THE CONTROL OF MAGNETICALLY CONFINED PLASMAS (IN TOKAMAK FACILITIES)
– talk –

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Fossil fuels (oil, gas, coal) account for approximately 85% of the worldwide sources of primary energy today. But they should run out with in some tens of years and they are responsible for a climate change via the contribution in the greenhouse effect of the CO2 generated by their combustion. Magnetic fusion is one of the options being studied in order to eventually provide an answer to these issues. Several conditions have to be met to produce fusion reactions: the fuels have to be heated up to very high temperature (around 100 million degrees) in order to overcome the electrostatic potential barrier between positively charged nucleuses. To reach such a temperature, the ionized gas or plasma must be confined, for example by magnetic confinement in a so-called tokamak facility, which seems to be the most promising way. The key world project in the domain, ITER (www.iter.org) , is led by seven partners (Europe, United States of America, Japan, China, India, South Korea, Russia) accounting for one half of the world population. The main objective of the ITER project is to demonstrate the scientific feasibility of magnetic fusion. The ITER tokamak facility is currently under construction in Cadarache in France, with first experiment scheduled for 2020.

Tokamak control issues are becoming more and more important for the success of magnetic fusion research and will be crucial for ITER. Feedback control of the main plasma macroscopic parameters, such as plasma position and shape, total current or density is now quite well mastered in the different worldwide tokamaks. But the control of internal plasma radial profiles is still in its infancy, whereas it now appears to be crucial in order both to ensure safe tokamak operation and to sustain high performance plasma regimes. More precisely, it has well known that the so-called safety factor profile is a key parameter for the global stability of plasma discharges and it has also been observed that some specific profiles may generate some enhanced confinement of the plasma energy, which may reduce the size and cost of future fusion reactors. To control his infinite dimension profile, model-based controllers seem to be necessary in front of the complexity of studied physical phenomena and the need of simulation validation before carry out any real experiment.

In this talk, after a short introduction to the fusion energy source development issue, we will focus on the tokamak configuration. The actuators and the diagnostics needed to perform plasma inside this facility will be presented. Then a large overview of the main control requirements for tokamak operations will be proposed. Finally we will detail the plasma infinite dimension profiles control issue. First principles model based on partial differential equations will be presented to illustrate the difficulties of the problem.

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