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Implementing a finite-state off-normal and fault response system for robust disruption avoidance in tokamaks

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A finite-state off-normal and fault response (ONFR) system is presented that provides the required supervisory logic for robust disruption avoidance and machine protection in tokamaks. Robust event handling is critical for ITER and future large tokamaks, where plasma parameters will necessarily approach stability limits and many systems will operate near their engineering limits. The ONFR system presented provides four critical features of a robust event handling system: sequential responses to cascading events, event recovery, simultaneous handling of multiple events and actuator prioritization. This system has been deployed during live experiments on DIII-D and KSTAR. In the most complex demonstration on DIII-D, the ONFR algorithm asynchronously applies "catch and subdue" electron cyclotron current drive (ECCD) injection scheme to suppress a virulent 2/1 neoclassical tearing mode, subsequently shuts down ECCD for machine protection when the plasma becomes over-dense, and enables rotating 3D field entrainment of the ensuing locked mode with synchronized ECCD deposition on the locked mode O-point to allow a safe ramp-down, all in the same discharge without user intervention.

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