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Benign Termination of Runaway Electron Beams on ASDEX Upgrade and TCV

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Runaway electrons (RE) pose a significant threat for ITER and a mitigation technique is yet to be validated. Preliminary experiments on DIII-D and JET showed that reduced damage to the vessel can be achieved by accessing MHD instabilities that lead to spreading of the RE beam impact area [Paz-Soldan 2019, Reux 2021]. These instabilities were attained by "flushing"impurities and recombining the companion plasma, thus reducing the resistance and electric field (E), and sustaining beams until a low edge safety factor (qa) was achieved. Regeneration of the REs did not occur during the current quench due to the low E. This approach was successfully applied on ASDEX Upgrade and TCV this year. On-going experiments have been exploring the possible operational space and the underling physics involved and this paper will report the preliminary findings and outlook of this program.
RE beams were generated via massive gas injection (MGI) of argon on ASDEX Upgrade and neon on TCV. Secondary injections of D2 to flush impurities and recombine the companion plasma were executed with combinations of MGI, fueling pellets and fueling valves. Experiments on TCV showed that neutral pressure was more directly linked to plasma recombination than injected quantity. This was due to pumping effects that become non-negligible with beam durations in the order of seconds. It was found that neutral pressures of 0.10-0.15 Pa were required on both machines to recombine companion plasmas with RE currents of 120-600 kA. This study was further extended on TCV through variations in injected impurity gas quantity and the use of H2 instead of D2 as the secondary injection gas. It was found that higher neutral pressures were required to recombine the plasma when higher neon quantities were injected and no significant differences between H2 and D2 secondary injection were observed.
Fueling valves were used to maintain the neutral pressure required to prevent re-ionisation of the companion plasma and access a low E. This led to a record RE beam duration of ~4s on ASDEX Upgrade and the ability to increase the RE current on both machines. Reduction of qa was achieved via plasma current ramps on TCV and compression of the plasma onto the central column on both machines. Beam currents, current ramp rates and compression rates were scanned. Most beams terminated at a qa of ~2, with the exception of a 200kA beam on AUG, compressed over 500 ms, which produced a benign termination at a qa of ~3. Experiments compressing partially recombined plasmas have also begun on both machines and differences in wetted area and RE beam energy for flushed and unflushed plasmas have been measured on both machines. Preliminary results show significantly reduced heat fluxes to the inner wall and a reduction in beam energy during the recombined companion plasma phase.
Further experiments are planned on both machines for later this year. These experiments will focus on benign termination of partially recombined companion plasmas, scans of compression rates and variations in secondary injection gas species and concentration.
Images

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