ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOCPR03

PLANNING OF INTERVENTIONS WITH THE ATLAS EXPERT SYSTEM

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Abstract

The ATLAS Technical Coordination Expert System is a tool for the simulation of the ATLAS experiment infrastructure that combines information from diverse areas such as detector control (DCS) and safety systems (DSS), gas, water, cooling, ventilation, cryogenics, and electricity distribution. It allows the planning of an intervention during technical stops and maintenance periods, and it is being used during the LS2 to provide an additional source of information for the planning of interventions. This contribution will describe the status of the Expert System and how it is used to provide information on the impact of an intervention.

INTRODUCTION

The ATLAS [1] Expert System [2] is a diagnostic tool created by ATLAS Technical Coordination to increase the knowledge base of the ATLAS experiment, allow easier turn over of knowledge between experts and foresee complications before the interventions take place. It describes different systems like sub-detectors, gas, cooling, ventilation, electricity distribution and detector safety systems which result in an extremely complex tree of relations between them. It consist of a friendly user interface in the form of a graphical simulator which allows the user to simulate an intervention and to foresee its consequences on all the other systems of the experiment.

The requirements of the ATLAS Expert System are the following:

- Provide a description of ATLAS and its elements in a way that is understandable to a multidisciplinary team of experts.
- Emulate the behaviour of the sub-systems to foresee possible consequences of interventions.
- Help to understand what would remain operative in case of events like fire or electrical perturbations.
- The simulator has to accept input from the user and quickly answer how ATLAS would behave with the given input.
- Use standard technologies as possible to simplify maintenance.

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Goals

The goal of the ATLAS Expert System is to become an important tool in the Technical Coordination of ATLAS as part of the standard procedure prior to an intervention and to be a helpful tool in the ATLAS Control Room in many situations.

It can help in the diagnostic of a complicated problem. For example when a system is out of power and the reason is unknown it can help to find what are the possible causes. It also can help to take a quick and well educated action when time is critical and experts are not available.

Brief Description

The ATLAS Expert System contains a virtual representation of the ATLAS experiment which is presented to the user in the form of visual diagrams. This representation is also a simulation that imitates the behaviour of the infrastructure of ATLAS. In this simulation the user can take actions like switching off a system or triggering an alarm. Once an action is taken, the simulation is executed and the user can immediately see the consequences. The units of the structure are the systems, which normally can accept one input, either to be switched on or off. Different ways of obtaining information are available to the user such as list-oriented interfaces and different deduction explanation levels.

The construction of the ATLAS experiment was completed in 2008 and more than ten years after the completion, the reliability of certain systems is decreasing over time. The ATLAS Expert System was started in 2016 and the following sections of this document summarises the current state of the Expert System description of ATLAS and outlines the last improvements in descriptions and tools.

ARCHITECTURE

From a technical perspective the system is divided in three well separated components: database, python server and a web application.

Backend

The backend is composed of the database and the python server. The database stores all the information about the elements that describe ATLAS and the relations between them. The database used is the ATLAS TDAQ object oriented configuration database, so called Object Kernel Support (OKS) [3], which holds the description of objects, classes, relationships, inheritance and it is expected to be maintained during the life of the experiment. To simulate the ATLAS

ISBN: 978-3-95450-209-7   ISSN: 2226-0358   doi:10.18429/JACoW-ICALEPCS2019-MOCPR03

infrastructure we require three very general categories of entities: the different types of actual equipment, alarms and actions. These categories are represented in the database as classes. The improvement in the granularity of the description is reflected in the growing database, which currently is 62 classes and 9747 objects. Figure 1 shows a chart of the database objects. Class attributes and relationships represent system properties and connected systems. As example, physical racks are described using the class "Rack". Relevant properties and behaviours for the simulation are for example: what is the power source (*poweredBy*), computers contained in the rack (*contaniedIn*), interlocks (*interlockedBy*) or cooling requirements (*waterFrom*). Given that many of these attributes are common among types of systems inheritance is used. This makes easier describing new systems with new classes. Super classes provide often used attributes like "poweredBy" or "requiresCoolingFrom". Figure 2 shows the super class "coolingReceiverBase".

