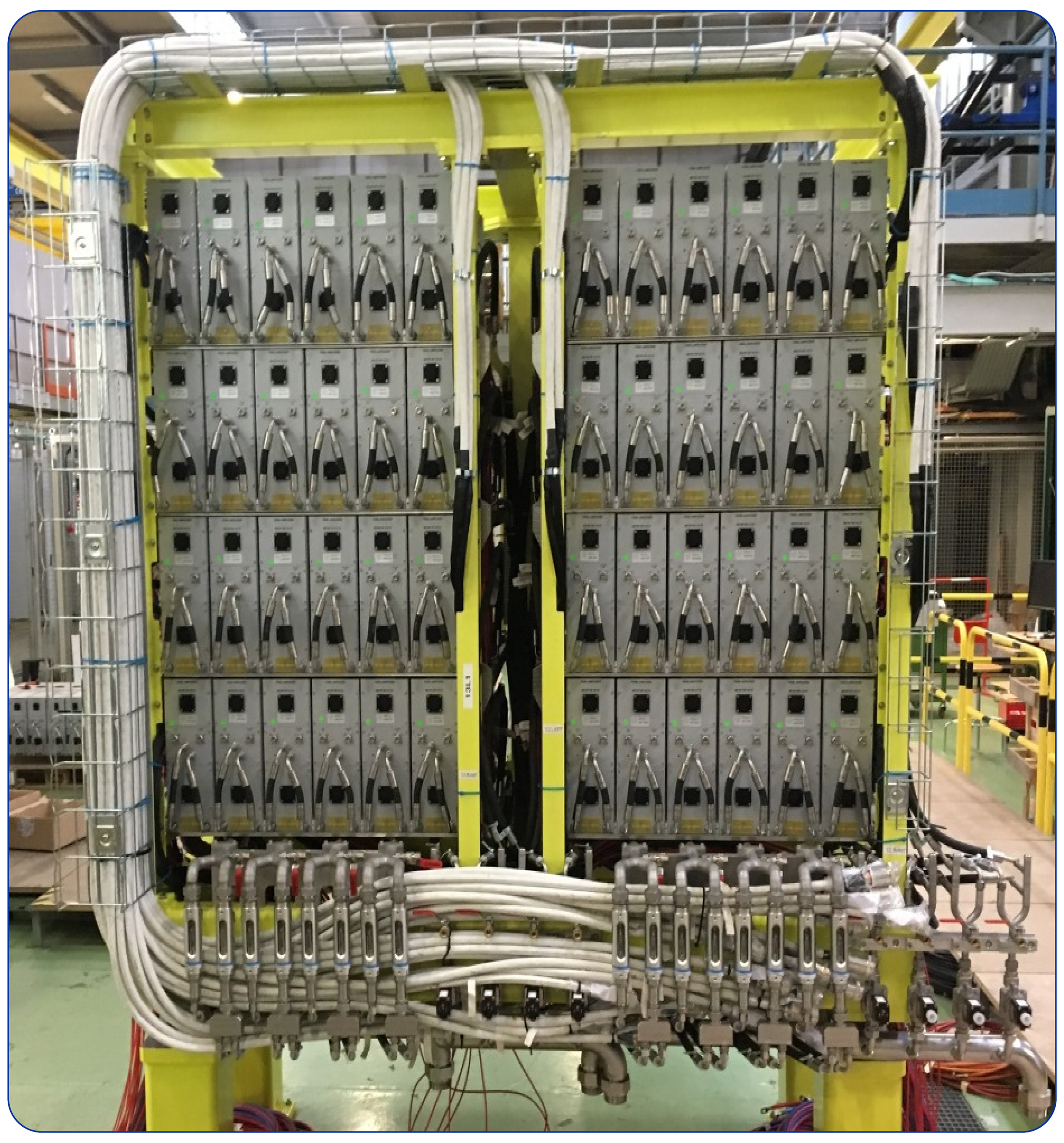
Design of the Control System for the CERN PSB RF System

D. Landré, Y. Brischetto, M. Haase, M. Niccolini - CERN, Geneva, Switzerland

SUMMARY

The PSB RF system was entirely replaced in the framework of the LIU project, to ensure the performance required for the High-Luminosity Large Hadron Collider (HL-LHC) project. In conjunction with the hardware renovation, a state-of-the-art control system was developed and commissioned to ensure the system's optimal operation.



