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PPPL- 4921

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June, 2013

Prepared for the U.S. Department of Energy under Contract DE-AC02-09CH11466.

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Hardwired Control System Changes for NSTX DC Power Feeds*

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Abstract

The National Spherical Torus Experiment (NSTX) has been designed and installed in the existing facilities at Princeton Plasma Physics Laboratory (PPPL). Most of the hardware, plant facilities, auxiliary sub-systems, and power systems originally used for the Tokamak Fusion Test Reactor (TFTR) have been used with suitable modifications to reflect NSTX needs. The original TFTR Hardwired Control System (HCS) with electromechanical relays was used for NSTX DC Power loop control and protection during NSTX operations. As part of the NSTX Upgrade, the HCS is being changed to a PLC-based system with the same control logic. This paper gives a description of the changeover to the new PLC-based system

INTRODUCTION

NSTX uses the original TFTR FCPC Hardwired Control System designed and implemented in the seventies. Four sets of Control Boards were designed and installed for each of the four groups of loads. Electro-mechanical relays were used.
The controls incorporated the following functions:

- Interfacing with the Hardwired Interlock System operated from the main control room
- Providing Permissive to the Rectifier Power Supplies
- Allow Configuration of the power loops by Safety Disconnect Switches
- Disabling the system by opening Line switches and closing ground switches
- Invoking Level 1 Fault of the Rectifier system. In this case the Thyristor Rectifiers are suppressed and a Thyistor Bypass path is provided for the load current for discharging the magnet coil. Thus, this essentially is a soft trip of the load. A Level 1 fault is invoked when specific events such as (a) Load overcurrent, Load thermal overload, excessive mechanical forces etc.as computed by a digital coil protection device with built in algorithms based on the current, (b) ground fault, (c) other conditions such as under-voltages in protection and control devices etc.
- Invoking Level 3 Fault of the Rectifier system. In this case in addition to invoking Level 1, the load side is shorted and grounded.
- Each of the Level 1& Level 3 Fault initiations has two redundant systems; one is designated as “Series” system L1S & L3S, and the other “Parallel” system L1P & L3P.
- Emergency Stop (E-Stop) of the Field Coil Power Conversion system. E-Stop will trip all the 13.8kV feeder breakers to the system. Note that when a trip command is given to breaker trip coil, it will also initiate suppression of the Thyristor Rectifier so that the breaker contacts do not have to interrupt the load current. Also the cooling water pump to the Rectifiers will be tripped.
- Interfacing with CICADA by providing the status of the system

For the NSTX upgrade it has been planned to redesign the HCS using a PLC. Siemens PLC - Simatic S7-300 system is proposed. The CPU for the PLC will be housed in a new cabinet to be located near the TF Control Boards. Transition from the present HCS (Electro-mechanical relays) to PLC will be in two or three stages as stated below:
Stage 1: Perform following changes in two of the four Control Boards controlling the rectifiers for the NSTX TF & OH Power Supplies.
Only the primary relays for the defined functions are given below. Resultant changes eliminating other relays to PLC will also be incorporated within these functions.

- Install the CPU in a new cabinet to be provided in TF wing. The enclosure shall be naturally cooled.
- Eliminate the Permissive Relay (69/TPS)
- Eliminate the PAUX Relay (from water system)
- Eliminate the Relay 69/TSDS (TDDO)
- Eliminate the Level 1 Series Relay F1S
- Eliminate the Level 3 Series Relay F3S
- Retain the Level 1 & 3 Parallel Fault System

Stage 2 / 3: System to be designed such that a) the conversion of all other functions to the PLC is achievable in future b) Conversion of the rest of the control boards controlling the PF rectifiers is readily achieved.
The change to PLC will be implemented such that it will be easy to revert back to the old electro-mechanical system in case major problems arise in PLC performance.

SYSTEM DESCRIPTION

Existing system

A block diagram of the existing system is given in Figure 1. In the present system the Levels 1 & 3 are combined.

New System

The block diagram of the proposed new system is given in Figure 2.

Following functions will be performed by the PLC. The associated electro-mechanical relays will be eliminated.

- Permissive
- Breaker Advanced Trip signal logic
- Level 1 Series & Level 3 Series.

