REAL TIME NEUTRAL BEAM POWER CONTROL ON MAST

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The Mega Ampere Spherical Tokamak (MAST) at Culham uses Neutral Beam (MNBI) heating from two Joint European Torus (JET) style Positive Ion Neutral Injectors (PINIs) designed to provide up to 5MW of power. The MAST PINIs are of a tetrode arrangement, operate in deuterium and use a filament driven discharge to produce up to 65A of extracted beam current [1].

JET utilises 15 PINIs, independently controlled and modulated to provide time averaged power waveforms with resolutions smaller than the power of an individual PINI. This method of 100% on-off pulse-width modulation on JET is successful as the time taken to slow NB fast ions [2] in the plasma (τ_s) is relatively long (~100ms) compared to the PINI re-application time (40ms) and therefore insensitive to it. However on MAST, τ_s is shorter (~30ms) and the plasma would respond to beam modulation even with the shorter re-application time of MNBI (23ms) [3], so an alternative method of power modulation is required.

Beam divergence is dependent on perveance, and it has been demonstrated that for the MAST PINI a variation in perveance of 20% has only minimal effect to the beam footprint [1]. As beam current is proportional to the arc current, the beam power can be varied by controlling the arc power supply in real time with almost no loss of transmission. This has the additional advantage of maintaining the beam voltage which is beneficial for diagnostics such as Motional Stark Effect (MSE) which use and are calibrated against beam voltage. Injecting a signal waveform into the arc power supply enables the necessary additional control signals (such as filament, snubber and protection thresholds) to be determined. Operation in full neutral beam mode establishes the power ramp rate and magnitude that can be sustained without compromising HV stand off or beam transmission. The plasma response is monitored using Thomson scattering and other diagnostics to measure density, temperature and total stored energy to demonstrate the effect of neutral beam power control.

This paper provides an overview of the experiment, shows how Field Programmable Gate Arrays (FPGA) will be used in the implementation and integration of this real time control into the current neutral beam system and will discuss how this integration will allow real time control of each individual injector by MAST for the MAST Upgrade, providing more flexibility for the experimental program.

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[1] D. A. Homfray et al, “Overview of MAST Neutral Beam System Performance”, 23rd Symposium on Fusion Engineering, 2009.
[2] T. Stix, “Heating of Toroidal Plasmas by Neutral Injection”, Plasma Phys. Vol 14, P367-384, 1971.
[3] P. Stevenson et al, “Design and Commissioning of the MAST Neutral Beam Power Supplies for the Long Pulse Beam Upgrade, 23rd Symposium on Fusion Engineering, 2009.