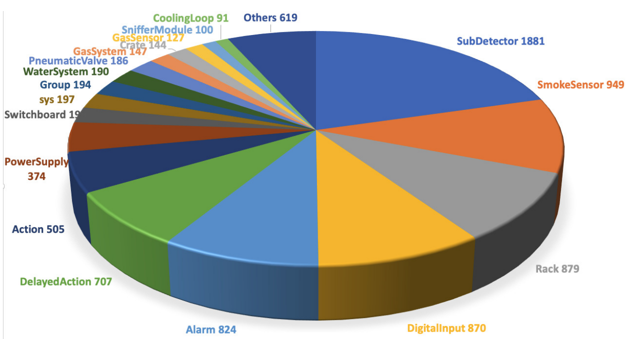

Figure 1: Layout of papers.

A python server reproduces the behaviour of the ATLAS experiment using the objects and their relationships in the database: it loads elements and relations from the database, provides the scenario to the user using the web application, receives user inputs in the scenario and provides the answers to the given inputs.

Frontend

The user interface is a web application with standard JavaScript and PHP. An in-system diagram editor has recently being developed to move from static to dynamic images based on MXGraph [4] library. This new approach can open the possibility of database-generated diagrams and the use of metadata for better visual representations. Python server, web server and client side communicate with each other using standard protocols like JSON, AJAX and HTTP.

ATLAS DESCRIPTION

The Expert System user interface has currently 90 diagrams to simulate the most relevant parts of the ATLAS infrastructure.

Electricity

Electricity is summarised in a general electricity distribution page shown in Fig. 3. 18KV lines, diesel, UPS, Racks

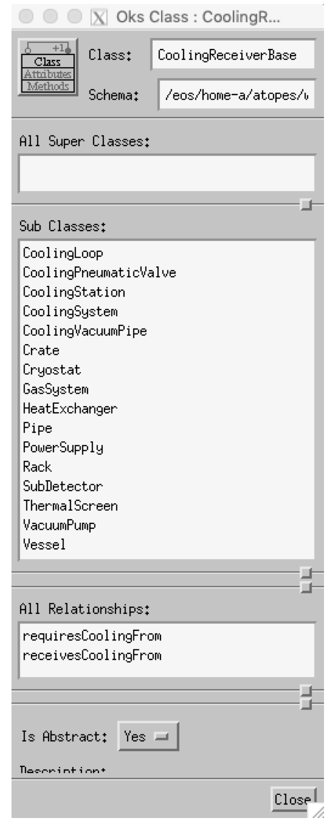

Figure 2: Base class for cooling receiver systems.

and magnet electricity are described in detail in their own page.

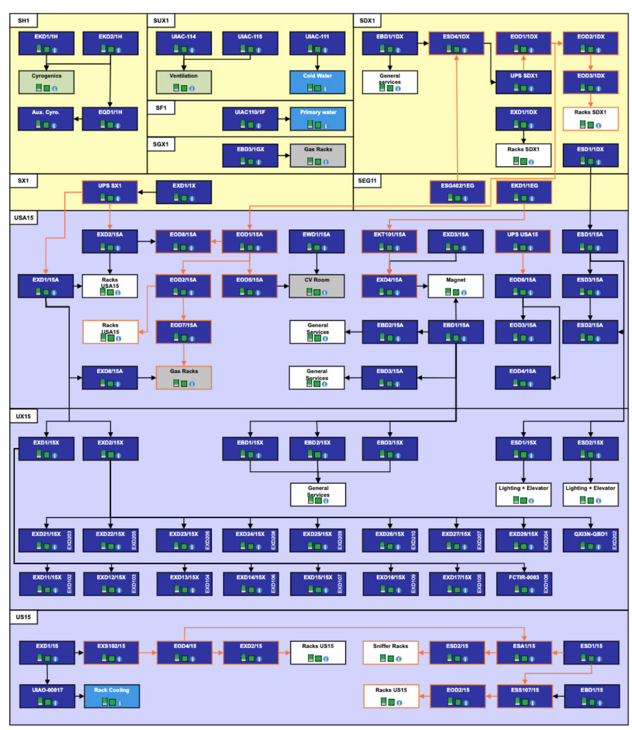

Figure 3: General electricity distribution page.

17th Int. Conf. on Acc. and Large Exp. Physics Control Systems ICALEPCS2019, New York, NY, USA JACoW Publishing
ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOCPR03

Water

There is a general water distribution page shown in Fig. 4 and a detailed page for each zone.

