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SAFETY OF CMS EXPERIMENT SYSTEMS OPERATION – INTEGRATION OF A NEW CO_2 FIRE EXTINGUISHING WEIGHING SYSTEM TO THE CMS SAFETY PANEL

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Abstract: The subject of the article is the integration of a new CO_2 fire extinguishing weighing system to the panel displaying the status of Compact Muon Solenoid (CMS) detector safety systems (CMS Safety Panel) at CERN. The CO_2 fire extinguishing system is responsible for protection of unique control devices, so safety of its operation and the weighing system was designed to monitor the state of it and make it reliable. CMS Safety Panel displays status of safety systems used in CMS Experiment and it is based on JCOP Framework that guarantee compatibility of all the projects. The integration of the new CO_2 fire extinguishing system to the CMS Safety Panel requires that the system meets the assumptions that other projects fulfil and allows for clear monitoring of its situation along with the rest of the security systems.
Keywords: safety systems, Python programming, sensors, WinCC OA, CERN

1. INTRODUCTION

The need of having CO_2 fire extinguishing system integrated to the CMS (Compact Muon Solenoid) Safety Panel was triggered by complicated maintenance procedures and past accidents. An automated solution was necessary in order to monitor current state, analyze collected data, react faster and make system safe for people working around. Main activities that had to be done at the very beginning to achieve those goals are study on software and hardware that can be used for described purpose, getting knowledge about technology and behavior of sensors (Fraden, 2010); checking Python programming language capabilities in the field of data analysis and possibilities of communication for mixed environments (Henley and Wolf, 2018). Next, practical steps are writing scripts that allow for data collecting and analysis, preparing tests for designed solution, implementation on an example of one sensor, SCADA

(Supervisory Control and Data Acquisition) system development according to requirements set for all CMS systems.

2. METHODOLOGY OF RESEARCH

The project consists of hardware and software components. Each of them had to fulfil specific requirements that were main criterions during the research.

2.1. Hardware and software

SEN-13332 sensors were used to measure the weight of CO_2 bottles. Their main advantages were: measuring range (up to 200 kg), shape, compact size and price (~50 CHF). Those sensors have been already used at CERN for similar systems, so it was sure, that they can fulfil requirements.
The way the object is placed on the sensor significantly affects the accuracy of the weight measurement. The fact that the whole weight of the bottle is placed exactly on the measuring point and the measurement is reliable is ensured by supports designed for this purpose. They match the following specs: sensor and bottle geometries, weight resting on the central knob of the sensor, vertical stability, mechanical resistance, easy installation and maintenance and costs.
A computer, which was used in this project, is Raspberry Pi 3. Based on the experience with this device, it was described as trusted and able to fulfil the project's tasks. The advantages of Raspberry Pi are number of the possibilities and freedom offered by it, but also reliability influenced by the fact that in case of any software problems the computer is able to restart itself.
The selected software plays the same important or more important role in the project. Python (Miller, 2018) was used as the programming language for Raspberry Pi, DIM (Distributed Information Management System) for communication between different environments and WinCC OA (Burkimsh, 2016) for displaying data, alarm handling and archiving.

