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THE NEW SMALL WHEEL LOW VOLTAGE POWER SUPPLY DCS FOR THE ATLAS EXPERIMENT

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Abstract

A series of upgrades are planned for the LHC accelerator to increase it's instantaneous luminosity to $7.5 \times 10^{34}\,\mathrm{cm^{-2}s^{-1}}$. The luminosity increase drastically impacts the ATLAS trigger and readout data rates. The present ATLAS Small Wheel Muon(SW), will be replaced with a New Small Wheel which is expected to be installed in the ATLAS underground cavern by the end of the Long Shutdown 2 of the LHC. Due to its complexity and expected long-term operation, the New Small Wheel (NSW) requires the development of a sophisticated Detector Control System (DCS). The use of such a system is necessary to allow the detector to function consistently and safely and have a seamless interface to all sub-detectors and the technical infrastructure of the experiment. The central system handles the transition between the probe's possible operating states while ensuring continuous monitoring and archiving of the system's operating parameters. Any abnormality in any subsystem of the detector triggers a signal or alert (alarm), which notifies the user and either defaults to automatic processes or allows manual actions to reset the system to function properly. The part that will be described is the modular system of Low Voltage(LV). Among its core features are remote control, split of radiation sensitive parts from parts that can be housed in a hostile area and compatibility with operation in the radiation and magnetic field as in the ATLAS cavern. The new Low Voltage Intermediate Control Station(ICS) will be used to power the Low Voltage Distributor(LVDB) boards of the NSW and through them, the readout and trigger boards of the system providing data and functioning safely.

ATLAS NEW SMALL WHEEL

ATLAS [1] is the largest high-energy physics detector ever built by man. The LHC delivers millions of collisions each second, that take place in the heart of ATLAS. These collisions though, create a dangerous radiation environment, which the detector has to endure. To efficiently handle the increased luminosity of the High-Luminosity LHC (HL-LHC), the Small Wheel (SW) which is the first station of the ATLAS muon spectrometer end-cap system, will be replaced. The New Small Wheel (NSW) [2] will have to operate in a high background radiation region (up to $22\,\mathrm{kHz/cm^2}$) while reconstructing muon tracks with high precision as well as providing information for the Level-1 trigger. The New Small Wheel consists of two detector technologies of gaseous detectors, the first is called small-strip Thin Gap Chambers (sTGCs), and the second comes from the category of micro-pattern gaseous detectors and is named Micromegas (MMG) [3]. The NSW apart from the two new detector technologies is a platform presenting new Custom ASICs and electronic boards. The readout system is based on Front End LInk eXchange (FELIX) housing 2.5 Million readout channels, common configuration, calibration & Detector Control System (DCS) path and new power supply system.

THE NEW SMALL WHEEL DETECTOR CONTROL SYSTEM

In order to monitor and control the operation of the detector, a framework has been devised, which allows for remote supervision and intervention in the detector and its sub-systems: The Detector Control System (DCS) [4].The DCS is simply a Supervisory Control And Data Acquisition (SCADA) system equipped with User Interfaces (UIs), automated scripts and control/monitor functionality. This control scheme is used daily, in the ATLAS Control Room. It is also used by the subdetector experts to guarantee a safe and efficient physics run. The main task of the DCS is to enable the coherent and safe operation of the full detector by continuously monitoring its operational parameters and its overall state.

Finite State Machine Hierarchy

The chosen software used for the back-end system is called WinCCOA [5]. WinCCOA is a highly modular, device oriented product also with event driven architecture. The back-end system, used by all the four LHC experiments, is implemented using this commercial SCADA package. On top of the SCADA package, the Joint Controls Project (JCOP) framework [6] provides a set of software tools and guidelines and assures the back-end homogeneity over the different sub-systems, sub-detectors and LHC experiments. The projects are mapped onto a hierarchy of Finite State Machine (FSM) elements using the JCOP FSM toolkit . The FSM is conceived as an abstract machine that is able to be in only one of a finite number of states at a time. The state can change when initiated by a triggering event or condition (transition state).

System Architecture

The NSW DCS projects closely follow the existing look, feel and command structure of MUON DCS, to facilitate the shifter and expert operations. The top node of both MMG and sTGC will propagate its state and receive commands from the ATLAS overall DCS. Shifters will mainly use the

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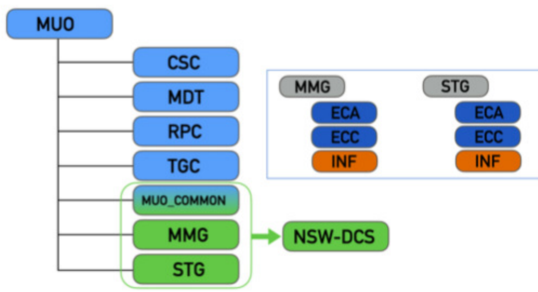

Figure 1: The overview of the ATLAS MUO DCS FSM structure with NSW DCS integration and brief structure of the sub-detector node structure.