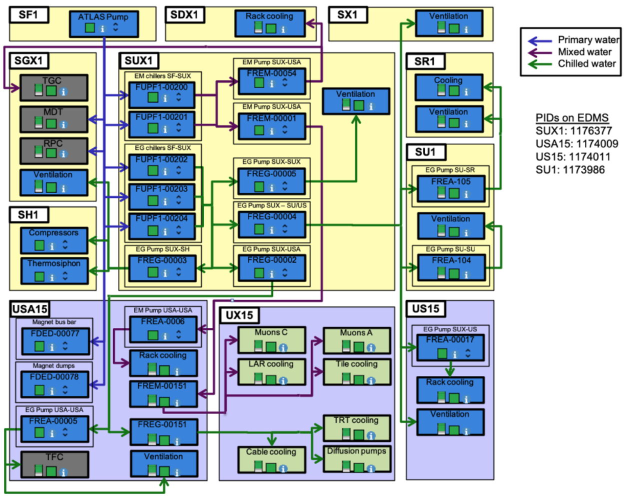

Figure 4: General water distribution page.

Cooling

Cooling description is described in several detailed pages: US15, UX15, TRT, muon cooling loops, detector cooling, evaporative cooling system and IBL. The granularity of the descriptions is up to individual rack and it meets the individual subdetector requirements.

Subdetectors

Subdetectors have been recently described in detail. Figure 5 shows the summary status page and detailed description of IBL, Pixel, SCT, TRT, LAr, Tile, RPC, MDT, CSC, TGC and FTK.

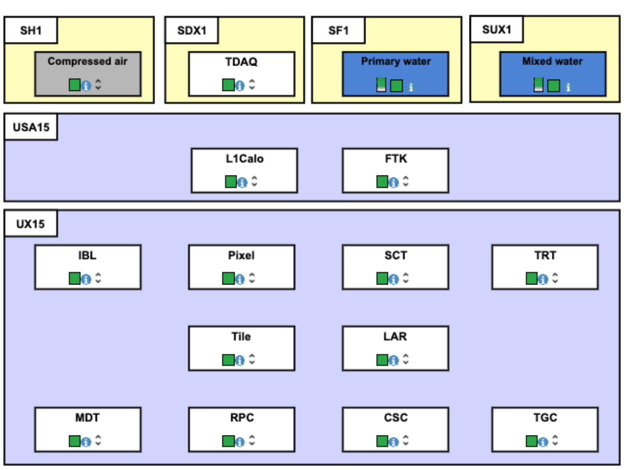

Figure 5: Detector status page.

Safety

ATLAS Safety infrastructure focuses on fire, water, gas detection and the Detector Safety System (DSS). Currently every smoke and gas sensor has been described in the Expert System, 949 smoke and 127 gas sensors linked to their respective central. This description lets the Expert System to foresee the consequences of each sensors in the detector and service cavern. A positive signal on a sensor is read by its central which triggers alarms and actions that have been recently described in the Expert System. Figure 6 shows the implementation for gas and fire detection in the Expert System.

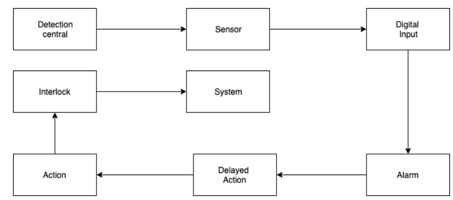

Figure 6: Diagram of smoke and gas detection.

Others

There are other systems described such as cavern lighting, computing racks, compressed air, cryogenics, ventilation and elevators.

SIMULATIONS

Checking the Expert System descriptions accuracy relies on different approaches: postmortem analysis of intervention and events, documentation and experts advice. New concepts and systems of ATLAS are constantly being added and improved to the simulation which implies many changes in database and server. To prevent duplication or inconsistencies an effort of simulation tracking and revision is required.

New Simulation Concepts

The latest concepts introduced in the simulations are: electrical repowering on switchboards to simulate when a switchboard has a manual change of power source, PLC and interlock control from one object to another, LAr cryogenics and vessels, magnet vacuum and smoke and gas sensors with zone coverage.

Simulation Tools

Simple systems have been fully checked with documentation sources. More complex systems that do not have a single data source have to be crosschecked with intervention outcomes and experts advise. Detector Safety System (DSS), gas and smoke detection have been proved 100% accurate. The following tools help to verify the accuracy of the simulations:

- Continuous integration aiming to improve simulation consistency. This tests are performed in the back end every time there is a new version. Changes in the simulations are manually checked.

