DCS Development of the MicroMeGaS detector for the New Small Wheel

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Abstract

In the context of the ATLAS New Small Wheel (NSW) Phase-I upgrade a prototype detector was built, the so called, “MicroMeGaS for the Small Wheel” (MMSW). This new detector is “aligned” to the ATLAS general baselines for the NSW upgrade project. The MMSW will be installed in ATLAS and will be readout and monitored through the common infrastructure. Hence, the necessity of an intuitive control system is of vital importance. The aim of this note is the description of the development and implementation of a Detector Control System (DCS) for the MMSW detector the so called “ATLAS DCS MMG”.

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1 Introduction

A MicroMeGaS [1, 2] prototype with four planes (MMSW) will be installed, as part of the ATLAS New Small Wheel (NSW) project, on the HO structure (Side A) next to the end-cap. The installation will be carried out during 2015, in order to test this prototype in LHC beam conditions during Run-II. To remotely control the prototype, the MMSW Detector Control System (ATLAS DCS MMG) was developed, following closely the existing look, feel and command architecture of the other Muon sub-systems, in view of being a basis for future developments for the final NSW DCS integration. The principle task of the DCS is to enable the coherent and safe operation of the detector by continuously monitoring its operational parameters and its overall state.

2 Finite State Machine (FSM)

The FSM [3] 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). A particular FSM node is defined by a list of states, and the triggering conditions for the transitions between them. Figure 1 depicts the ATLAS FSM architecture. The Global Control Station (GCS), which is in supervision of the overall operation of the detector, provides high level control and monitoring of all the sub-detectors; the execution of the commands and the data processing are managed at the lower levels. Sub-detector Control Stations (SCSs) constitute the middle level of the “back-end” architecture.

Figure 1: The ATLAS DCS architecture.

The SCS allows the full local operation of a sub-detector. The DCS activates the supervision of the equipment using commands, processes and actions on the operational parameters of the detector. It is also responsible for the communication between the internal parts of the system and with external control systems. At this level in the hierarchy, the connection with the Data AcQuisition (DAQ) system is
established in order to guarantee the synchronization between the detector operation and the physics data taking. For this purpose the sub-detector is divided into partitions which are based on the DAQ TTC (Timing, Trigger and Control) zones [2]. Both systems are synchronized via the DAQ-DCS Communication (DDC) software package. The FSM plays an important role, reporting the DCS state of the TTC zones to the DAQ and executing commands received from DAQ. The final part of the FSM hierarchy on the back-end side, is the Local Control Stations (LCSs). This layer provides the low level control and monitoring of the SCS services, executing all the received commands from it and at the same time is able to trigger autonomously predefined actions if necessary. Each LCS is in charge of a certain system within the sub-detector (i.e. HV, LV, Racks, gas, cooling, etc). The lowest level is composed of Device Units (DUs) which implement the connection layer between the FSM and the hardware, defining in such way the granularity of the system. Everything below these boundaries is not accessible through the FSM.

3 Communication

The WinCC-OA is not a control system but a tool in order to built one. It can be used to connect and parameterize software and hardware devices, to acquire the data they produce and use them for their supervision. For the correct establishment of the communication between the above Control Stations and their objects, specific communication protocols need to be used. The communication method varies depending on the device used and hence in this section the most vital protocols that WinCC OA is using are presented. These are the widely used OPC and the DIM protocols.

3.1 OPC Protocol

In order to communicate with the hardware, DUs use the OPC [4] standard. The acronym OPC derives from the “OLE (Object Linking and Embedding) for Process Control” and is implemented in server-client pairs. OPC was designed to provide a common bridge for Windows based software applications and process control hardware, providing a set of standard interfaces, properties and methods, such that any OPC client can connect/disconnect, obtain information and read/write data in a standardised manner from a process control device (Figure 2). An OPC server is an abstraction layer between the real hardware and the user. It implements the configuration needed in order to initialize the communication with the hardware and provides easy access to the data, which are available from the hardware.

3.2 Distributed Information Management (DIM)

The WinCC-DIM [5] toolkit allows WinCC to communicate with devices which are not using any of the protocols supported by WinCC (such as OPC). The interface can be used across different platforms (Windows and Linux) and in our case will be used for the communication with the DDC software package. WinCC can behave as a DIM Client or as a DIM Server.
4 The ATLAS DCS MMG sub-system

The DCS is responsible for the safe and coherent operation of the detector. All ATLAS sub-detectors have their own local DCS, controlling and monitoring the sub-detector and its equipment. The detailed architecture of the local DCS relies on the structure of the general DCS system of the ATLAS experiment and on electronics architecture. Each sub-detector is implemented and organized in a unique way but it must also conform to the guidelines defined by the ATLAS central DCS [5, 6]. When special requirements need to be handled by the detector then tailored solutions must be applied.