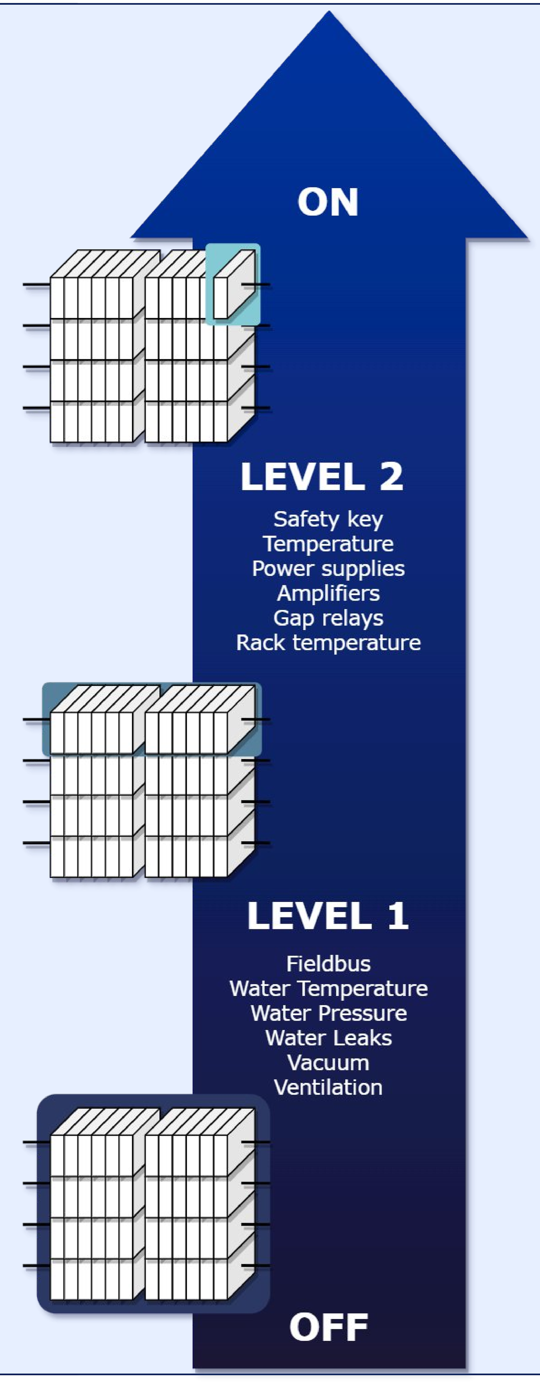
ARCHITECTURE

The PSB machine consists of four superimposed rings, and the acceleration of particles is ensured by the new wideband Finemet RF system, which is installed in three straight sections of the machine. In each sector two groups of Finemet cells are installed per ring, resulting in structures composed of forty-eight cells per sector. The new RF system thus consists of a total of one hundred and forty-four cells, each with independent power supplies, amplifiers and control electronics. Air and water cooling distribution are shared by the cells in each sector.

CONTROL

In order to ensure the safety of the system, which consists of accelerating cells, amplifiers, power supplies and auxiliary services such as cooling, machine vacuum and fieldbus communication, an advanced industrial control and interlocks system was developed. Each structure installed in a sector is controlled independently through one PLC and measurement and control cards (AI – analog input, AO – analog output, DI – digital input, DO – digital output) tailored to the equipment installed. The control program is structured to follow a sequence of data acquisitions, each authorizing the start of the next step and ensuring that all necessary conditions are met before the RF can be pulsed. The control sequence is composed of sub-sequences, which span from overseeing general services to granting authorization for RF pulsing on a cell.

CONTROL SEQUENCE



Level 1

The initial part of the first level of the sequence runs checks on the fieldbus communication, water temperature and pressure, water leaks and machine vacuum. In the event of any equipment failure within this segment, an immediate shutdown of the RF system is triggered in the affected sector to ensure safety and prevent potential hazards.

