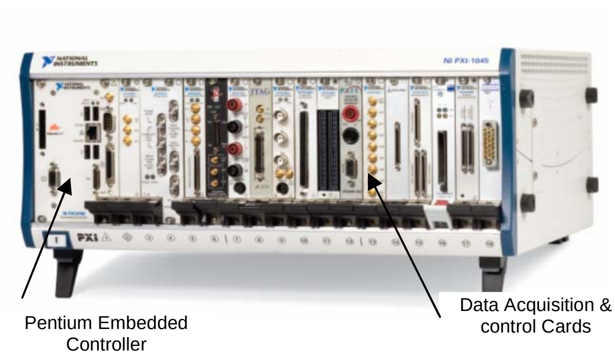


Figure 4: PXI Chassis with cards.

## PROPOSED SSW SYSTEM SOFTWARE

Windows based software in Visual C++ should replace the existing code. The software should be designed with object-oriented approach to adapt to the future needs. Three-tier architecture shall be adopted for the software. The front-end software modules would essentially be for the hardware interaction (software Drivers) modules which would normally be provided by the commercial NI system. The middleware would have to be written in a structured manner and would interact with the drivers and should have clear interface for easy modification in case of changes in commercial hardware and software. The higher-level user application module and GUI should cater for the need of data presentation, analysis and display. The essential features should be presented as follows:

- There should be only one GUI to carry out all the tasks. All sub-tasks e.g. *readtension*, *contactcheck* should be in the menu driven application.
- A check should be made of the status of all the signals coming into the PXI cards. Subroutines should check the individual device status.
- The GUI should also display the level of each stage.
- Clicking the contact check routine should automatically check the continuity of the wire and insulation of the wire with respect to the magnet.
- The GUI should be able to display real-time current applied to the magnet, status and so forth.
- File selection in case of different types of magnets and different measurements should be automatically driven by selection based on the name of the magnet and corresponding scripts.
- Combo box type selection of test instead of writing of the test name in command prompt.
- A combo box on the GUI should provide the choice regarding apertures for double-bore magnets.
- During the analysis, the results should be displayed with a range of colours. For under range it should be yellow, green for OK and over range with red.

## CONCLUDING REMARKS

The existing SSW system used for LHC magnet tests had various drawbacks, which resulted in stringent constraints in the overall tests throughput. The Operations Team, based on their vast experience, has therefore proposed a modified SSW system to overcome these drawbacks. The proposed system will reside on a single, compact PXI chassis with various modules communicating over a single PXI bus, unlike the existing system which is bulky and where different buses and protocols are involved in communication between the modules. This modified architecture, along with proposed Windows based software with better GUI would enhance the ease of use and hence, the operator efficiency & overall tests throughput.

## REFERENCES

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