4.1 ATLMMGSCS: Architecture and Hardware

To operate the MMSW detector, high and low voltages need to be applied. They are supplied by the widely used CAEN system due to its scalability. The MMG sub-system consists of two CAEN mainframes, one for each channel type. The first chain contains the CAEN SY1527 [7] hosting two A1821(P/N) HV boards [8] located in USA15. On the contrary, the LV chain uses an A1676 branch controller [9], installed on the CAEN mainframe SY4527 in USA15. The chain completes with one CAEN Easy Crate (Easy3000) which hosts one A3025B [10] low voltage board and is located in the detector cavern (UX15) due to their radiation tolerance. The SY4527 mainframe [11] is powered externally by a service power system. This is a CAEN 48V AC to DC converter installed outside the cavern in US15. The communication with the control machines is achieved through an ethernet based OPC server-client connection. The first OPC server (ATLMDTPS3OPC) for the LV and the second OPC server (ATLMMGSCSOPC) for the HV, are deployed on an MDT (vmatlmdtps3) and on a MUO (vmatlmuos01) Windows 2008 virtual machine, respectively. The OPC clients, running on the same machines, gather the address space of the operational parameters and transmit them to the MMG control station. Finally, the infrastructure consists of a VME Wiener Maraton Crate\(^1\), able to provide the high current needed.

\(^1\)https://wikis.web.cern.ch/wikis/display/EN/WIENER

Figure 3: ATL.MMG connection chain
which hosts the readout drivers and the Remote Control Modules (RCM’s). The power to the Maraton devices is provided by primary rectifiers (PFC) installed in US15, providing 380V. All the components of the VME Crate are connected on a chain and controlled via a dedicated CANbus on a 16-port CAN Systec device. The Systec device\(^2\) is connected via USB to an MDT (pcatlmtdmdm7) control machine. An OPC client sends the address space to the MMG machine through ethernet and makes the control and the monitoring possible (Figure 3).

### 4.2 ATLMMGSCS: FSM Hierarchy

The MMG project is located under the MUON FSM tree (Figure 4) and it is composed of two Control Units (CU) that correspond to the MMSW detector power supply and its infrastructure sub-tree (Figure 5). The first CU is represented by the homonymous node under the MMG top node. It includes both HV and LV channels, which are the lowest nodes of the FSM hierarchy, the so-called, Device Units (DU). The second CU, the INFRASTRUCTURE, consists of two main nodes, the CAEN SYSTEM and the VME CRATES. The VME CRATES node hosts only the Wiener VME crate DU. On the contrary, the CAEN SYSTEM, contains the two mainframes, the CAEN SY1527 and the CAEN SY4527 for the HV and the LV respectively. The SY1527 includes the DU nodes for the respective A1821(Positive and Negative) HV boards. The other mainframe includes a CU A1676 branch controller which controls an EASY3000 crate. The chain is completed by a DU A3025B LV board. Figure 5 shows a representation of the MMG FSM hierarchy. There are two nodes, the MSW node which corresponds to the Power Supply and the Infrastructure which refers to the hardware. The commands are propagated from the top node to the lower, in the devices of the chain, while their states and statuses, are propagated upwards. The top node of MMG, propagates its state and receive commands from the ATLAS overall DCS.

![Figure 4: The MMG top node at the MUON tree.](image)

### 5 ATLAS DCS MMG: FSM OPERATION PANELS

In 2014 a module of four micromegas with an active area of 95×48 cm\(^2\) was built. This module is the first attempt to study the performance of a detector “stack” \(^2\). It is the first micromegas quadruplet built according to the NSW specifications. For each individual layer, a main panel has been developed, providing the user with useful information, reflecting the state and status of the detector, while a secondary

\(^2\)https://wikis.web.cern.ch/wikis/display/EN/Wiener-Systec+Config+Consideration
Figure 5: The MMG FSM Hierarchy.

panel provides supplementary or of secondary significance details. The FSM and the panels follow the state/status color convention of the ATLAS DCS making the supervision of the detector easy.

5.1 Operation Panels

In WinCC-OA, all the graphical user interfaces (GUI’s) for the process operator are called “panels” and they are created with fixed dimensions\(^3\) using the GEDI graphical editor. The panel which is the actual operator’s screen, contains several elements providing the monitoring of the system and allows the control of the detector and the navigation along the different levels of the DCS hierarchy.

