Implementation of the Control and supervision of ALICE ZDC positioning Systems-TWEEP-08

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Abstract

The ALICE Zero Degree Calorimeters (ZDC) have been installed to either side of the LHC IP2 in the machine tunnel next to the dipole magnet D2. The calorimeter modules are mounted on a special table equipped with a mechanism to lower the modules away from the beam orbit during injection and acceleration. During stable operation the modules can be raised individually to be aligned with the beam orbit. The horizontal clearance between ZDC modules and beam pipe will be only about 3 mm. Anti-collision switches are therefore installed to protect the beam pipes against accidental damage. The movement of the calorimeter modules and the protection switches are remote controlled by the ALICE ZDC positioning system.

I. INTRODUCTION

The ALICE Zero Degree Calorimeters (ZDC) are installed to either side of the LHC IP2 in the machine tunnel next to the dipole magnet D2 [1]. The calorimeter modules are mounted on a special table equipped with a mechanism to lower the modules away from the beam orbit during injection and acceleration (Figure1) [2].

During stable operation each calorimeter module can be raised individually and centered with the vertical beam position. The horizontal clearance between ZDC modules and beam pipe will be only about 3 mm (Figure 1).

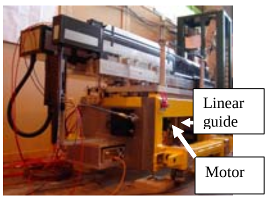

Figure 1: ZDC Detector assembly

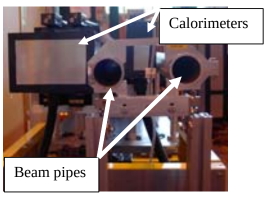

Figure 1: Integration of calorimeter and beam pipes

Anti-collision switches are therefore installed to protect the beam pipes against accidental damage.

The movement of the calorimeter modules and the protection switches are remote controlled by the ALICE ZDC positioning system. The architecture of the control system is based on a Programmable Logic Controller (PLC) which connects to the local servo-controllers via a field bus. Two application interfaces have been created; one using Labview® for the development and maintenance and the 2nd in the SCADA [3] framework for the detector control system. The layout and the implemented controls algorithms are explained.

II. ACRONYMS

ALICE	A Large Ion Collider Experiment
DCS	Detector Control System
DSS	Detector Safety System
IP2	Intersection Point 2
JCOP	Joint Controls Project
LHC	Large Hadron Collider at CERN
LVDT	Linear Voltage Direct Transformer
MMI	Man Machine Interface
PLC	Programmable Logic Controller
SCADA	Supervisory Control and Data Acquisition
ZDC	Zero Degree Calorimeter

III. OVERVIEW OF THE SYSTEM

The general concept of the controls system follows a 3 layer architecture (Figure 3). The hardwired sensor and actuator level is connected to the device control and data acquisition layer which includes servo-controllers and PLC. The SCADA level communicates with the PLC through industrial Ethernet.

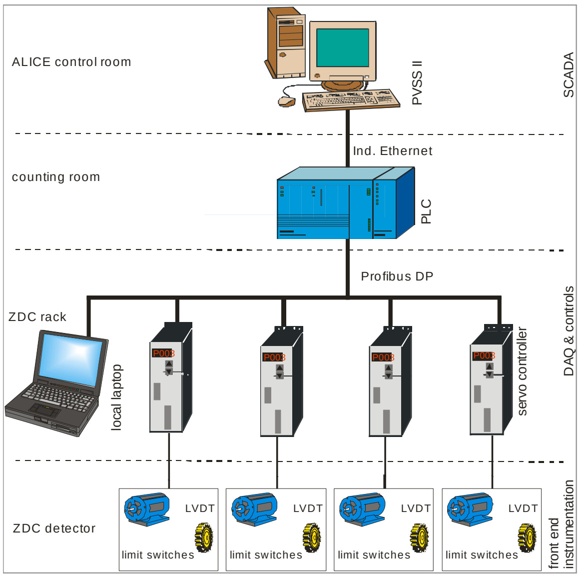

Figure 3: ZDC positioning control - Data flow diagram

Signal flow and interlock chain are shown in the diagram (Figure 4) for one calorimeter. The acquisition of the value of the LVDT is done directly via an analog input channel of the servo-controller. All interlock switches are also cabled to the servo-controller.