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- Simulation reports are stored and can be loaded to manually check differences.
- There is an integrated tool to upload logs from the DSS system. This log is compared with the simulation and checks for differences.
- Importing tools to automatically import data from other sources. There is an automatic tool to check the DSS data with the Expert System database. There is a first version of an REST interface to exchange data with ATLAS Central Equipment System (ACES) [5].

Simulations and Interventions

As example of a simulation, the IBL (Insertable B-Layer) CO2 cooling plant is one of the most critical systems in ATLAS, it removes all the heat produced inside the IBL detector. Failures in the plant have severe consequences in the detector and thus unexpected shutdowns are to be avoided.

A power glitch on December 2018 affected the production of compressed air but not the IBL cooling plant directly. There is no backup for compressed air which was required by two key systems in IBL CO2 cooling. Only after the postmortem analysis in the Expert System the dependency on compressed air by the IBL cooling plant was understood as seen in Fig. 7. In this case the Expert System easily outpoints the strong dependency of the IBL cooling on compressed air, a fact that was not obvious event to cooling experts and it helps understanding the situation in the ATLAS Control Room.

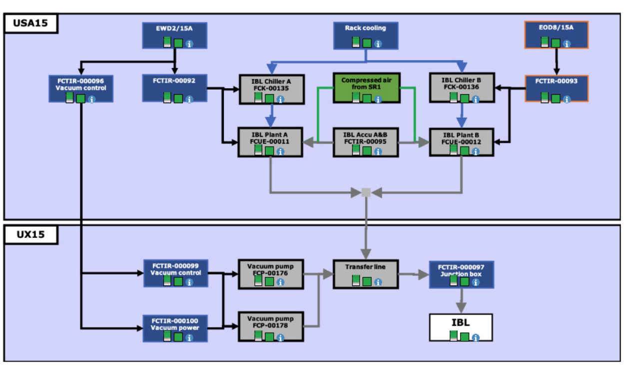

Figure 7: Diagram IBL cooling.

Another situations were the Expert System can prevent small interventions becoming major incidents are safety tests on which the Expert System can quickly evaluate the risk of an intervention and planing counter measures.

Portability

Documentation is the Expert System primary source of knowledge. The majority of the knowledge is obtained from CERN's Engineering Data Management System (EDMS). Secondary sources are imported data from other sources like DSS and ACES, visual inspections and experts advise.

The Expert System implementation is close to a model-view-controller pattern as shown in Fig. 8 and all license are free to use. Adapting the ATLAS Expert System to another detector is possible since types of systems and relationships would be very similar. The first step would be to fill the database with new elements and using the same superclasses with slight modifications. The second would be to create the adapted diagrams to the new infrastructure. Migration would be easy from the application point of view, remaining as main task the knowledge acquisition.

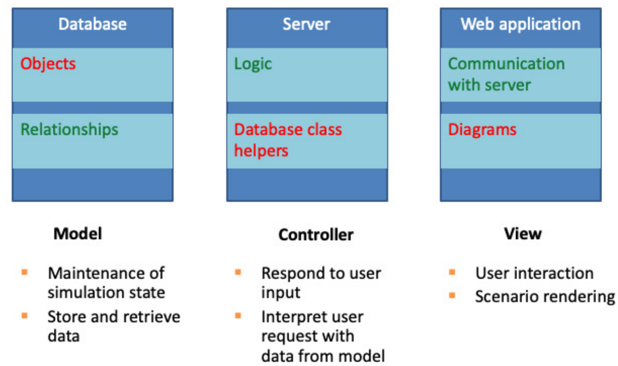

Figure 8: Description of the system. Red items are ATLAS specific.

CONCLUSIONS AND NEXT STEPS

An Expert System of the ATLAS experiment has been developed by ATLAS Technical Coordination. The descriptions and simulations cover all the most relevant aspects of ATLAS. It has been proved useful evaluating the impact of interventions. The granularity of the descriptions and the simulations has reached the goal in most of the subdetectors and systems. Simulations have been compared with actual intervention outcomes during LS2. Future plans include the ability to search the causes of current state in the simulations and the automatic production of impact matrix as tools to plan interventions.

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