OPERATIONAL EXPERIENCE WITH A PLCBASED POSITIONING SYSTEM FOR A LHC EXTRACTION PROTECTION ELEMENT

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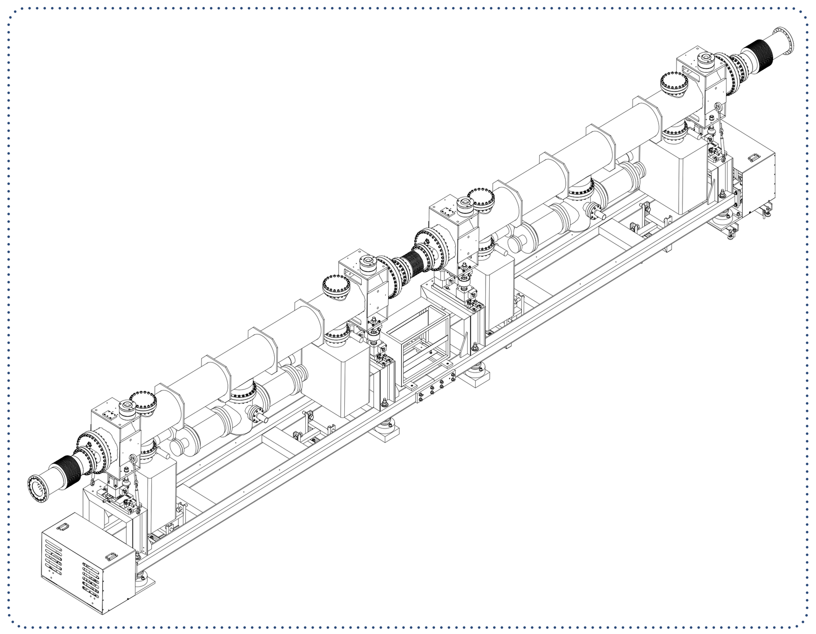
ABSTRACT

The LHC Beam Dumping System (LBDS) nominally dumps the beam synchronously with the passage of the particle free beam abort gap at the beam dump extraction kickers. In the case of an asynchronous beam dump, an absorber element protects the machine aperture. **This is a single sided collimator (TCDQ),** positioned close to the beam, which has to follow the beam position and beam size during the energy ramp.
The TCDQ positioning control is implemented within a **SIEMENS S7-300** Programmable Logic Controller (PLC). A positioning **accuracy better than 30 µm** is achieved through a **PID based servo algorithm**. Errors due to a wrong position of the absorber w.r.t. the beam energy and size generates interlock conditions to the LHC machine protection system.

LAYOUT

The TCDQ is composed by **two 3m long graphite blocks** acting as jaws housed in **2 separate vacuum tanks** mounted on **a single girder.** Both extremities of the girder are equipped by a positioning system composed of:

- A **DC motor** associated with a **mechanical coupling**, a **reduction gear** and a **mechanical clutch**;
- A **potentiometer** used as feedback signal for positioning regulation loops;
- A **Linear Variable Differential Transformer** (LVDT) for the protection system;
- A set of **mechanical switches** to determine the operational limits of the jaws;
- A second set of switches used for the protection of the mechanical limits.

