Thesis abstract of Cédric Lhomme

Title : Studies for the optimization of the cryogenic distribution and control systems of the MYRRHA superconducting linear accelerator

Abstract : Transmutation shall be used to stabilize the long-lived high-level waste (LL-HLW) stocks produced by the thermal-neutron power plants worldwide. This process can be carried out in an Accelerator-Driven System (ADS): a neutron spallation source featuring a proton accelerator, driving the criticality of a dedicated fast-neutron nuclear reactor.

In Europe, the MYRRHA project (Multi-purpose hYbrid Research Reactor for High-tech Applications) has matured through several R&D programs for about 25 years and aims at being a pre-industrial ADS in the 2040's horizon. Its neutron source requires a proton energy of 600 MeV and a beam current of 4 mA in continuous wave mode, that only the most powerful superconducting particle accelerators can provide. The reactor operation also sets stringent requirements to the accelerator beam dynamics which, in turn, implies a yet unreached reliability of its sub-systems, even more challenging in view of an energy-sober facility. The MYRRHA initial 100-MeV accelerating section, MINERVA, is under construction in Belgium by SCK•CEN for a first beam in 2027: on top of supplying two target facilities, the purpose of MINERVA is to demonstrate the MYRRHA reliability.

The heart of the superconducting accelerating section is the cryomodule; a series of thirty identical units will be produced and aligned, following a modular strategy. The cryomodule hosts the accelerating superconducting radiofrequency cavities and concentrates all the necessary functions for their optimal operation.

The demanding reliability target combined with the overall accelerator efficiency objectives require a global system approach rather than individual optimizations of the functions of each component.

Therefore, the thesis proposes to develop a detailed cryomodule process model, that implements the strong couplings between the cryogenic, radiofrequency and mechanical tuning functions, their respective internal dynamic as well as their control systems. The substantial initial effort to develop such a model is motivated by the broad application panel of this simulation tool during the current MINERVA prototyping phase, until the commissioning and beyond.

Following a bottom-up model creation, models of individual as-built components are instantiated based on thorough investigations of their actual properties. The created digital twin is used to conduct the prototype test phase, through control system virtual commissioning and model-based performance analysis. It is in turn validated against the experimental results. Finally, in view of the series, several practical applications of the simulations are illustrated: component design updates, implementation of a PLC virtual commissioning platform and of tool for quenches classification.