Automatic Fault-Checking System on the DIII–D Tokamak

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Modern tokamaks are highly sophisticated devices consisting of a large number of state-of-the-art systems that must function in unison to obtain a successful plasma discharge. An unsuccessful discharge can result if one or more systems fail, and may be very difficult to diagnose in an efficient and timely manner. The resulting reduction in tokamak availability and productivity can be expensive, therefore justifying a significant effort in the automation of fault diagnosis.

For the DIII–D tokamak, a software system has been developed to automatically monitor and test the performance of hundreds of tokamak systems and components. The Fault Identification and Communication System (FICS) is automatically triggered to run immediately after each tokamak discharge and report its results via a simple color-coded graphical user interface.

FICS is based on the C Language Integrated Production System (CLIPS), inference engine software in the public domain that was developed by the Software Technology Branch at NASA. The execution of FICS is driven by the availability of data following a tokamak discharge, therefore resulting in minimal delay before the start of processing. The data-driven feature also makes it relatively straightforward to add new rules, with no need to modify the logic structure, keeping FICS current with changes in device operation.

The FICS automatic fault-checking system has been in routine use on the DIII–D tokamak since 1999. The system has expanded considerably since its inception and now performs routine tests on a variety of systems including power systems, computer systems, magnetic field coils, vacuum systems, gas injectors, plasma diagnostics, plasma shape control, auxiliary heating systems and even other fault detection systems. The diagnosis of an obvious fault after a discharge is often performed more quickly by an experienced operator, but FICS detects secondary faults that the human operator misses. The large number of routine tests run by FICS far exceeds the capabilities of the operator, allowing them to concentrate on other tasks. The significant advantage of FICS, however, is in its detection of insipient faults, e.g. the slow degradation of performance of a tokamak system that would have caused future discharges to fail. It has been estimated that FICS has saved an average of one to two shots per day, which equates to approximately 5% of all tokamak pulses. Examples and details of the FICS fault-detection system will be presented.

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