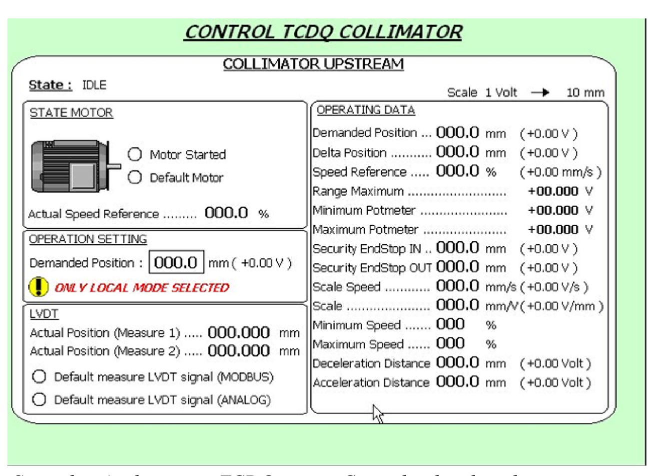


POSITIONING SYSTEM

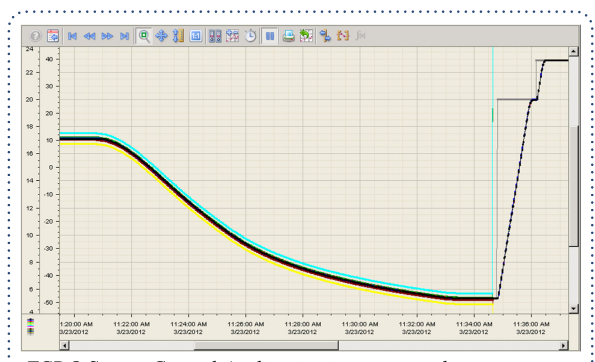
The positioning system is controlled by a SIEMENS® S7-300 and supplies the following functions:
- Motor Drive and Control functions (**MDC**);
- Position and Readout Survey functions (**PRS**);
- Temperature controls;
- Position and speed regulation;
- Fault diagnostics and system security.

LOCAL MODE

Touch Panel (TP) is used to control and test the system in local mode. Communication between the TP and the PLC is based on PROFINET.



Specialist Application – TCDQ system Control in local mode



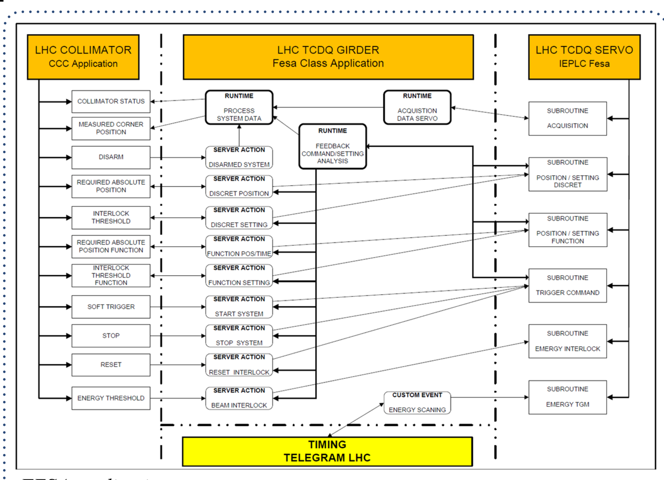
TCDQ System Control Application in remote mode

REMOTE MODE

SIEMENS WinCC Supervision is used to control the system in remote mode. Communication with the PLC is based on the TCP/IP protocol.

FESA Application

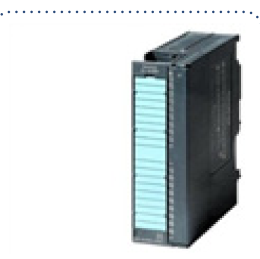
An implementation of the **CERN standard front-End Software Architecture** (FESA) is used to remotely control and monitor the TCDQ positioning system from the CERN Control Center (CCC)



FESA application structure

IMPROVEMENTS DURING OPERATION

After a **review phase** before the start of LHC run 1 and a two years long **commissioning phase**, the system has been continuously optimized during the operation in order to improve the global performance of the TCDQ positioning system.

