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Enhancing Operational Safety: The NSTX-U Shorted Turn Protection (STP) System

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The NSTX-U Shorted Turn Protection (STP) system is an essential safety feature of the NSTX-U tokamak, designed to safeguard its coils during experimental operations. With the upcoming upgrade of the NSTX-U facility, the implementation of the STP system becomes even more critical in ensuring the reliability and safety of research activities.

The development of the STP system was prompted by a non-detected short circuit incident on one of the upper divertor poloidal field coils during NSTX-U operations in 2016. This incident, attributed to manufacturing errors, underscored the importance of robust safety measures and proactive monitoring systems.

The STP algorithm is based on a Kalman filter that estimates the currents through the coils and their corresponding standard deviations. The state-space representation of NSTX-U that STP uses for the Kalman filter is based on a fixed plasma distribution response. STP uses as inputs the measurements of the coil voltages, currents and plasma current. The detection algorithm calculates the ratio of the current mismatches to the standard deviations (for each coil). If any of the ratios is greater than a certain limit, it means there is a significant statistical difference between the nominal model and the plant. This corresponds to a situation where one or more coils have changed their impedance or are shorted (between terminals or turns). If STP detects a fault or anomaly it responds rapidly by terminating the tokamak pulse. This real-time protection helps prevent potential damage to equipment and ensures the safety of the machine.

The STP algorithm was developed based on Matlab and Simulink; it benefits from advanced modeling techniques and automated code generation. By leveraging these tools, the development process is streamlined, thus reducing the time and effort required for implementation.

Since NSTX-U is currently not operating, it has only been possible to test the algorithm using the Autotester system; this system sends a pre-configured set of waveforms to the real-time input data stream, simulating healthy or shorted-turn shots. This testing process helps validate the performance and effectiveness of the STP software.

As the NSTX-U undergoes upgrades and enhancements, the STP system remains a cornerstone of fusion safety. By continuously monitoring and analyzing the behavior of the coils, STP contributes to the ongoing research on fusion operations.

In summary, the NSTX-U Shorted Turn Protection represents an advancement in safety, leveraging technology and sophisticated algorithms to mitigate risks and ensure the reliability of experimental operations.

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