Seminar

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Institute for Plasma Research

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Title: FPGA based real time density feedback control system for ADITYA-U tokamak

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Abstract

Real time density feedback system can help achieve better plasma parameters in a tokamak. Moreover, the density feedback system can also help in performing plasma experiments in a controlled parametric regime. Feedback systems generally consist of three sub-systems. First one is the diagnostics system for measuring the parameters which needs to be controlled accurately, for instance, the plasma density. Second, the heart of the feedback system, is control system which decides the extent of the feedback to be applied and, essentially is a controller and its program. Finally, the system to implement the feedback is the actuators or drivers, which physically act to implement the feedback by controlling the desired parameters of the feedback.

In this work, for ADITYA-U tokamak, gas-puff based feedback system is commissioned for plasma density feedback. For fast and reliable plasma density measurement an indigenously developed, 100 GHz microwave interferometer is commissioned as plasma diagnostic tool for real-time electron density measurement in ADITYA-U. For calibrating the interferometer, a pneumatic calibrator controlled by an Arduino processor is developed. The processor measures the displacement of the microwave reflector using ultrasound sensors and correlates this distance with the path length measured by the developed interferometer. For estimating the plasma density in real-time, using the interferometer, an FPGA-based signal processing algorithm is developed in LabVIEW. Phase between the two arms of the interferometer is estimated using the CORDIC algorithm implemented on FPGA. This fast phase detection algorithm helps to generate the density signals for processing the density feedback. Real-time density from the interferometer is fed to the feedback control system that decides the feedback action based on the deviation from the set density value at a given instant of time. Subsequently, the feedback controller generates an error signal which is amplified depending on requirement of the physical system for the feedback.

The feedback action is performed by gas injection into the vacuum vessel using a piezoelectric valve. For effective feedback action using a gas puff, it is essential to have detailed information of the gas dynamics and pressure evolution within the vacuum vessel. However, presence of a very high magnetic field limits the use of ionization gauges for pressure measurement during the plasma operation. Hence, an ASDEX pressure gauge is developed and commissioned on the vacuum vessel to precisely measure the real-time neutral pressure inside the vacuum vessel. The piezoelectric valve based gas injection system is calibrated for the mass flow using the ASDEX gauge and mass flow controllers. The developed density feedback system based on the heterodyne interferometer is commissioned in ADITYA-U and its performance is evaluated in details for a fairly large number of plasma discharges. Based on the response of the feedback system, further optimizations on the gas puffing system are carried out. Smooth and continuous evolution of plasma density is observed during the real-time density feedback in ADITYA-U.