ISBN: 978-3-95450-238-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2023-TUPDP082

ESS TARGET SAFETY SYSTEM MAINTENANCE

A. Sadeghzadeh†, O. Ingemansson, O. Janson, M. Olsson, L. Coney
European Spallation Source, Lund, Sweden

Abstract

The Target Safety System (TSS) is part of the overall radiation safety plan for the Target Station in the European Spallation Source (ESS). The Target Controls and Safety group (ESS – Target Division) is responsible for the design and construction of the TSS.

The TSS stops proton production if vital process conditions measured at the Target Station are outside the set boundaries with the potential to cause an unacceptable radiation dose to third parties (public outside ESS).

The TSS is a 3-channel fail-safe safety system consisting of independent sensors, a two redundant train system based on relay and safety PLC techniques and independent ways of stopping the proton beam accelerator.

The TSS will continuously monitor safety parameters in the target He cooling, wheel and monolith atmosphere systems, evaluate their conditions, and turn off the proton beam if necessary.

After passing several stages of off-site testing, the TSS cabinets are now installed on site and successfully passed internal integration.

In this paper, we explain the features built into the system to ease emergency repairs, system modification and system safety verification and general maintainability of the system.

TSS SYSTEM OVERVIEW

The TSS is a distributed system, including electrical, I&C (Instrumentation and Control) and mechanical equipment with components placed in locations across the ESS facility according to Fig 1. The TSS consists of sensors, signal collecting units, signal intermediaries, logic equipment, software and actuators.

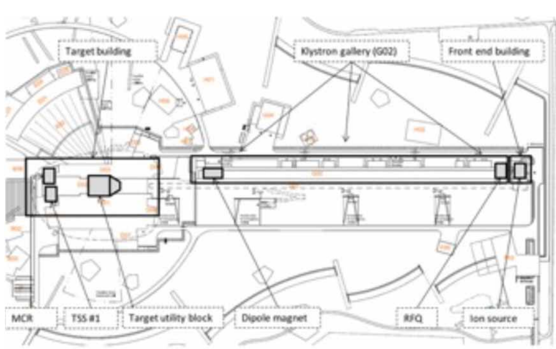

Figure 1: TSS distribution in ESS facility.

The basic design for the TSS consists of a three-channel (A, B and C) system divided into two main trains (relay trains and PLC-train), each of them with separated 2oo3 logic for tripping the proton beam. The TSS follows the fail-safe, redundancy, diversity and separation principles. The fundamental architecture of the TSS is shown in Fig 2.

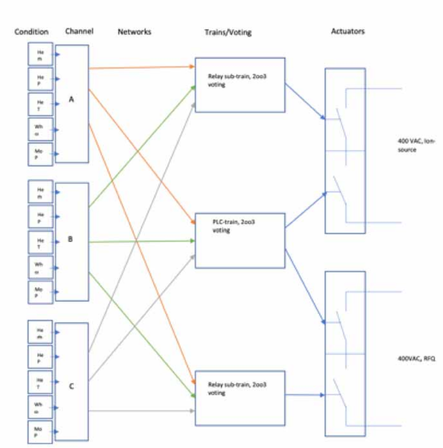

Figure 2: Basic architecture of the TSS.

Physical Separation

Physical separation for the TSS is obtained through a design containing mechanical barriers and/or distance between three channels to ensure that one event, internal or external, does not impact more than one channel. To achieve this, electrical cabinets of the three TSS channels are located in different floors with different fire zones and their cables are routed through different metal conduits.

Functional Separation

Functional separation for the TSS is obtained via the following principles:

- The channels are galvanically separated at the 2oo3 voting relay setup; each channel has a dedicated relay. There is no communication between channels.
- The trains are galvanically separated by having dedicated actuators, i.e., one train cannot affect any other train. There is no communication between the trains.

