LHC RF SYSTEM RELIABILITY

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Abstract

The LHC ACS RF system is composed of 16 superconducting cavities, eight per ring, housed in a total of four cryomodules each containing four cavities. Each cavity is powered by a 300 kW klystron. The ACS RF power control system is based on industrial Programmable Logic Controllers (PLCs), with additional fast RF interlock protection systems. The Low Level RF (LLRF) is implemented in VME crates. Operational performance and reliability are described. A full set of user interfaces, both for experts and operators has been developed, with user feedback and maintenance issues as key points. Operational experience with the full RF chain, including the low level system, the beam control, the synchronization system and optical fibers distribution is presented. Last but not least overall performance and reliability in 2015 are reviewed and perspectives for future improvement outlined.

INTRODUCTION

In 2015 the energy of LHC has reached for the first time 6TeV with nominal beam intensity: 1.15e11 p/bunch and 2244 bunches. The experience gained with the ACS system together the big effort made to improve its reliability has resulted in good performances. The RF system did not suffer from any limitation this year. However a dedicated cavity field dephasing gymnastics was also implemented to limit the power consumption during the injection phase.
The damper system (ADT) was also extensively used, and all the studies and measurements that could be made with all kind of beam configuration have allowed putting in evidence the good performance of this system. Lessons learned have also shown the reliability of the ADT system.
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PERFORMANCES IN OPERATION

Several main activities took place during LS1: A large campaign was launched to repair the defective klystron high voltage cables connectors, the crowbars were upgraded with solid state technology devices of better reliability and performance, and the sick module (M1B2) was replaced by the fully operational spare module.

During operation these modifications proved to be efficient. No more klystrons filament glitches or spurious crowbars were observed.

LHC RUN – ALL RF TRIPS

A total of 57 trips were recorded in 2015. Amongst these, 13 dumped the beam.

These trips, which cover 15 categories, are grouped in six different types as shown below

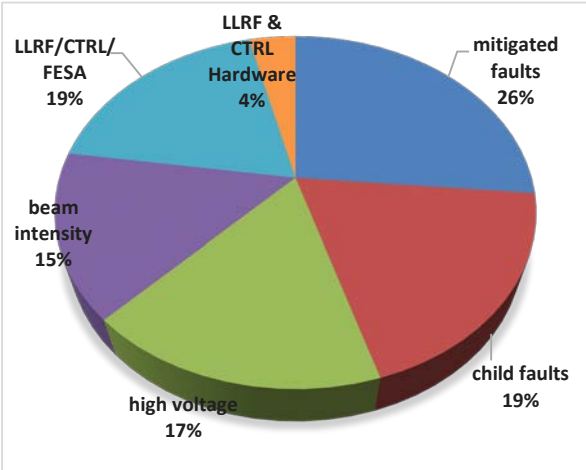

Figure 1: all RF trips

Mitigated faults

Following the start up the RF system suffered from several little problems that could shortly be cured. Some were straightforward (e.g. interlocks levels adjustments) and some others required some more thorough analysis (e.g. error in communication protocol in the main coupler control system). All these were cleared up for TS2.

Child faults

Events such as thunderstorms causing electrical glitches or loss of cryogenic conditions are unavoidable in a machine like LHC. This impact of child fault is not negligible and represents about 20% of the total number of RF trips.

Crowbars

Crowbars were the major cause of trips during run1. Most of these were spurious trips and during LS1 a new modern version, based on solid state technologies, was deployed. This change proved to be very efficient during run2 where all 9 recorder crowbars could be connected to real klystron vacuum activity. These are not unusual after restarting the RF system.

Low level RF and controls

Last year the RF system suffered from different controls hiccups: crates or FESA classes to be rebooted, losses of frequency reference. Several LLRF cards, PLC control i/o modules and 5V power supplies had to be replaced. The frequency of problems has increased during the year and shows how essential is the spare management of these equipment.

Increase of beam intensity

Some type of trips have emerged with beam intensity increase. Oversaturation of klystrons were sorted out by fine adjustment of the LLRF settings.

More strange are the arc detectors, which dumped the beam on several occasions, although there was no evidence of real arcs. Different modifications were done to the system in order to mitigate the problem: all remaining old plastic connectors were replaced, AD were redistributed in order to have systematically, where possible, 2 AD looking at the same location (AND logic). Finally a fast diagnostic system (pico-scopes) has been implemented in each klystron rack, with the aim to “hopefully” record the analogue signature of these spurious trips.

CONCLUSION

Work done during LS1 and along run 2 proved to be effective. No spurious trips since TS2.

More frequent (minor) hardware failures were observed. Preventive maintenance and replacement campaigns during YETS will be implemented (e.g. 5V P.S.)

Although the LHC RF system behave very well, it became more sensitive with increasing beam intensity. It is approaching its limits and shows the importance of the time dedicated to conditioning and LLRF setup.

The (most of) arc detectors trips do not seem real. New configuration and new diagnostic system was installed during the YETS with the aim of identifying the problem.

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