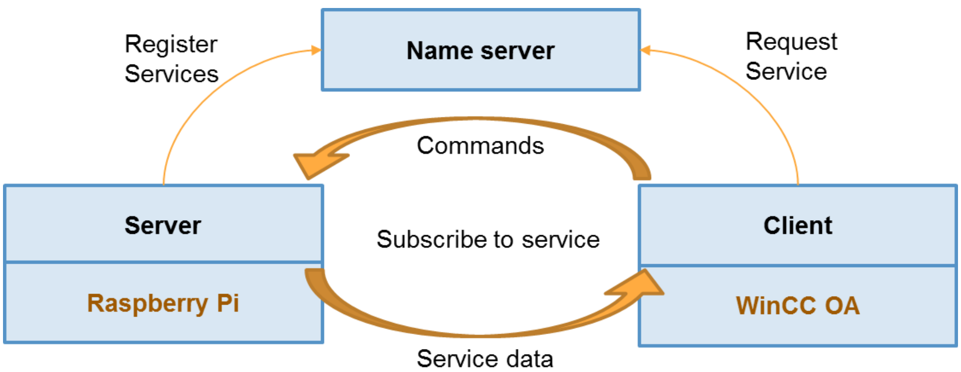

Fig. 1. Communication and data flow between Raspberry Pi and WinCC OA scheme

Python, so high-level programming language for general-purpose programming is one of the most convenient ways of programming Raspberry Pi. It provided well-developed standard library, which allowed for data analysis. Python interpreters are available for many operating systems, this project required working on both Windows and Linux. This software was used for collecting data, data cleaning and all tests. CERN communication system named DIM provides exchange of data between Raspberry Pi and WinCC OA (Fig. 1). The basic concept of DIM consists of services,

or data sets, sent from the server to the client. These data structures can have different types and sizes and are recognized by their names, in the selection of which the user has full freedom. Usually services are requested only once, at the beginning of using the project. After that they are only updated. This change, depending mainly on the type of variables, takes place when the value of the service variable changes in real time. Whenever one of the processes in the system crashes or dies all processes connected to it is notified and reconnect as soon as it comes back to life.
WinCC OA was not only chosen to fulfil client role, but also for current measurements displaying, alarm handling, data archiving. This SCADA system used for visualizing and operating of processes, together with JCOP (Joint Controls Project) Framework (Burkimsh, 2016), is standard for more than 200 projects at CERN (CERN JCOP FW Team, 2010). Current CMS's systems are really advanced and based on about 60,000,000 parameters. In order to achieve this, it was necessary to proceed according to the established concept from the beginning. It consists the following main principles:

1. Future maintenance: thinking about the future, at the design stage, creating and maintaining documentation of projects.
2. Version control: to record changes to software components and recall specific versions of them.
3. Access restrictions.
4. Redundancy: WinCC works on two independent computers on the principle of redundancy mechanism. If one of them fails for some reason, the backup system takes over the main role.
5. Access control cannot limit development: For this purpose, the CMS Online portal was created.

2.2. Tests

The sensors have different zeros and slope and the readings of sensors are disturbed by noises. Also, after changing the weight placed on the sensor, it takes time for the reading to become reliable and external factors such as temperature have a huge influence on the reading. However, the sensors have been selected according to other requirements and are not that noisy that it would prevent from using them. In this case, they require special treatment and during the research several test were prepared. They verified the operation of the technology used and allowed compensation for inaccuracies using the appropriate scripts.
Registered noises were changing results of calculations, so encountered spikes had to be removed. For this purpose, data-cleaning script was written and it can filter the data removing noises. Before performing the tests, it was necessary to calibrate the sensor, in this case check its linearity and determine the functions describing conversion of the sensor's read-outs to kilograms. For this system, incorrect measurement would not only have influence on the quality of the data, but could case an accident as a consequence.
The frequency of measurements is needed to understand and analyze sensor's read-outs, but it could not be check in any technical documentation, because the speed of data transfer to the master device also affects the final frequency. In order to estimate the amount of data received by Raspberry Pi from sensors per second, the amount of data received by the computer during: minutes, hours, and days was checked and divided by the appropriate number of seconds. It was measured for different sensors,

computer inputs and even external factors. The results of all tests were summarized and the frequency was estimated for one measurement per second. Such accuracy is satisfactory and will allow the system performing its functions.

The linearity of the read-outs was checked in order to have a better view on the data but also to know, if the system will be able to fit requirements set for this kind of system by the French law (it is precisely defined, because, as it contains CO_2, it can be dangerous and threaten the environment). The linearity test was performed and afterwards a function that converts the readings from sensors to kilograms was calculated.

The technology was also checked in terms of changing weigh on the sensors. Two situations that will happen in the future were analyzed. First, replacement of empty bottle with a full one and second, weighing bottles manually (required during every year maintenance). It had to be checked how the sensors behaves after change of weight. For both scenarios, the script prepared for data cleaning and calibration worked in a proper way and removed noises, no hug drift was observed and no alarm triggered.

The influence of external factors, like temperature, on the measurements is the easiest to observe when looking at two sensors operating under the same conditions. Based on this information and using reference sensor, a script that reduces the impact of the environment on the values has been created.

