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Title:
Digital Control and Power Systems for the URANIA Experiment

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Fully digital control systems leveraging Field Programmable Gate Array (FPGA) technology are being developed to support power supply and control system upgrades for the new URANIA experiment. Power supply upgrades include: a modular ~144 MVA (40 × 4 kA × 900 V) H-bridge buck converter system for driving electromagnets; a 0.4 MVA, 80 kV, 5 A zero voltage switching (ZVS) resonant converter for a diagnostic neutral beam (DNB); a ~1 MVA resonant converter for electron Bernstein wave (EBW) RF heating and current drive; and a next-generation 32 MVA low-ripple, continuous current power supply with voltage gain capability for driving advanced, high-power local helicity injection (LHI) sources and sustained coaxial helicity injection (CHI) systems. Control system upgrades will include digital active feedback controllers for these power systems, as well as an LHI cathode spot suppression system. An initial digital controls upgrade was deployed on the PEGASUS ST that replaced the optical interface between individual power supply switches and their analog feedback controllers. The new FPGA system improves power system protections by providing continuous safety monitoring for fault conditions; digital input command stream filtering; and improved EMI rejection. Fully digital, FPGA-based replacements of the electromagnet analog PWM feedback controllers are being developed. These digital controllers will allow for reconfigurable control algorithms, are easily expandable with off-the-shelf hardware, reduce susceptibility to EMI, and eliminate analog drift. These FPGA-based systems support the expanded poloidal field (PF) and toroidal field (TF) coil sets of URANIA. The PF expansion will improve plasma shape and position control. A four-fold increase in B_T to 0.6 T ($I_{TF} = 1.15$ MA; 24 turns, 48 kA/turn) and pulse length (~100 ms) is necessary for planned URANIA experiments that will examine: higher-power LHI; EBW heating and current drive; and both transient and sustained CHI. A three-phase, ZVS resonant converter driven by an FPGA control system for the URANIA DNB has been tested in 40 kV, 6 ms pulses to date. When fully commissioned, it is expected to provide output time response < 200 μs, and have an output ripple $\ll$ 1% at 80 kV. A variant of the ZVS resonant converter topology with higher stored energy is planned to drive the EBW RF sources. Digital active feedback control will also drive a new 32 MVA LHI power supply that will improve upon the H-bridge topology by providing continuous current and voltage gain capabilities with low output ripple. These improvements will enable time-varying LHI voltage control and improve energy storage utilization. Active control of the time varying LHI voltage will provide a new actuator for the active control of LHI initiated plasmas. A prototype based on the Ćuk topology has achieved a ~1.2 MW (340 V at 3.4 kA) flat-top pulse with ~3% ripple for ~25 ms while realizing 60% stored energy utilization.

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