Plasma current ramp-up strategies for first wall heat load reduction in ITER

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In the standard ITER plasma current (I_p) ramp-up scenarios [1-4], the plasma is limited on the central column beryllium first wall panels (FWP) in the early phase, with the transition to X-point (divertor) configuration made as early as possible, satisfying the constraints of acceptable FWP heat loads and minimizing poloidal flux consumption such that burn duration is maximized. The transition is typically made when I_p ~ 3.5 MA (ramp-up rate ~0.2 MA·s^{-1}). Recently, however, it has become clear that the near scrape-off layer heat flux channel width is likely to be much narrower than previously suspected [5], posing a problem for wall heat loading, if I_p is too high in limiter configuration and FWP alignment is not tightly controlled. Whilst efforts are now underway to improve on the original wall alignment targets, it is also important to examine different strategies for the current ramp-up phase in the event that heat loads are still too high.

The ITER Poloidal Field (PF) system comprises the 6 module central solenoid (CS) and 6 outer PF coils. With the exception of the two central CS modules (which are connected in series in the circuit CS1), all PF coils and CS modules have independent power supplies. At plasma start-up, the PF system uses a set of resistors in the Switching Network Units (SNU) of the 5 CS circuits and in those of the two nearest to the CS PF coils (PF1 and PF6), as well as pre-programmed voltages of AC/DC converters in all 11 CS and PF coil circuits. The SNU provide the main fraction of the voltages required in these circuits for plasma start-up. All SNU, except for that in the CS1 circuit, are switched off when I_p ~1.5 MA.

Simulations of plasma magnetic control are being performed with the DINA code, taking into account the engineering limits imposed on the coils, their power supplies and plasma-wall gaps [1-4]. At plasma initiation, feedforward control of a circular limiter plasma is performed until ~0.5 MA. These feedforward voltages are then corrected by feedback voltages produced by the system controlling I_p, plasma radial/vertical position, and elongation k_p. In the standard scenario, k_p is steadily increased from k_p ~1.1 (t ~3.5 s, I_p ~1.7 MA) up to formation of the divertor configuration at k_p ~1.6 (t ~10 s, I_p ~3.5 MA).

This paper presents a possible alternative scheme for plasma current ramp-up, which may be used as a mitigation option to reduce the central column FWP heat loads in the event that the required first wall alignment targets prove difficult to meet. In this new approach, I_p is increased up to ~2 MA at the same rate as in the standard scenario, but then maintained constant for ~10 s preparing the plasma shape for the X-point transition. Following the transition, the current ramp-up can continued at the same rate as in the standard scenario. It was found that in the case of plasma current ramp-up performed keeping the ratio of the electron density to the "Greenwald" density at ~0.34 assuming 2 MW of ECRF heating in the limiter phase, both ramp-up schemes lead to about the same burn duration in 15 MA baseline DT scenarios.

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