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C3Po1B-06: Development of the 17 kW orifice-type heater control system for thermal compensation induced by nuclear heating at the ESS hydrogen moderators

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The European Spallation Source (ESS) is one of the largest science and technology infrastructure project being built in Sweden. Protons at 2 GeV (with a normal current of 62.5 mA) are delivered by a superconducting linear proton accelerator and are injected onto a rotating tungsten target at a pulsed repetition rate of 14 Hz. Neutrons via spallation reaction are moderated to cold thermal energies by two dedicated moderators. The cryogenic moderator system (CMS) was designed to circulate subcooled liquid hydrogen at a temperature of 17 K and a pressure of 1.0 MPa to remove static and dynamic heat load induced by the nuclear heating at the moderators, which is estimated to be 6.7 kW for a 5-MW proton beam power. The liquid hydrogen is transferred from the CMS cold box (CBX) to a distribution box (DB) via a main transfer line (HTL) and is split into each moderator transfer line. A 17kW orifice type heater is used for thermal compensation induced by the nuclear heating by the moderators when the proton beams are injected and tripped.

The CMS Process Control System (PCS) is based on multiple Programmable Logic Controllers (PLCs) and is responsible of controlling a wide array of equipment, consequently the system logic was designed with modularity, ease of expansion, and maintainability in mind. Different device types are implemented using custom software control blocks providing a wide range of features and Operator Interface (OPI) block icons and faceplates.

The heater is composed out of 15 separate sheathed heater elements that are submerged in liquid hydrogen allowing for fast process response times. From electrical design and control logic perspective, the most important objective is to ensure that the all the heater elements combined function as one single heater element providing the highest response times and accuracy of the power output possible.

In order to provide high reliability, good cost to performance ratio and easier serviceability the controller hardware used is an industrial grade one manufactured by SIEMENS from the SIPLUS HCS product family. These components however lack in certain functionalities such as current and voltage monitoring, compensation for electrical grid fluctuations and accepting setpoints in energy units such as watt. To combat these shortcomings a multi-functional energy measuring device was used as well.

To provide easy control and overview with all the necessary functionalities a new device type was implemented in the PCS. This software block provides functionalities such as accepting setpoints in watts, calculating the total and per heater element power output, even power distribution across all elements, line voltage compensation, health monitoring of the heater elements and the electrical supply, setpoint ramping, overheating protection and PID control algorithm for temperature control beside other.

The basic functions of the electrical heater together with its controller hardware and software functionalities were successfully tested during the preliminary CMS commissioning using helium at 17 K prior to hydrogen operation.

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