Diversity

In order to have protection against common cause failure, diversity for the TSS is obtained through:

- A two-train solution with different technologies: one train with electromechanical components (relay, divided into two sub-trains) and one train with programmable electronics (PLC)
- Diverse components to disconnect the electrical supply to the Ion Source and RFQ (radio-frequency quadrupole), using contactors or switch disconnectors;
- Diverse mechanisms to stop proton production via the RFQ or Ion Source;

† atefeh.sadeghzadeh@ess.eu

Content from this work may be used under the terms of the CC BY 4.0 licence (© 2023). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI

ISBN: 978-3-95450-238-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2023-TUPDP082

Content from this work may be used under the terms of the CC BY 4.0 licence (© 2023). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI

- Two different measurements (combination of different conditions) to detect an initiating event (functional diversity), normally expressed as 1st and 2nd condition.

TSS SENSORS

In order to have robust design, TSS sensors were selected from off the shelf and well-known sensors used in similar environmental conditions.

Mass Flow

The mass flow measurement is based on differential pressure measurement over a venturi pipe where the TSS uses a Rosemount 3051 SMV (programable transmitter), see Fig 3. A multivariable type transmitter is used that provides the TSS with a 4-20 mA signal corresponding to the mass flow in the helium cooling circuit. A sample of the pressure from the venturi pipe is brought to the instrument located in a different room with no access restriction using impulse piping.

Figure 3: Mass flow measurement instrumentation, the manifold is He tight.

He Pressure

The TSS measures the He pressure through pressure switches. Helium pressure is measured using impulse piping and a mechanical switch unit. The TSS uses Barksdale Beta C-series pressure switches. Two different mechanical switches in one unit feed the PLC and relay trains, see Fig 4.

Figure 4: TSS He Pressure switch.

He Temperature

The TSS uses 4-wire Pt-100 for measuring temperature. The sensor will be located inside a basket in the pipe to protect it from vibration induced by vortex whirls due to high volumic speed. The sensor is designed to be exchangeable while the system is pressurized, see Fig 5.

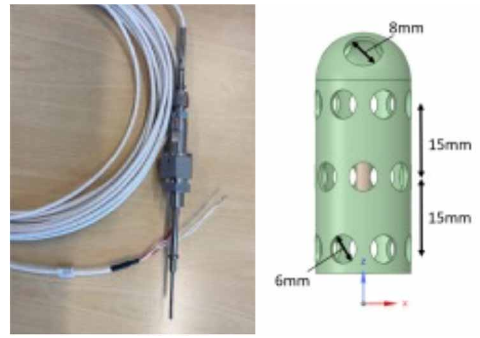

Figure 5: Left: prototype of hot exchangeable temperature sensor, right: basket inside the pipe to protect the sensor from self-resonance.

Wheel Rotation

Target wheel rotation speed is measured by an Emerson AMS 6500 conductive sensor, see Fig 6. There is a distance of 30 meters between the sensor and first transmitter. Due to high radiation in the area, radiation hard cable is used.

Figure 6: Wheel rotation speed sensor mounted to detect holes on the notch wheel around the target wheel shaft.

Monolith Pressure

Monolith pressure is measured using impulse piping and a mechanical switch unit. The pressure switch reads the actual monolith system pressure and shall initiate a trip of the proton beam if the pressure is over a certain threshold. The Barksdale D2T pressure switch is used for measuring the monolith pressure, see Fig 7.

ISBN: 978-3-95450-238-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2023-TUPDP082

Figure 7: Monolith pressure switch.

TSS INSTALLATION

All TSS instrument pipes, cabinets, cable and conduits are installed in different parts of the facility.

Impulse Pipe

In order to always have access to the instrumentation, the process instrument is not installed directly on the system. Instead, impulse pipes are used to transfer pressure from the helium cooling or monolith system to the pressure or mass-flow switches or transmitters, see Fig 8.

Figure 8: TSS impulse piping.