2.3. Design

After the tests, it was agreed that following services are sent to WinCC through DIM:

- Current measurement (raw value)
- Current measurement (filtered and compensated value)
- Standard deviation
- Noises [% filtered data]
- Date and time of last measurement
- Ratio (used for compensation)
- Time of last measurement
- Time of system's operation.

By sending and displaying these values, system users know not only about alarms for protected installation, but also if the system works properly itself. The user can easily notice, when the number of spikes increased rapidly or the system does not show up-to-date information.

Archiving is another concept of WinCC necessary for reporting and trending. It stores historical values of DPE and historical alerts. All connection and data transfer between DPs and Oracle database is done by an archive configuration. To do this, a special manager named RDB Archive Manager has to be added in the project and the configuration file has to be updated.

The last thing to configure were alerts. They consists of two parts. First, conditions under which the alert should be raised. This is kept in the alert handling config. Second, related information in alert class config. That means attributes, which generally apply to more than one alert:

- Priority; Color; Acknowledgement rules;
- Automatic script execution.

WinCC-OA thus allows a flexible definition of an alert. The JCOP Framework unifies these principles for the four LHC experiments. This system does not use any third

level, so raised in situations endangering people and requiring immediate action by the Fire Brigade, they all have informing character.
The project closes with the design of the UI (User Interface). Main factors taken into account were:

- that the main panel is clear for every user;
- that the calibration panel should be simple enough that the person who does not use WinCC on a daily basis could use it;
- that an expert panel would show not only the status of alarms, but also whether the panel is currently operating, since when it has been running, and what is the time of the last measurement. It also includes an overview of the placement of bottles and buttons that allow to go to the calibration panel or expert panel for a given trolley.

All panels are available only for selected users and inactive for others.

3. CONCLUSION

Summing up, tests carried out on Python scripts on Raspberry Pi ended with the constructive conclusions, as it was expected. Selected software worked well in its role. The values sending by DIM describe the state of the bottles and the quality of the data. Sensors required work, but in the end, they fulfil their role. An interesting change in the design could be replacing Raspberry Pi with a small PLC or Arduino. After the testing and preparation phase, this solution is waiting to be extended to a larger scale, starting with one fully equipped trolley and ending with over 100 bottles. During this process and Long Shutdown 2 (LS2), some new conclusions will definitely come and consequently the system will require changes. However, the project was prepared in accordance with the previously mentioned rules and is ready for possible development.
Extinguishing systems are vital elements in infrastructures exposed to a huge thermal emission or a high temperature, especially if the infrastructure contains sensitive and expensive research devices. Such situation may be met in many industrial and research areas. In materials science, it may be a powder sintering (Dudek et al., 2010), a laser beam machining (Scendo et al., 2014; Dwornicka et al., 2017; Radek et al., 2018), a wear investigation (Korzekwa et al., 2014), testing of thermal coatings (Guidoni et al., 2005), an analysis of thermal reaction (Ulewicz and Radzymińska-Lenarcik, 2011; Klimecka-Tatar et al., 2015), a corrosion limitation (Szabracki and Lipiński, 2014; Klimecka-Tatar, 2018), a bioceramic coatings creation and testing (Dudek, 2011). It may be also met in biotechnology (Skrzypczak-Pietraszek and Pietraszek, 2009; Skrzypczak-Pietraszek et al., 2018) or technical fluid mechanics (Lisowski and Filo, 2017; Fabiś-Domagała et al., 2018). In general, such situation may be modelled by many aspects e.g. (Styrylska and Pietraszek, 1992; Pietraszek, 2003; Pietraszek et al., 2014; Pietraszek et al., 2016; Pietraszek et al., 2017), however finally, it should be tested experimentally (Radziszewska-Wolińska and Kaźmierczak, 2018; Radziszewska-Wolińska and Milczarek, 2018; Radziszewska-Wolińska et al., 2018).
Analogous situation may be observed in industrial environment. In power engineering, it may be related to the combustion process (Opydo et al., 2016) as well as to the entire infrastructure of a power plant system (Dwornicka, 2014). Similar situations appear in other huge industrial infrastructure e.g. foundry (Ulewicz et al. 2013) or

large research facilities e.g. FAIR in Darmstad (Singh et al., 2016a; Singh et al., 2016b; Singh et al., 2017).

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