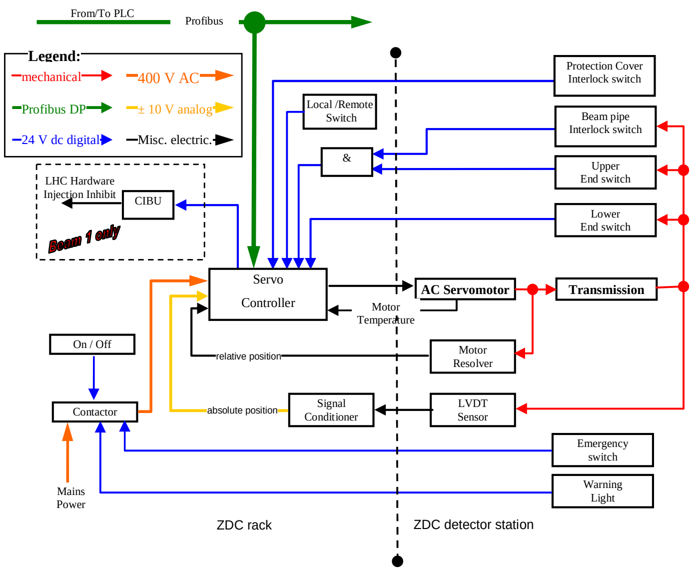

Figure 4: ZDC positioning control - Signal flow diagram

IV. Positioning Systems Control

The vertical movement to approach or retract each of the ZDC with respect to the recombination beam pipes is controlled by one dedicated PLC which acts on a servo-controller for each of the four calorimeter modules.

The control functions can be separated in process control functions and supervisory control functions. They later run in the PLC and partially in the Detector Control System (DCS) of the ALICE experiment [4] which also provides the standard MMI for the operation of the positioning system. The process control functions are shared between PLC and the servo-controllers.

A. Process Control

The PLC monitors the position of the calorimeters and controls the movement of the servo-motors which is hard limited by a number of the interlock switches.

The main actions and status of the system are:

- on/off: PLC active or disabled
- stop: interrupt any active command and halt servo-motor
- garage position: when normally all calorimeters are retracted
- hold: calorimeter in position outside garage position
- run: calorimeter changes position
- limit detection (calorimeter at end stop, limit switch or anti-collision switch)

The PLC monitors and registers the complete installation: physical parameters (position, speed, direction, etc.) and status (operation mode, on-off, warnings, alarms, etc.).

B.Movement control

The vertical position of each calorimeter is permanently monitored by an LVDT. This value is received by the dedicated servo-controller which converts the value to internal coordinates by applying a transfer function of format:

$$Vpos(Zxy) = offset + V_{LVDT}\ (Zxy)$$

The result is converted by the PLC into physical coordinates.

In order to change the position of a calorimeter the supervisory system needs to send first the new set point value to the PLC and then the go command. This causes an activation of the corresponding servo-drive until one of the following conditions becomes true:

- Vpos(Zxy) = Vrequest(Zxy) or
- Alarm (Zxy); i.e. an exception condition has been detected or
- PLC receives a new command which supersedes the previous command.

In order to avoid any hysteresis due to mechanical tolerances of the drive gear the control algorithm is constructed such as to reach the requested position always by a movement against gravity.

C. Movement limits and LHC interlocks

The movement of each of the calorimeters is constraint by limit switches and mechanical stops. The limit switches act directly on the servo-controllers and stop the motors. The mechanical stops act as an ultimate emergency device preventing any further motion and eventually causing a power interruption by a motor protection function in the servo-controller.

It is not foreseen to provide programmable range limits in the PLC. These thresholds can be better integrated in the supervisory system where they can easily be changed on the fly.

The ZDC station which is located just downstream of the beam injection area for beam 1 of the LHC is directly exposed to miss-injected beam. The position of the calorimeter modules of this station is therefore interlocked with the LHC Beam Interlock System (BIS) during injection. A current loop output of the servo-controllers is used to generate the “beam permit flag” signal as long as the calorimeter modules are in the out position which is detected by an end switch. Outside injection periods the flag has no effect. During injection mode the absence of the flag will prevent through the hardware beam injection inhibit system any injection of beam 1 into the LHC ring. The request for two independent signal sources for this flag has been implemented by feeding the output from each calorimeter to a different channel. Consequently, the injection permit will only be true if both calorimeters are in the garage position.

D. Recovery

Each of the described exception conditions aborts the received movement command and the calorimeter stops immediately. However, a command to move in the reverse direction will still be accepted by the controls system.

In case of a hardware failure a remote reset will not be possible.

E. Movement calibration

The absolute position of each of the calorimeters can be calibrated during an initialization run. The device needs to be moved previously into a defined position; i.e. the lower mechanical stop. The measured value from the LVDT is then stored in the servo-controller as permanent offset.

V. Local supervision

A local/remote switch mounted at the electronics rack in the LHC tunnel allows switching to local control of the ZDC positioning system. In this mode the PLC will accept commands for the servo-controllers concerned only and ignore other sources like the supervisory system of the DCS. The access to all the control functions of the graphical interface are password protected.