One of the most important components of the FSM operator’s screen is the FSM node browser (on the top left in Fig. 6). It displays the specific parent node and its children with their corresponding STATE and STATUS. The STATE button can be used to issue commands (actions) to the respective FSM node if applicable. Navigation history is kept and also a navigator similar to that of web browsers, having four buttons for its “direction” (Back, Forward, Home and Up) is provided. Another important component of the FSM screen is the main panel, which is associated with the selected node, showing information related to the specific hierarchy. The supplementary to the main panel component, is the secondary panel. This carries information of secondary significance and allows for a navigation independent from the main navigation. There is also a “Problem list” screen where the relative to the system alarms with their time stamp are displayed. Finally, all the panels (main and secondary) which are associated with a certain FSM node must follow the naming convention that has been established by the ATLAS DCS community.

5.1.1 The MMG panel

The MMG DCS project closely follows the existing look, feel and command structure of CSC and MDT DCS, to facilitate the shifter/expert operations. It is mapped onto a hierarchy of Finite State Machine (FSM) elements using the JCOP FSM toolkit. A general review of the graphical user interfaces of the

\(^3\)The dimensions of the main panel are 859x866 and for the secondary panel, 381x390.
MMG top FSM node and its infrastructure is shown in Figure 6, 7 and 9. On the top left of the main panel region (Fig. 6), the position of the MMSW chamber in the ATLAS cavern is shown and on the top right the geometry of the MMSW is presented accompanied by the FSM state and status (green trapezoids on the center and on the right respectively) for each layer. In the center, there are four indicator boxes, where one can monitor the individual channel STATE belonging to the respective layer. At the bottom part the four layers of the MMSW are presented with all the additional information making the task of the shifter/expert easier. In order to have a broad in content image of the chamber each of them has a “zoom in” button which leads to a “pop-up” panel that holds both voltage (HV and LV) and current online values with the ability to trend information from the archived values.
5.1.2 The MSW panel

Following the same architecture as before, in Fig. 7, the main panel of the MMSW detector is presented. On the central window the MMSW geometry dominates. It has been divided into four parts (top, bottom, right, left) accompanied by their respective channels. For each channel a trapezoidal schema has been developed in order to indicate its STATE using the same functionality as the FSM nodes. A supplementary trapezoid also completes the scheme displaying the STATUS. On the left area of this panel there is a summary list with all used channels and a cyclical indicator shows whether a channel is switched on or off. A color legend chart is attached to all panels, in order to introduce to the user the possible states and statuses of our detector.

![Figure 7: The main panel of the MMSW](image)

Similar panels have been developed for all FSM nodes (channels, boards, etc.) following the ATLAS DCS conventions in order to facilitate a coherent and intuitive way for a smooth operation. Fig. 8, 9 show two examples of such panels which will be discussed in detail in the following sections.
5.2 The Wiener VME Crate panel

One of the most commonly used bus standard in the experimental area of high energy physics is the VME (Versa Module Europa). It is a high performance bus system with a multiprocessor capability. In general, all CAN devices are controlled by a dedicated OPC via a PCI CAN interface card but there are cases where they can also be controlled via the Systec USB gateway. Internally, the Wiener OPC Server uses the Kvaser API to communicate with the CAN hardware. In order to use the Systec USB gateway the calls to the Kvaser API must be mapped to the Systec API. EN-ICE provides a wrapper DLL which maps Kvaser $\rightarrow$ Systec API calls\(^4\). The crate main panel is shown in Fig.8. On this panel, the general state and status of the VME crate are presented supplemented by information of the primary monitored parameters (OPC server connection, Bus communication, etc). Moreover, the values of voltages, currents, cooling air temperatures, fan speed, power dissipation of inserted modules and power supply state are some of the parameters displayed.

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\(^4\)https://wikis.web.cern.ch/wikis/display/EN/WIENER

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Finally, the VME crate monitoring is completed with the information about the crate model, its location at USA15 and a group of alarms indicating the status of the parameters of vital importance for the crate.
5.2.1 The CAEN SY1527 panel

This panel accurately reflects the basic image and functions of the CAEN SY1527 mainframe, using a summary list of dpe’s of primary significance on the right, such as the OPC Server and Client connections, the communication status of the mainframe, the stable beam signal, etc. Moreover, on the bottom of the panel, there is a new feature showing the fans of the mainframe from where the user can monitor their rotation speed (in rpm). These are connected to the respective datapoint _config and if their value deviates from a predefined “good” range then the rotation speed changes generating an alarm. Finally, on the top there are three buttons; starting from the left, the “EXPERT ACTIONS” menu contains the fundamental commands that a mainframe can receive, the “CLEAR ALARMS” and the “KILL ALL CHANNELS”. Moving to the right, the “Alert config” button navigates the user to a second panel from where the alert can be configured and monitored.

Figure 9: The main panel of the CAEN SY1527 mainframe.

