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Physics of Tokamak Plasma Start-up[1]

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This tutorial describes and reviews the state-of-art in tokamak plasma start-up and its importance to next step devices such as ITER, a Fusion Nuclear Science Facility and a Tokamak/ST demo. Tokamak plasma start-up includes breakdown of the initial gas, ramp-up of the plasma current to its final value and the control of plasma parameters during those phases. Tokamaks rely on an inductive component, typically a central solenoid, which has enabled attainment of high performance levels that has enabled the construction of the ITER device. Optimizing the inductive start-up phase continues to be an area of active research, especially in regards to achieving ITER scenarios. A new generation of superconducting tokamaks, EAST and KSTAR, experiments on DIII-D and operation with JET's ITER-like wall are contributing towards this effort. Inductive start-up relies on transformer action to generate a toroidal loop voltage and successful start-up is determined by gas breakdown, avalanche physics and plasma-wall interaction. The goal of achieving steady-sate tokamak operation has motivated interest in other methods for start-up that do not rely on the central solenoid. These include Coaxial Helicity Injection, outer poloidal field coil start-up, and point source helicity injection, which have achieved 200, 150 and 100 kA respectively of toroidal current on closed flux surfaces. Other methods including merging reconnection startup and Electron Bernstein Wave (EBW) plasma start-up are being studied on various devices. EBW start-up generates a directed electron channel due to wave particle interaction physics while the other methods mentioned rely on magnetic helicity injection and magnetic reconnection which are being modeled and understood using NIMROD code simulations.

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