IAEA FEC 2014

Contribution ID: **736** Type: **Poster**

Radial Localization of Alfven Eigenmodes and Zonal Field Generation

Friday 17 October 2014 08:30 (4 hours)

In the well-accepted and widely-exercised paradigm, the Alfven eigenmode (AE) growth rate can be calculated from a perturbative energetic particle (EP) contribution to a fixed mode structure and real frequency given by MHD properties of thermal plasmas. However, our studies show that accurate prediction of the AE growth rate requires non-perturbative, self-consistent simulations to calculate the true mode structures. GTC gyrokinetic particle simulations of DIII-D discharge #142111 near 525ms find a radial localization of the toroidal Alfven eigenmode (TAE) due to the the modification of the MHD mode structure, i.e., non-perturbative EP contribution. The EP-driven TAE has a radial mode width much smaller than that predicted by the MHD code NOVA. The TAE radial position peaks at and moves with the location of the strongest EP pressure gradients. Experimental data confirms that the eigenfunction drifts quickly outward in the radial direction. The EP contribution also breaks the radial symmetry of the ballooning mode structure and induces a dependence of the TAE frequency on the toroidal mode number, in excellent agreement with the experimental measurements. The radial localization could have profound implications on the EP transport.

GTC nonlinear simulation of the TAE in DIII-D discharge #142111 near 525ms finds that zonal fields are driven by TAE mode coupling (passive generation). The collisionless skin-depth effects suppress the modulational instability. The growth rate of the zonal fields is twice of the TAE growth rate, consistent with earlier MHD-gyrokinetic hybrid simulations. A threshold of the TAE amplitude for driving the zonal fields is also observed. The effects of the zonal fields on the TAE nonlinear saturation are weak. GTC nonlinear simulations of beta-induced Alfven eigenmode (BAE) show that the mode frequency has a fast chirping associated with the oscillation of the mode amplitude. Localized zonal fields with a negative value around the mode rational surface are generated by BAE. In the weakly driven case, the zonal fields with a strong geodesic acoustic mode (GAM) component have weak effects on the BAE evolution. In the strongly driven case, the zonal fields are dominated by a more significant zero frequency component and have stronger effects on the BAE dynamics.

Paper Number

TH/7-2

Country or International Organisation

USA

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Session Classification: Poster 7