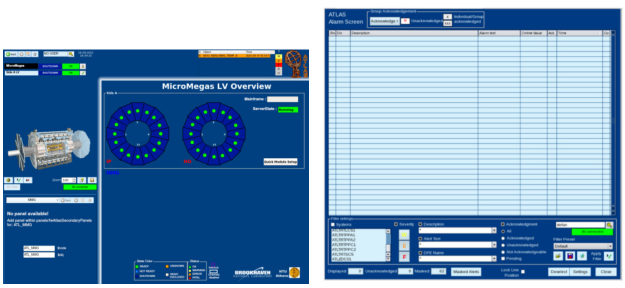

Figure 2: The DCS Overview panel and the Alarm Screen.

Overview DCS FSM panels and DCS Alarm Screen (Fig. 2).

THE LOW VOLTAGE PROJECT

Power Supply

Low voltages for MMG and sTGC are supplied by the widely used CAEN system [7], which is developed for the LHC experiments. Among its core features are:

- Remote control
- Split of radiation sensitive parts from parts that can be housed in a hostile area
- Compatibility with operation under radiation and magnetic fields as in the ATLAS cavern

All the devices are reachable only via the ATLAS Point 1 network. Communication with the control machines is achieved through OPC UA server-client connection. The NSW will be installed at both Side A and C ATLAS End Caps.

The LV CAEN OPC UA servers are also partitioned into Side A and C and deployed on the equivalent host servers. The OPC UA clients, running on the same machines, gather the address space of the individual channel parameters and transmit them to the projects. The two CAEN mainframes of type SY4527 that control the NSW LV also also follow the side architecture of the OPC UA servers and host servers. The mainframes are installed in the ATLAS Service area (USA15). Each mainframe houses 8 branch Controllers.

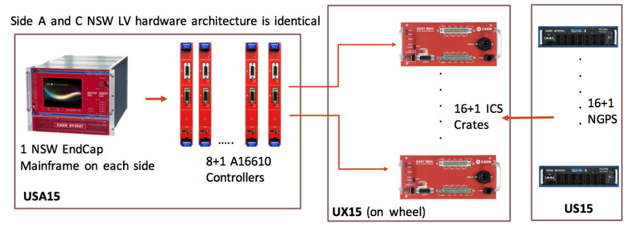

Figure 3: An overview of the installed hardware that is connected to each NSW Endcap.

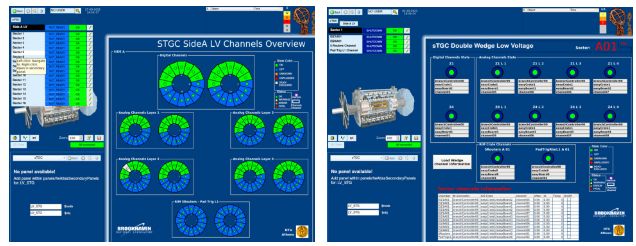

Figure 4: Power supply Control and FSM monitoring panels.

These specifically designed for the NSW branch controllers are connected to the Low Voltage Intermediate Conversion Stage (ICS) modules. ICS will be the provider of the Low Voltage for the readout cards. ICS will be in the hostile environment of the system near to the chambers that are mounted on the NSW.

Each LV controller is connected with two ICS crates, 16 in total for each side. The ICS crates power two adjacent sectors of each sub-detector technology, providing the low voltage for the readout cards. Also two extra ICS are needed for powering the trigger electronics of sTGC detectors. Each Crate hosts 4 modules while every module has 8 output channels, adjusted output channel voltage is 9–11 V and output current 0–17 A.There is also one "virtual" internal channel for general board settings. The LV ICS crates are powered from primary generators called NGPS-30300 with adjustable voltage output. These primary generators are also constructed by CAEN and are located in another service area of the ATLAS experimental cavern (US15). The 34 NGPS primary generators are housed in the allocated NSW racks in US15. The project and CAEN OPC UA server connected to NGPS devices is hosted in a dedicated MUON machine. All the NSW equipment parts were tested and validated by the author with specific automated power cycling and control tests.

Low Voltage FSM

The FSM is based on a strict hierarchical structure with parent-children relations. In this tree-like structure commands propagate from the parents down to the children whereas the states propagate from the children up to the parent on a "most-severe" priority. In this way, when an action is required on all children it is sufficient to give the command to the very top node and correspondingly, the state of the top node summarises the state of all children nodes of

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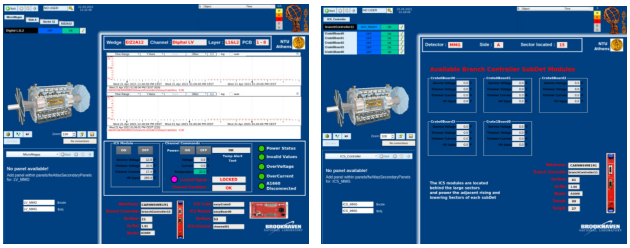

Figure 5: The LV channel node and the ICS Controller accommodating the control panels.