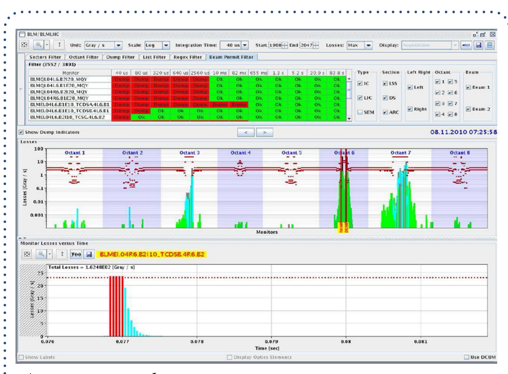


New input analog card for 16 bit of resolution

The input analog card which measures the potentiometer feedback has been replaced by a new version with **16 bit of resolution**. This update has permitted to improve **the positioning accuracy from 100µm to 30 µm.**

A new processor card has been used with **PROFINET network** which improve the **cycle time** and the capacity of treatment

SIEMENS CPU S7-319 PROFINET



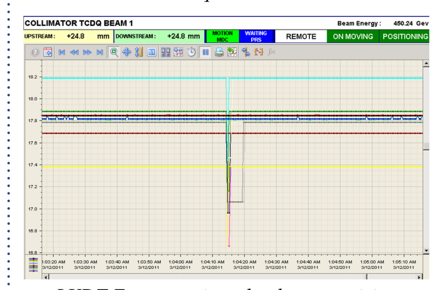
A post-mortem loss maps

An **eXternal Post Operational Check** (XPOC) has been implemented to check the TCDQ state and positions w.r.t the beam position at the time of the beam dump.

OPERATIONAL EXPERIENCE

LVDT acquisition chains have shown to be less accurate than potentiometers and have caused **several disturbances** during the operation phase due to the double conversion mechanism needed for its acquisition (frequency-to-analog conversion followed by an analog-to-digital conversion).

LVDT acquisition module

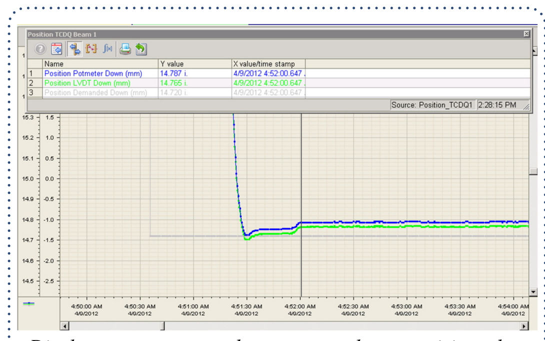


LVDT Error monitors by the supervision

Comparator used to read the mechanical position of the TCDQ jaws

An **error of the mechanical position readout** used during calibration has caused an **offset at the operational position**. This errors has been detected by the external checks prior to the LHC restart.

An **important mechanical clearance** has appeared on the **clutch** inducing a speed regulation disturbance and causing a **displacement error** after a stop of the motor.

