Progress and challenges of steady state operation of fusion devices

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The steady-state operation of high temperature plasmas is on the critical path for the development of fusion. It requires a high-level of integration of both physics and technology aspects.

On the physics side, one must rely either on an intrinsically steady-state configuration such as the stellarator or on a fully non inductive one, through a mix of non-inductive current sources. The low efficiency of the external current drive methods and the necessity to minimize the re-circulating power forces a current mix strongly weighted towards the internal "pressure driven" bootstrap current, itself sensitive to the plasma heat and particle transport properties. A virtuous circle known as the "advanced Tokamak" may form as the transport properties are themselves sensitive to the current profile conditions.

The physics scenario needs to be combined with steady-state technological constraints. These include both specific technologies required to reach steady-state conditions and generic technologies linked to long pulse operation. The first category includes specific additional heating and current drive methods (through externally launched radio-frequency waves or energetic atoms), fuelling and pumping methods, dedicated plasma diagnostics as well as software technologies required for real time control involving actuators and sensors. The second class of technologies, generic to any magnetic fusion device, includes superconducting magnets providing stationary magnetic fields, actively cooled plasma facing components handling power fluxes often in excess of $10MW/m^2$, dedicated diagnostics monitoring the interfaces (e.g. infrared survey of plasma facing components), etc. The detailed specifications of all elements must comply with a reactor relevant environment, in terms of operational parameters as well as life time.

A synthetic status and outlook of technology and science of the steady state operation in magnetically confined plasmas within the European fusion framework will be given.