5.3 The creation and the configuration of the FSM structure

The creation of the FSM is not a trivial task and that’s why a dedicated service panel was developed. The specific panel is presented in Figure 10 and is devoted to the configuration of the FSM tree. Using the first button, the FSM tree is built for the whole MMG system from scratch. The next step is to set the labels of every node so that a name will appear on the FSM tree panel instead of the default node.
name. This is achieved by the second button. Finally, the assignment of the dedicated panel to each FSM node is done using the third button. It is worth mentioning that there is a simultaneous assignment of the secondary panels since they are predefined with the same name as the main panels adding the suffix _info. When a tree is built from scratch using this panel, it is essential not only to generate and start the FSM in the Device Editor and Navigator (DEN) User Interface but also to stop it before applying anything of these.

5.4 The Archive Handling

In order to have a more efficient supervision of the hardware some internal tools are used, like the condition database\(^5\). It archives and manipulates the values acquired from the hardware. To use the full spectrum of the database we need first to set the archive\(^6\) in the datapoint elements of interest. In order to achieve this, we have to use the service panel where an extra button exists, dedicated to the archive handling of our project. The button navigates the expert to a new panel (Fig. 11) from where the manipulation of the archiving for all the HV/LV channels simultaneously is possible. Specifically, this panel is able to check the existence or not of the archive config, to set, to start, to stop and to remove the archive configuration. Looking on this panel one could recognize on the bottom right a “pop-up panel” button. This leads to a panel (the right panel in Fig. 11) that is used to edit the archive config of a single or multiple channels in the system.

The archiving starts by pressing the “START” button, while there is an option to be stopped by pressing the “STOP” button. Similar to these, there are two more buttons, one to set the archiving (“circled plus

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\(^5\)WinCC-OA has a built-in database where all the data coming from the connected devices are stored in real time. These data are structured in form of Data Points (DP) of a predefined Data Point Type (DPT). A DPT describes the data structure of the corresponding connected device. DP contain the information and the values coming to the device. The structure of a DPT is defined by the user and can be as complex as needed. The creation and modification of the DPT and the DP can be done either by using the graphical parameterization tool (PARA) or by using programming code with the control scripts.

\(^6\)Each DP element can accommodate different sub-elements named “_configs”. With the use of these _configs the user is able to parameterize the DPT and also to add some functions such as the archiving of the values and the automatic creation of alert signals.
signed” button) and one for the removal (“circled dustbin” button) of the archiving. In order to monitor the procedure there is a debug screen where the progress of each step is displayed. Supplementary to this on the top of the panel there is an indicator showing the running procedure.

Figure 11: The panels for the archive handling of the MMG project. On the left there is the main archiving panel where the full archiving is done. On the right panel, one is able to configure one or multiple channels simultaneously.

5.5 The Alarm Handling

The MMG DCS project deals with the values that come from the channels, the boards, and the mainframes of the MMSW detector. The project monitors a big variety of datapoints, some of them are for pure monitoring while others are to accommodate the alarms. Fundamentally, the alarm handling [14] is based on the continuous check of a predefined limit, boundary, text, state or status. For instance, if the value of the entity deviates from the “good” range, an alarm is automatically generated on the supervisory station in order to inform the operator. The alarms are added to the datapoint elements as “alarmHandling” configs. It is highly recommended for the safe and efficient operation of the MMG system to add alerts in the datapoint element values (DPE). To facilitate this, a panel for the alarm handling has been developed (Fig. 12).

The aim of this panel is to set and handle the alerts for each DP. Starting from the top, there are two
screens from where the channel selection is possible. Then, by using the buttons below one can add alarms to the selected channel. Due to the wide variety of the alarm types there are different sets of regions for each DPT (board, branch controller, mainframe, opc server, etc.) containing specific actions (set, activate, deactivate and delete). At the right of the panel there are two frames with 3/4 region alerts in order to set the temperature alert for both the HV/LV boards. Last but not least, at the bottom of the panel there is a screen which displays information about the progress of the current action.

Figure 12: The panel for the alarm handling of the MMG project.
6 Alarm Screen

The alarm screen presented in Figure 13, shows the list of current alerts within the whole ATLAS DCS system. The alerts are derived from individual hardware or software component malfunctions. During operation, any pending alert should be followed up according to its severity such that the alert condition is removed. In principle, any DCS hardware device controlled from the back-end software, can generate an alert, resulting in a potentially large number of simultaneous active alerts. Consequently, the alarm screen has an intuitive capability of offering a wide range of functions. The alarm screen "Filter" on different alert categories such as systems, alert description, alert text, alert severity, timestamp, etc., using and managing predefined and custom filter settings. In addition, it shows an overview information of the system and its alerts and queries the history of them. In general, the alarm screen is a tool which plays an important part to the final implementation and operation of the monitored system.

![Alarm Screen Diagram]

Figure 13: Alarm Screen

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