VI. Network connections

The ALICE ZDC position system is controlled from one single PLC Siemens S7-300, CPU 315T-2 DP located in one of the ALICE counting rooms in the PX24 shaft. The concentrator PLC is connected to the internal ALICE network (industrial Ethernet) available in the experimental and service cavern.

A direct connection with the Detector Safety System (DSS) is not implemented. All interlock switches act directly on the servo-controllers which are located in the electronic racks in the LHC service tunnel close to the detector stations.

VII. Data transmission

Communication with the ALICE DCS is implemented following the standards of the JCOP framework [5]. This PLC communicates with the ALICE DCS system over TCP/IP. The PLC can be accessed through the dedicated OPC server or using the native driver in the PVSSII supervisory system running on Windows OS or Linux OS.

Data exchange between PLC and the front-end instrumentation has been implemented over Profibus using the Profibus DP protocol suite. The integration of the servo-controllers required the use of the “technology function blocks” which are tailored for these instruments. This, however, limits the optimization of the FSM and the robustness of the transmission since the use of the preconfigured function blocks does not allow to adapt the transfer function between position measurement from an external instrument (LVDT) and the response of the servo-controller. Therefore, the integrated resolver of the servo-motor had to be used for the real-time feedback to the servo-controller. In a second step the measured position is compared to the set point followed by a new iteration loop in case of a difference.

The use of the technology functions restricts the communication over the Profibus to synchronous transmission mode which implies short latency for the data exchange between master and slave stations and therefore relatively high transmission speeds of 6 MB/s in our case. This reduces, however, the acceptable bus segment length dramatically. In order to cover the required distance of about 500 m between stations specific Profibus RS 485 repeaters have been added at each station.

VIII. Controls operator interface

A. Experiment Control Room ECR

In normal operation the ECR authorised operators can position each calorimeter individually within a preset range. The validity of the command is checked inside DCS with respect to the LHC operation mode. Only requests to change which have been validated by the DCS are transmitted to the ZDC control PLC.

The PLC application executes the command if no exception condition exists either in the PLC itself or in the front-end instrumentation.

On reception of an operator request the PLC application returns an acknowledgement. If an exception condition is detected an alarm status is returned. In this case the detailed status is returned to the supervisory system on request.

B. Local/Remote

This feature allows a direct intervention on the device and shall prevent any accidental remote activation. In local mode the positioning system will not accept any commands from the ALICE DCS but exclusively from a dedicated computer with the native Siemens software and the Labview interface.

The full controls functionality is also made available in local mode. The hardware interlocks remain active under all conditions.

IX. Parameters and variables

The following table shows the parameters and variables which are available at the interface between PLC and DCS.

Table 1: ZDC positioning system parameters and variables

Item	Description	Source	Dest.
Go	Start movement to set point	Scada	PLC
Stop	Stop movement immediately	Scada	PLC
Setpoint	Requested position (absolute physical coordinate)	Scada	PLC
Measurement	Actual value of the position of the calorimeter (absolute physical coordinate)	PLC	Scada
StationActive	Status of drive electronics	PLC	Scada
Error	Fault condition	PLC	Scada
InPosition	Actual position is equal to set point	PLC	Scada
IGP	Actual position is equal to garage position	PLC	Scada
ABI	LHC hardware injection permit raised	PLC	Scada
LOC	Remote / local status indication	PLC	Scada
CIL	Protection cover open	PLC	Scada
HES	Upper end switch reached	PLC	Scada
LPC	Lower end switch reached	PLC	Scada

X. Commissioning

The commissioning of the system has been performed in two stages. In a 1st period the complete ZDC system was assembled and tested in a surface hall. A full implementation of the control system was developed in parallel. Tests included the remote control of the movement, end switch interlock, remote and local command functions. A stand alone application was developed with Labview in order to have a comfortable tool to test the entire functionality and as debugging tool. This application will also be used later during operation and maintenance in local mode. At the same time the implementation of the SCADA application with the final MMI was also developed and tested.

After installation of the complete detector including support structure in the final position in the tunnel a full test sequence has been performed with the remote control application and in local mode. This included the test of all safety and limit switches as well as the injection inhibit interlock.

XI. References

[1] ZDC Technical design Report, ALICE-DOC-2004-003 v.1

[2] ALICE Zero Degree Calorimeter Platform, EDMS 674031

[3] PVSS II – Process visualization and control system, Version 2.0 (July 2004)

[4] Detector Control System for an LHC experiment, ALICE-INT-1998-03

[5] JCOP Programme Plan – CERN-JCOP-2000-002, version 4.5, January 2002