* This work supported by the US DOE Contract No. DE-AC02-09CH11466

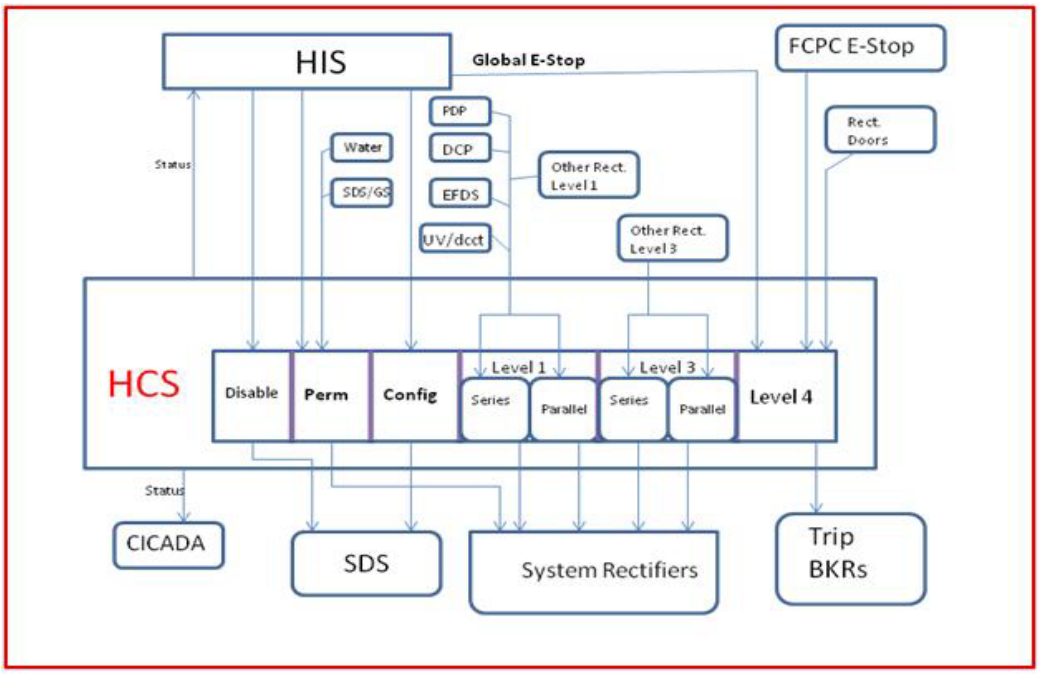

Figure 1 – Existing HCS System

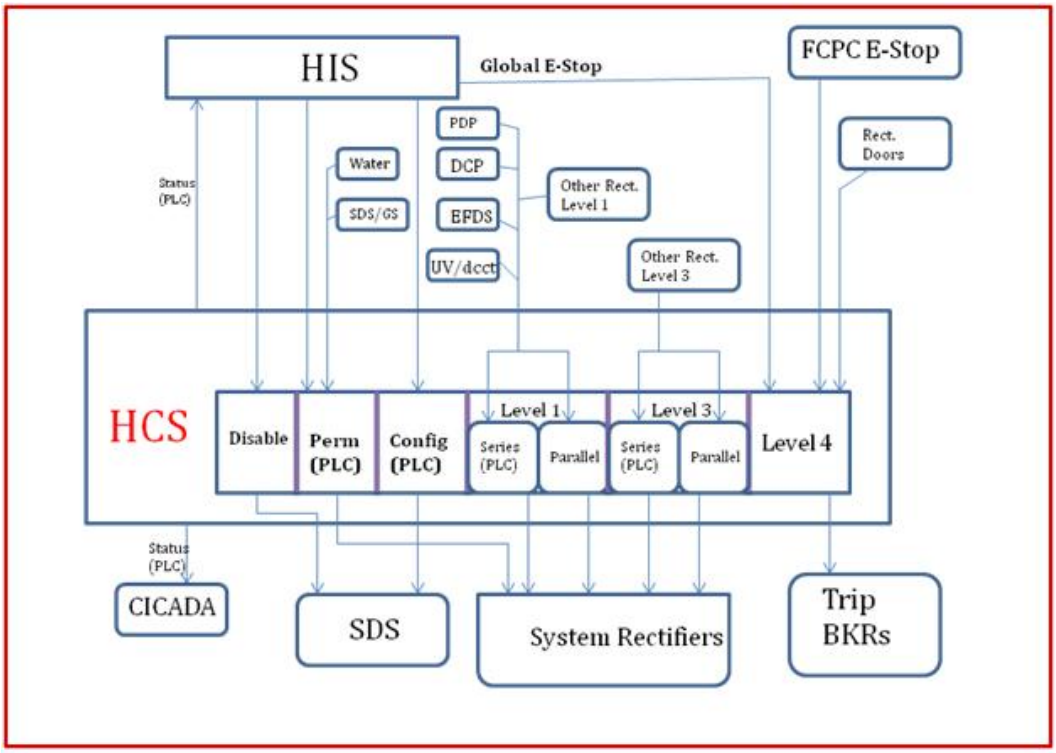

Figure 2 – New System

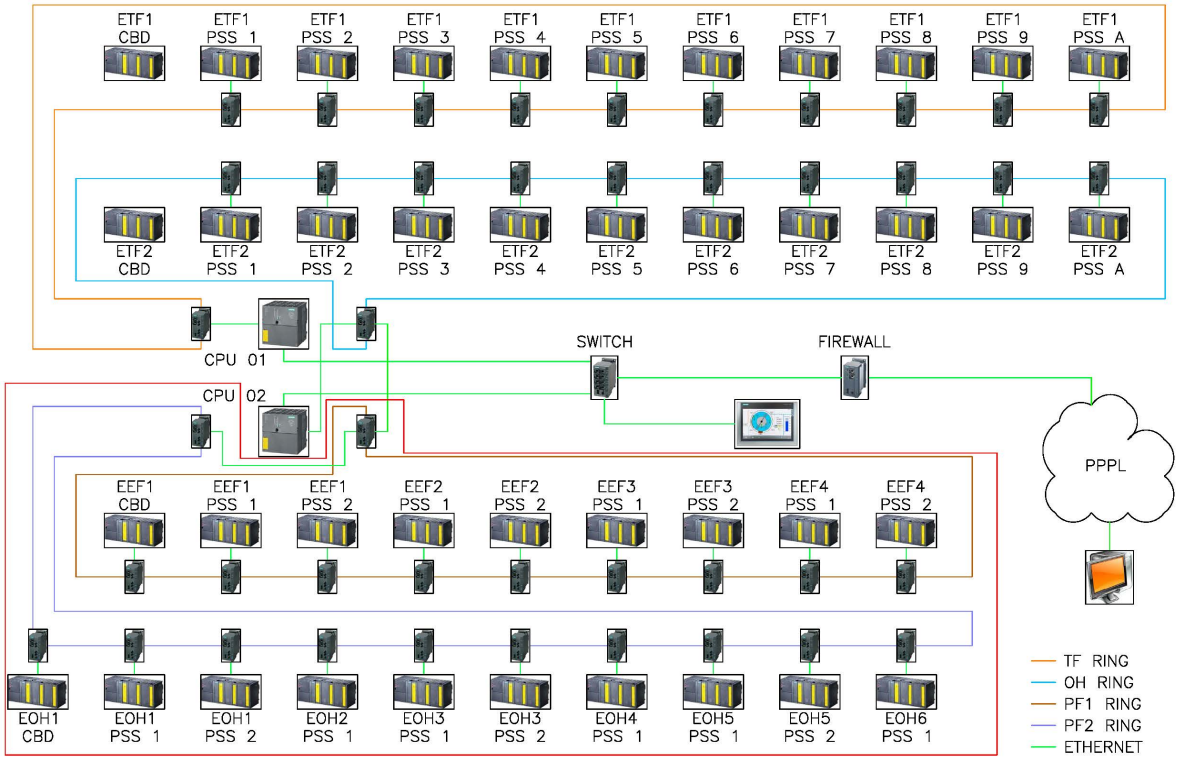

Figure - 3

Salient Features

Figure 3 gives a block diagram of the proposed system.

Initially only the top loop covering a total of twenty rectifiers will be installed. CPU (Siemens S7 319 Failsafe) qualifying to Safety Integrity Level 3 will be installed. Thus eventually the system can include personnel safety related functions (E-Stop) as well. The CPU and the I/O modules (Siemens S7-326 failsafe I/O) for the Control Boards will all be powered from the existing Battery System. The I/O modules in the individual Rectifier cabinets (Siemens S7- 321/322) are proposed to be the standard units in order to get a faster response.

The PLC will:

- Accept the interlock commands from the Hardwired Interlock System (HIS) from the main control room. This includes (a) accepting the configure command to permit line and ground switches to be configured as needed, (b) accepting the Arm command to give permissive to the power supplies so that the rectifiers can be fired as needed by the FCPC Computer (c) accept the Enable/ Disable command to suppress the rectifiers, open the line switches, and close the ground switches.
- Process the fault trip signals originating from each of the associated system rectifiers, and invoke Level 1 (Series) Fault in all the associated supplies.
- Display the status in the device
- Feedback status to Hardwired Interlock System (HIS).

All the existing logic and functionalities will be retained.

Interface with NSTX EPICS and Data Acquisition

The interface with the NSTX EPICS and Data Acquisition will be provided for operator information and troubleshooting capability. However it will not include direct links with the computer system between the processors.

Local Interface and Tools:
A secure, key and password controlled local PC interface will be provided for software upload, parameter upload, reset, and test. All Level 1 fault line interfaces to the FCPC HCS CBDs and EPICS shall be put into a fault state while these activities are underway.

An automated test capability will be provided, via a separate external device, to generate faults.

A test procedure shall be developed to confirm proper PLC functionality.

Performance Features

Time Response

- Time response shall be as reasonably achievable with the standard industrial PLC products and the logic functions

Ladder Logic and Programming

- The required ladder logic will be developed and PLC programmed.
- This will be independently verified and documented

Reliability

The system will be analyzed to conform to SIL 2 standard for equipment protection and SIL 3 standard when the Personnel protection part is also converted to PLC.

Single Point Failure Criteria

In addition to the requirements derived from the analysis to establish SIL 3 standard for personnel safety applications, and SIL 2 standard for equipment protection needs, there shall be no single point failure mode in the PLC system, i.e. no single failure will prevent the PLC from performing in case of any of the causal events listed in the analysis. It is possible to avoid single point failure modes by providing redundancy and/or fail-safe design. With a fail-safe design the failure mode itself results in the annunciation of a fault condition.

F. CONCLUSIONS

The existing HCS system used technology of seventies and uses electromechanical relays. It was decided to transition to a PLC based system to facilitate easy monitoring and trouble shooting.

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[2] S. Ramakrishnan, et.al.,"NSTX Electrical Power Systems", 18th IEEE/NPSS Symposium on Fusion Engineering, Albuquerque, NM, October 1999.

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