In the latter part of the sequence, the water cooling of the amplifiers is started independently for each ring, such that any fault happening in this stage only affects the specific ring and does not influence the operation of the others. Moreover, the program runs ventilation system checks. Any malfunctions exclusively impact the cells connected to that specific ventilation, ensuring that the neighboring cells within the sector remain unaffected.

Level 2

At this stage the designated power is distributed to the cells. Each cell is controlled independently, allowing for power redistribution among cells in the event of a malfunction as long as the minimum required power is attained.

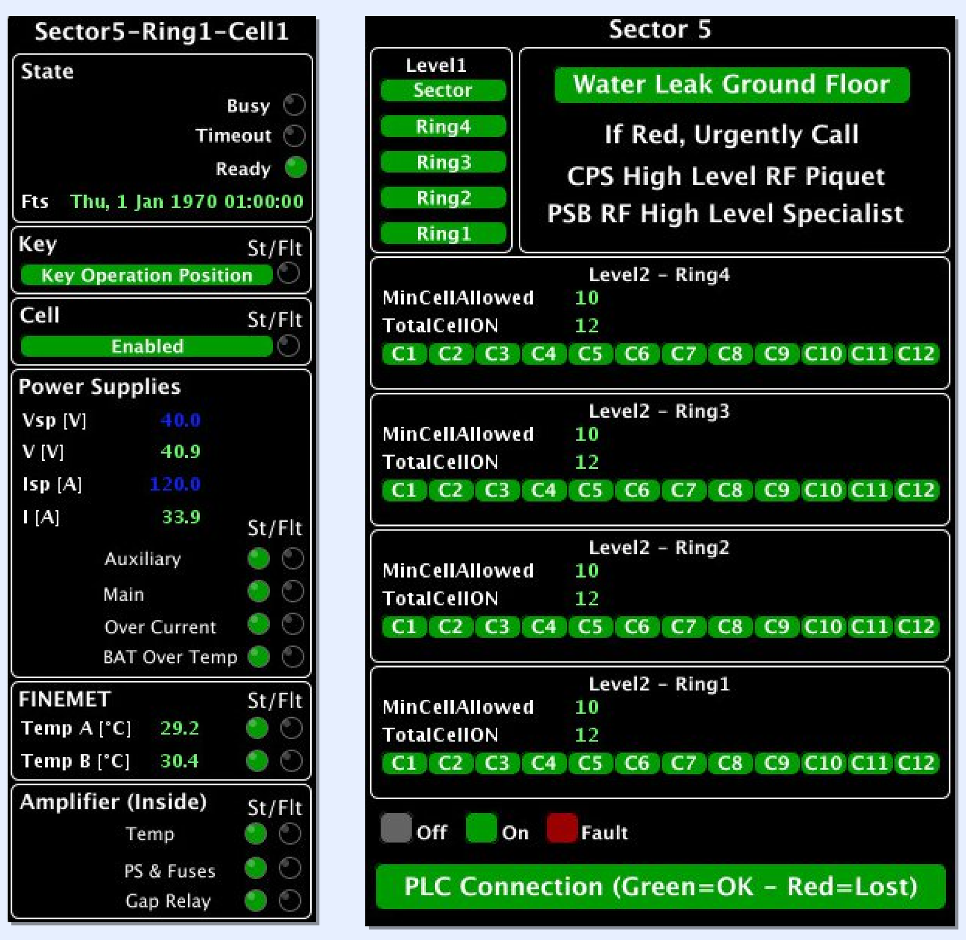
At this stage the position of the sector safety key is checked. If the key is either removed or placed in the safety position, no power is sent to any of the cells within the relevant sector, thereby allowing safety conditions for interventions on the sector. In the second step, the system assesses the cells' ability to operate correctly. The operation of each cell is halted if a specific number of faults have occurred, thanks to a fault counter which can only be reset by an expert. As a third step, the temperatures of the cells are checked to ensure they fall within a specified range, thus protecting against any malfunction of the cooling system, for example a foreign object being trapped in the cooling pipes. As a final step, checks are performed on the status of the amplifiers' electronics, the auxiliary power supplies and the main power supplies. Furthermore, the sequence verifies whether the current remains within the programmed maximum limit established by the expert, checks the integrity of the amplifiers' fuses, the statuses of the gap relays, and the temperatures of equipment racks situated around the cells. Once the sequencing steps are completed, permission to pulse the RF on the cells is granted. When a fault occurs on a cell, only the faulty cell is switched off and all other cells in the sector continue operating normally.