any generation. Three different FSM structures and designs were needed in the case of the NSW LV DCS: the Low Voltage General , NSW NGPS Controller and The ICS module Controller. These three FSM structures are also interfacing through their common hardware parts. The Device Unit (DU) is the base of the FSM and the nodes of this type usually correspond to a device instance and are used to interface to this device. Commands coming from their parents are translated to values, settings of the devices parameters and accordingly, the parameter's values define the node's state which propagates to the highest nodes. A Device Unit node of course cannot contain any children. In the case of the Low Voltage General FSM the DU is a NSW LV individual channel. Each individual channel can be controlled separately while value, status and alarm monitoring is available on the panel. The state and Status of the DU depends on the status data point element of each ICS channel and the communication validity of the OPC UA server.

The design of the ICS Controller FSM DU is based on the channel DU and it is adjusted to accommodate the "virtual" channel error bits. However, the NGPS FSM follows a different design. Each NGPS generator is a DU. This device has different characteristics, functionalities and errors compared to the ICS channel controller. These are seemingly integrated to the control scripts of it.

The projects were validated through daily usage from shifters at the commissioning site as a first stage and then through the NSW control in ATLAS Control room. Except for the FSM design the mapping of channels to detector layers and crates to Sectors was validated. Then the communication with the device setup in ATLAS cavern was established and validated too, The LV FSM operates as expected and is well integrated with the setup in everyday operation.

Interfacing NSW Projects

The NSW LV project will have to interface with the rest of the projects while all are being monitored by the Supervisory Control System.The most important interfacings are the electronics and the temperature monitoring projects. NSW separate configuration/monitor, readout and trigger path consists of 2.4 million readout channels that result in 100 000 DCS parameters. NSW on-detector and cooling temperature monitoring relies on 64 MDT Device Modules (MDM) [8], 32 on each wheel. These devices will monitor the detector

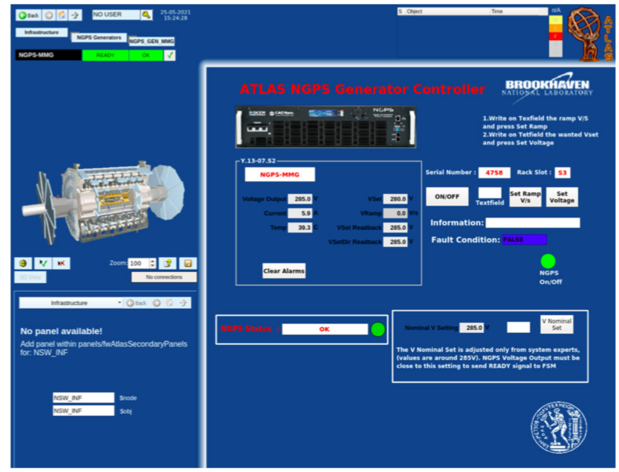

Figure 6: Among others the NGPS DU panel includes: On/Off button, Control of Ramp and Set voltage, Clear Alarms function, Slot and Serial number indications, Vnominal set. Alarms are developed and included to all the aforementioned FSMs.

temperatures and magnetic field. The electronics powering and then the temperature values are directly connected with the LV FSM. In case of alarms incoming from raised temperature value flags, the LV FSM will have to automatically power off the connected devices to avoid failures within the system.

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REFERENCES

[1] The ATLAS Collaboration *et al.*, "The ATLAS Experiment at the CERN Large Hadron Collider", *Journal of Instrumentation*, vol. 3, p. S08003, August 2008. doi:10.1088/1748-0221/3/08/s08003

[2] T. Kawamoto *et al.*, "New Small Wheel Technical Design Report", CERN, Geneva, Switzerland, Rep. CERN-LHCC-2013-006 and Rep. ATLAS-TDR-020, Jun 2013. https://cds.cern.ch/record/1552862?ln=el

[3] T.Alexopoulos *et al.*, "Performance studies of resistive-strip bulk micromegas detectors in view of the ATLAS New Small Wheel upgrade", *Nucl. Instrum. Meth.*, vol. A, no. 937, pp. 125–140, Sep. 2019. doi:10.1016/j.nima.2019.04.050

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[4] A Barriuso Poy *et al.*, "The detector control system of the ATLAS experiment", *Journal of Instrumentation*, vol. 3, p. P05006, May 2008. doi:10.1088/1748-0221/3/05/P05006

[5] WinCCOA, https://www.winccoa.com/.

[6] Oliver Holme *et al.*, "The JCOP framework", in *Proc. ICALEPCS'05*, Geneva, Switzerland, Oct 2005, paper WE2.1-6O. https://inspirehep.net/literature/699121

[7] CAEN SpA Power Supply systems, https://www.caen.it

[8] Robert G.K. Hart, G. Bobbink, H. Boterenbrood and S. Zimmermann, "The ATLAS MDT Control System", in *Proc. ICALEPCS 2009*, Kobe, Japan, paper TUP079, pp. 263–265.

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