Particle density modeling for real-time density profile reconstruction and fringe jump detection on TCV and ASDEX Upgrade

T.C. Blanken\textsuperscript{1}, F. Felici\textsuperscript{1}, C.J. Rapson\textsuperscript{2}, the TCV team\textsuperscript{3} and the ASDEX-Upgrade Team\textsuperscript{2}

\textsuperscript{1} Eindhoven University of Technology, Eindhoven, the Netherlands
\textsuperscript{2} Max-Planck-Institut für Plasmaphysik, Garching, Germany
\textsuperscript{3} École Polytechnique Fédérale de Lausanne, SPC-EPFL, Lausanne, Switzerland

Particle density control is important in a tokamak reactor because the density determines, among others, fusion power, radiation, transport and non-inductive current density profiles. Presently, often the line-integrated density of only one interferometry chord is used as input to a density feedback controller. However, real-time knowledge of the particle density profile would allow more accurate real-time estimates of the fusion power, radiation, proximity to disruptions, diagnostics validity (e.g. ECE cut-off), and accurate ray tracing. Inversion of interferometry measurements to a profile is often ill-conditioned. A better approach is to combine measurements with a prediction of the profile evolution, improving the profile smoothness and robustness against sensor errors. We present experimental results of real-time density profile reconstruction on TCV and ASDEX-Upgrade. The reconstruction algorithm, a dynamic state estimator or Kalman filter, employs an interpretative transport model for the particle density \cite{Blanken16, Blanken15}, merging the predicted density evolution with various diagnostics signals. The model is physics-based yet control-oriented, simulating the evolution of the electron density profile and inventories of wall and vacuum. We show that the model is able to reproduce the particle inventory dynamics seen on TCV and ASDEX-Upgrade \cite{Rohde09}. Furthermore, a fringe jump detector is implemented that uses the difference between modeled and measured interferometry signals, allowing real-time correction of fringe jumps. The results show good accuracy of the reconstructed profiles, and demonstrate the feasibility to use them for control and other applications. Extending the algorithms to larger future machines is simplified by the transport code, which can easily be adapted to the specific physics, diagnostics and actuators of each tokamak.

References

\begin{itemize}
\item \cite{Blanken16} T.C. Blanken, F. Felici, M. de Baar and W.P.M.H. Heemels, “Model-based reconstruction and feedback control of the plasma particle density in tokamaks,” (to be submitted, 2016).
\item \cite{Blanken15} T.C. Blanken, F. Felici, M. de Baar and W.P.M.H. Heemels, “Modeling, observer design and robust control of the particle density in tokamak plasmas,” Conference on Decision and Control, Osaka, Japan (2015).
\item \cite{Rohde09} V. Rohde, V. Mertens, A. Scarabosio and the ASDEX Upgrade Team, “Gas balance in ASDEX Upgrade with tungsten first wall,” Journal of Nuclear Materials, 390-391 (2009).
\end{itemize}