CONTROL APPLICATIONS

The fine-grained control capabilities required the implementation of automation to ensure the efficient operation the system. To this end, a FESA class implements a sophisticated sequencer.

Another FESA class effectively compensates for and redistributes the voltage across various sectors and actively monitors the active cell count and the programmed voltage, aiming at improving even more the availability of the RF system. Furthermore, MOSFET radiation measurements are conducted daily over an approximately 40-minute period and stored on a logging server.

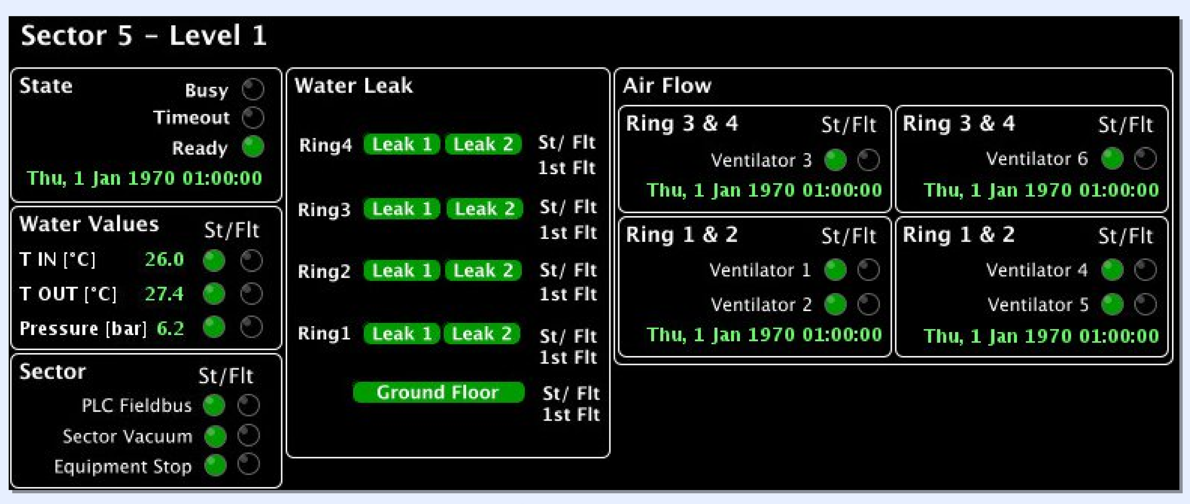
Numerous control GUIs were developed to facilitate the seamless operation and remote management of the equipment. The authors opted for the Inspector IDE to create comprehensive panels containing the necessary information and controls. The use of Inspector enabled the system's modularity to be maintained up to the application layer by allowing the development of generic panels capable of dynamically adapting to different data sources. Consequently, this resulted in the development of a single panel per structure, ie. one for all sectors, one for all rings and one for all cells. Furthermore, a global panel was developed to provide situational awareness of the RF system to both operations and expert teams, alongside another panel offering remote control of the system.



Monitoring panel for the ring 1 in sector 5 (left) and the general view panel for sector 5 (right)

A comprehensive control system was developed to operate the novel RF installations in the PSB accelerator. The software allows RF experts to easily control the equipment, fully exploiting the whole CERN control system stack. An extensive control sequence allows the supervision of any aspect of the RF system and allow for a time-efficient remote exploitation of the system. The whole software control system was successfully commissioned during LS2 and is presently used to operate the PSB RF system.

The authors would like to thank Alan James Findlay for his invaluable help during the commissioning of the system.



Monitoring panel for the RF system in sector 5