Design and validation of a 700 kW/CW water load for 3.7 GHz klystrons

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To upgrade the RF output power of the Tore Supra LHCD transmitter, a total of 16 klystrons (TH2103C) at a frequency of 3.7 GHz, able to deliver 700 kW/CW each on matched load will be installed.
The first set of eight klystrons TH2103C feeding one Tore Supra antenna will be set in operation in June 2010.
An actively cooled water load has been developed by SPINNER GmbH and validated by high RF power tests in Tore Supra Lower Hybrid test bed. On the transmitter, the water loads are connected through RF switches which allow transmitting the RF power either to the plasma or to the loads.
The water load, able to dissipate 700kW/CW with 250 l/min of water flow, is crucial to adjust and test klystrons for long pulse experiments in Tore Supra. The new compact design (300*240*100mm) optimizes the cooling circuit to homogenize the flow, avoids water stagnation and guarantees a low temperature of cooling water close to the ceramic surface. This minimizes the temperature raise and correspondingly the RF losses inside the ceramic. The simulations predicted 2 kW of power losses in the ceramic for 698 kW dissipated in the water. Low RF measurements performed in factory (S11 parameter) at different water temperatures remain under -33 dB at 3.7 GHz for a range of temperatures between 30 °C and 70 °C and are in very good accordance with the simulations.
In august 2009, the water load was installed and successfully tested in Tore Supra test bed for an RF power of 680 kW absorbed by the water load. The procedure and the interlocks were carefully monitored to avoid that any problem during the test could damage the klystron. Arc detection interlock and an infrared camera were positioned in front of the ceramic. The temperature surface of the water load was measured with the IR camera and compared to the modelling with good accordance. For conditioning, the RF power was applied during 20 ms pulses every 100 ms to reach the nominal electric field. The water load was then validated with ten 1000 s pulses of 680 kW .
The experimental procedure, the comparison between measurements and simulations are detailed in the paper.

[1] Validation of CW High Power Sources and RF Components for the Tore Supra LHCD System, L.Delpech and al. RF topical june 2009 p431-434.
[2] High Power CW klystron for fusion experiments, 199-200 Vaccum Electronics Conference, IVEC (2008). A.Beunas