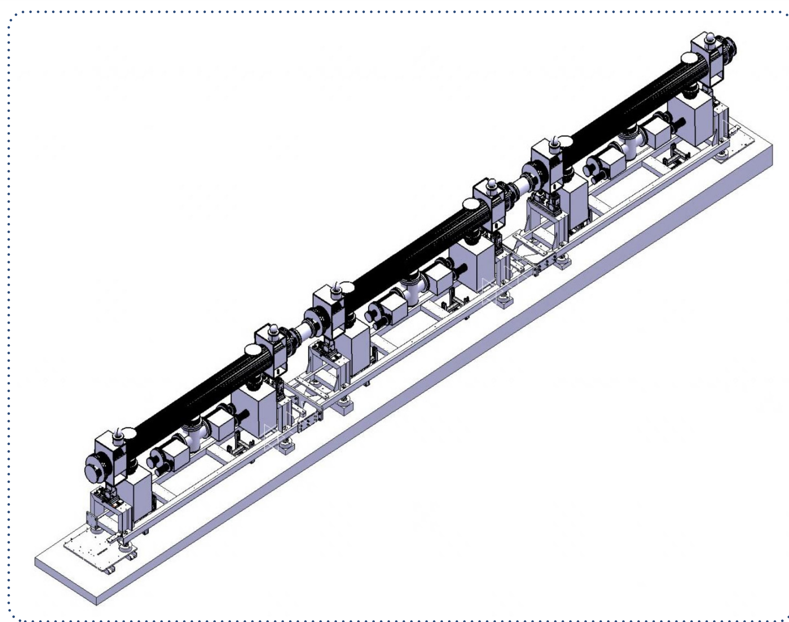


Displacement error can been seen on the supervision when the motor in stopped

FURTHER IMPROVEMENTS

The TCDQ will be upgraded to **three blocks**, each **3 m long, of Carbon Fibre reinforced Carbon (CFC)** housed in three separate vacuum tanks. The three tanks will remain mounted on a **single girder**.

In case of an **asynchronous beam dump** at 7 TeV this longer and **more robust jaw** will allow **dilution of the wrongly kicked bunches without** being **damaged**.

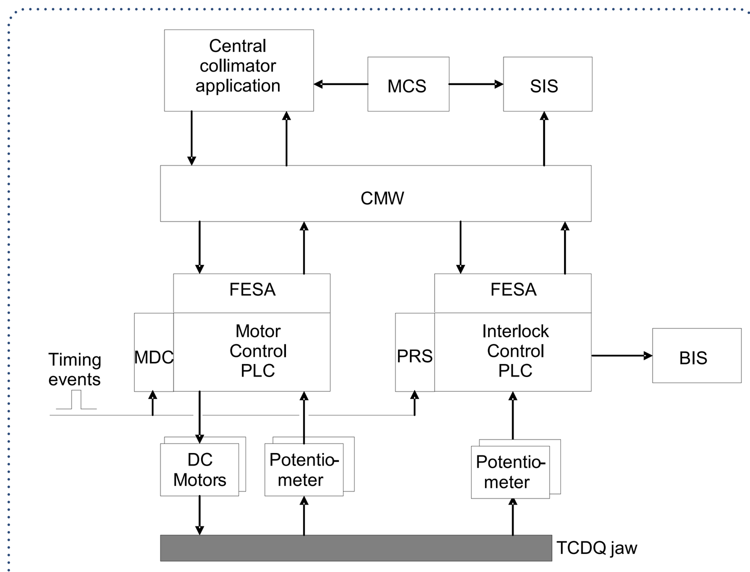


POSITIONING SYSTEM UPGRADE

An **external review** of the TCDQ positioning system has been realized in 2009 and a **common mode failure** at the level of the PLC that ensures MDC and PRS functions has been identified. **The dissociation** into **two separate CPUs** of the MDC and PRS functions will resolve this critical point of failure.

MDC functions:
- Position regulation loops;
- Motor protections;
- Potentiometer references and Position feedback.

PRS functions:
- Controls the Machine Critical Settings (MCS);
- Temperature controls;
- Position limits connected to the LHC Beam Interlock System (BIS).



Architecture of MDC & PRS software

ADD-ON FOR THE NEXT OPERATION

After four years of operation, a new TCDQ will be installed during the 2013-2014 long shutdown. The operational experience gained during this period has highlighted the need of several upgrades in order to continue to improve the performance of the TCDQ positioning system

New output analog card to generate references

New analog output cards with 16 bits of resolution are installed in the positioning system to replace the external potentiometer references. This new feature must allow to **compensate the impedance line** of the cable and **increase the accuracy**

All **LVDT sensors** are **replaced** by **linear potentiometers.** The **first potentiometer** will be used by the **MDC controller.** The **second potentiometer** will be used by the **PRS controller.** A **third potentiometer** will be installed to external position with the **Beam Energy Tracking system** (BETS)

Potentiometer

Camera used for the remote calibration

A **camera** will be installed to **remotely monitor** the mechanical position during the **calibration procedure**.

A **transducer** will be installed to measure the motor current and generate **overcurrent fault**.

Current transducer