Enhancements of the Fast Interlock System for Wendelstein 7-X operational phase OP2.1

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ABSTRACT

The Fast Interlock System (FIS) is an independent subsystem of the safety control system of W7-X. The main task of the FIS is to protect the inner plasma vessel components from thermal overload from both plasma heating systems (e.g. neutral beam injection) and the plasma itself. There are strict limits for reaction times, which have to be observed in order to prevent overload situations of the first wall.

The requirements for the FIS were substantially modified and extended in order to address the challenges due to the actively cooled divertor. This led to extensive revision of the technical implementation and the software of the FIS.

This paper gives an overview about the requirements of FIS for the operational phase OP2.1, followed by a description of the technical aspects of the FIS and the implementation of the interlock functions. Finally, the actual status of the project “FIS for OP2.1” is discussed.

SAFETY LEVEL CONCEPT FOR W7-X MACHINE PROTECTION

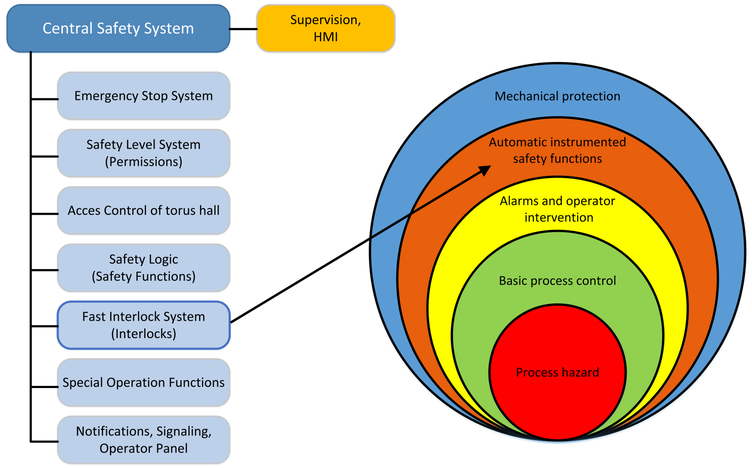

Fig. 3: Fast Interlock System as a part of the safety system for W7-X machine protection

Protection Layer	Responsible protection system	Action by
PrL 0	SCADA System	Basic process control (BPC), Process safety control functions (PSCF)
PrL 1	Safety Instrumented System (SIS), Fast Interlock System (FIS)	Safety Instrumented Functions (SIF) Fast Interlock Functions (FIF)
PrL 2	Active protection	Active safety parts (e.g. rupture disks)
PrL 3	Passive protection	Passive safety parts (e.g. Torus hall)

Table 1: Layer of protection for the W7-X device

STELLARATOR WENDELSTEIN 7-X: READY FOR OPERATION PHASE 2.1

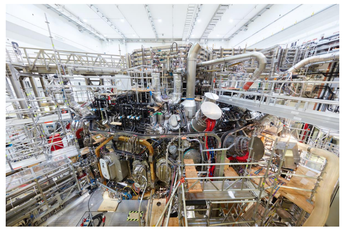

Fig. 1: Stellarator Wendelstein W7-X

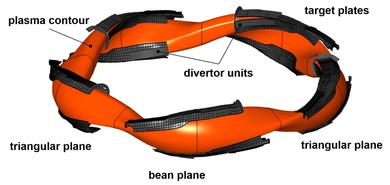

Fig. 2: Actively cooled divertor units

High heat flux operation OP2: September 2022+

- Full water cooling of all PFC to provide max. heat load 10MW/m^{2,}
- Considerable enhancement of heating, fueling and diagnostics systems,
- Consecutive increase of energy turnaround 1GJ (OP2.1 → 18GJ),

PROJECT FIS FOR OP2.1

Central Interlock System (cFIS)

Design phase:

- Specification of functional requirements for FIS-OP2.1 ☑
- Specification of non functional requirements for FIS-OP2.1 ☑
- ET-Specification for modification of the electrical cabinets ☑
- Software specification for the cFIS ☑

Implementation phase:

- Modification of all cFIS cabinets ☑
- Cabling between lFIS cabinets and cFIS cabinets ☑
- Network cabling an network configuration ☑
- PLC software and visualization ☑

Test phase:

- FIS signal transmission test ☑
- Unit and integration tests ongoing
- Validation cFIS August 2022
- Validation whole Fast Interlock system with plasma operation September 2022

Local Interlock System (lFIS)

Design and implementation for the local Interlock Systems are part of the CoDaC projects of the diagnostics and heating systems with lFIS tasks.

The working packages and the technical realization of IFIS projects are strongly coordinated with the cFIS project.

HIGHLIGHTS OF W7-X FAST INTERLOCK SYSTEM

- Enhancement of the Fast Interlock System for operational Phase 2.1 of W7-X,
- Using fast PLC CPU Siemens 1500 for processing of Interlock Functions,
- Input/Output of interlock signals via decentral periphery devices ET200SP,
- Using Profinet bus for connection the CPU 1500 with all ET200SP devices,
- Implementation of a new Unlock_Request / Heating_Release cycle for all heating systems,
- Integration of new FIS diagnostic signals for divertor protection, for ICRH heating and Continuous Pellet Fulling System (CPFS),
- Extension and modification of Interlock Functions for Op2.1,

REALIZATION OF FIS

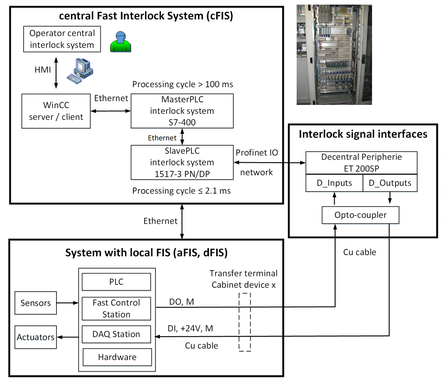

Fig. 4: Structure of Fast Interlock System

Central Interlock System (cFIS):

- cFIS Logic: Fast PLC Siemens 1500,
- Configuration, HMI: PLC S7-400,
- Signal interfaces: Et200SP with I/O devices,
- HMI: WinCC Server,

Signal Interface:

- Located in the near of the lFIS components,
- Signal information will be transmitted via Profibus connection between Et200SP and PLC 1200,

Local Fast Interlock Systems:

- Individually designed for every lFIS system,

FIS Type	SCADA System	FIS Tasks
cFIS	PLC based	Parameter sets for Interlock-Functions and for lFIS diagnostics. Send and receive interlock signals Processing of interlock functions. HMI for FIS. Archiving data into W7-X archive, **Cycle time < 10ms,**
Diagnostic_FIS	Interferometry Magnetics Divertor Observation Machine Instrumentations	Generation of events for the FIS-functions (e.g. plasma density for heating xy is not o.k., temperature overload divertor), **Cycle time < 100ms,**
Actuator_FIS	Plasma Heating ECRH Plasma Heating NBI20/21 Plasma Heating ICRH Plasma Fueling Pellet Injector	Control of Heating_Request signal according experiment program requirements, Immediately switch off heating, if the signal Heating xy_Release==inactiv, **Switch Off time < 5µs**

Table 2: Overview about local diagnostic and actuator Fast Interlock Systems OP2.1

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