1. Abstract

The KSTAR Quench Detection System (QDS) has been operated to protect the superconducting coil system of the KSTAR device for 11 years. A backup signal-processing system of the QDS is being developed mostly using Commercial-Off-The-Shelf (COTS) devices. Both the VME systems and the backup system simultaneously operate to detect quench, which alarms are detected by 1-out-of-2 (2oo2) logic to generate interlock signals, in normal operation. The backup system was integrated with the QDS, and its components for the Poloidal Field 1 (PF1)-PF4 coils were tested in the KSTAR campaign 2018.

2. Quench Detection System

- Quench is a phenomenon of an irreversible thermal runaway in superconductors by breaking critical conditions: temperature, magnetic field, or electrical current density. The superconductors have to be immediately discharged to prevent from overheating themselves in the event of quench. Quench may be detected by discriminating a change of physical parameters such as conductor voltage or temperature.
- The QDS mainly consists of High Voltage (HV) signal interfaces with 83 channels of voltage taps, 3 sets of VME systems with a host computer, and 1 set of a logic solver. The QDS discriminates a normal voltage of >100 mV on NbTi or NbSn Cable-in-Continuous Conductors (CICCs) in the event of quench, while the PF coils are applied with voltages of up to some kV by pulsed operation of the Magnet Power supply System (MPS). Induced voltages on the coils are compensated by quench detection circuits in the HV signal interfaces and digital signal processors of the aged VME systems.
- An allowable delay time to detect quench is about 3 s. Discharge time constants are 4 s, 7 s, and 360 s in the cases of PF, Toroidal Field (TF) fast, and TF slow discharges, respectively. A Mean Time Between Failures (MTBF) of the QDS has to be better than 4 months according as the length of annual KSTAR operation periods.

3. The backup of the Signal-Processing System

The backup signal-processing system duplicates the path of quench detection signals while the existing components operate with no change. The backup system conducts quench detection by using hardware logic including FPGAs, whereas, the VME systems are using CPUs for quench detection. Both the VME systems and the backup system simultaneously operate to detect quench, which alarms are detected by 2oo2 logic to generate interlock signals, in normal operation. The backup system may take over the total functions of the VME systems if the VME systems break down.

4. Results of the Development and Operation

The optical-signal repeater performs (1) Pass-through of the optical signals between the HV signal interface and the VME system, (2) Writedging of the optical signals for the RT signal processors, and (3) Switch of the supervisory system: the VME system or the backup system. All the functions were operational.

5. Conclusion

The backup signal-processing system was integrated with the QDS, and its components demonstrated expected functions for the PF1-PF4 coils in the KSTAR campaign 2018, while the existing components were also fully operational with no modification. This concept of the backup signal-processing system, therefore, seemed acceptable. The total components of the backup system will be tested in the upcoming KSTAR campaign 2019.

- The FGPA of this backup signal-processing system operated at a RT cycle latency of 10 ms in a time accuracy better than ±3 μs, and there was no malfunction during the plasma experiments in the last KSTAR campaign. These FGPA are planned to be inter-connected by a dedicated RT control network, such as Controller Area Network (CAN) bus, to implement advanced compensation methods of induced voltage on the coils.

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