Cable Conduit

In order to protect the TSS cables and also fulfil the requirement of physical separation, TSS cables are routed through metal conduits where cables from different channels never share the same conduit, see Fig 9.

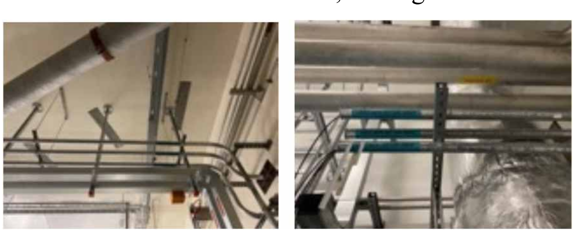

Figure 9: TSS metal cable conduits.

TSS Electrical Cabinets

The TSS has 11 electrical cabinets installed in different parts of the facility, see Fig 10.

- The cabinet in the Main Control Room (MCR) has the HMI, switches to change modes of operation and an emergency stop button.
- The sensors are connected to 3 cabinets in different fire cells in the Target utility area.
- The TSS logic cabinet and the gateway cabinet are located in a separate room accessible only by security-cleared personnel. Major actions of the system, like software updates, can only happen from this specific room.

Figure 10: TSS cabinet in Target utility.

TSS MAINTENANCE

Most of the TSS components are expected to last for 15 years of use. However, some components will not last for that long period of time. For those, predictive maintenance shall take place.

Several functions are built into the system to ease testing, trouble shooting and maintainability of the system.

Emergency Repairs

The TSS system is designed such that any emergency repair should not take more than one shift (8 hours) to be fixed. The following features contribute to this goal:

- Overview of the hardware and communication health: The TSS cabinet in the MCR and the safety PLC cabinet, include an HMI that shows communication and hardware health of the system and in case of malfunction, operators get a warning message.
- Very specific system warnings: warning messages are very specific. In case of a warning, an operator can specify exactly which hardware in which cabinet is not healthy, through the HMI in the Main Control Room
- Off the shelf standard equipment: All TSS components are off the shelf and tested and proved in an environment similar to that in which they will be used.

Content from this work may be used under the terms of the CC BY 4.0 licence (© 2023). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI

ISBN: 978-3-95450-238-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2023-TUPDP082

- Qualified spare parts: The ESS has already purchased TSS spare parts from the same batch of components with similar serial numbers for 15 years of operation.
- Easy access to field devices and electrical cabinets and impulse pipes: All TSS electrical cabinets are located in supervised area classification radiation zones (green) where it is considered safe for workers to be during any mode of operation or maintenance. Also, as mentioned before, process instruments are installed on instrument pipes where a small sample of the environment are brought to the green zone.

System Check/Verification of the Safety Functions

The TSS is checked through calibration and regular functional testing of the system to ensure that all safety functions are operational. It is planned to calibrate all instruments every six months in the beginning of operations and later once a year. Built-in features that ease calibration and functional testing are:

Calibration The following features will be used to facilitate the calibration:

- Test switches: Each cabinet is provided with test switches, located outside the cabinet and protected by a key-locked plastic cover, that make it possible to calibrate/test the system using overlapping and excluding principles. The HMI symbol of the sensor is changed when the test switches are used. See Fig 11.
- Test disconnect able terminals.
- Easy and safe access to field devices and electrical cabinets and impulse pipes.

Figure 11: Test switches placed on front door of the TSS cabinets in Target Utility area.

Functional testing The following features help facilitate functional tests:

- Test switches.
- Manifolds: Each switch is connected via instrument piping that can be isolated from the process using root valves and a manifold for test purposes. The root valves have seal-welded bonnets.

CONCLUSIONS AND REMARKS

The TSS is designed, tested and approved in a lab environment, installed on site, and tests are ongoing on site. The operational and maintenance procedures are planned and evaluated during the tests on site in order to be reliable and efficient when operation of the ESS facility starts.

Content from this work may be used under the terms of the CC BY 4.0 licence (© 2023). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI