NUMERICAL MODEL: FAR3D gyro-fluid code

The plasma velocity and perturbation of the magnetic field are defined as:

\[ \vec{v} = \nabla \times \nabla \times \vec{B} \]

where \( \vec{B} \) is the stream function of the electrostatic potential \( \vec{\psi} = \text{Poloidal flux} \)

The model uses the new vorticity definition:

\[ \vec{U} = \nabla \times \left( \nabla \times \vec{\psi} \right) \]

The perturbation of the next thermal plasma variable is evolved in time:

a) Poloidal flux \( \vec{\psi} \)

b) Vorticity toroidal component: \( \vec{U} \)

c) Pressure: \( \vec{P} \)

d) Thermal plasma parallel velocity (acoustic modes coupling): \( \vec{v}_p \)

e) EP density: \( \vec{n} \)

The numerical model uses an averaged Maxwellian distribution for the EP fitted to the slowing down distribution. The set of input equilibria is used in the simulations taking the fixed boundary results from the VMEC equilibrium code calculated for the LHD discharge 138675 and the Heliotron J discharge 61484 (reference cases).

EPM/TAE STABILIZATION IN LHD

- Continuum damping of the c-toroidal mode is observed only with a given threshold if \( \vec{B} \) decreases (c-toroidal injection). The \( \vec{B} \) threshold is linked to the destabilizing effect of the 1/2 radial resonance, entering in the plasma and overcoming the stabilizing effect of the magnetic shear.

- The frequency of the simulated n=1 EPM is 89 kHz and the n=2 GAE is 145 kHz, similar to the experiment (3a).

- 1/2 EPM and 2/4 GAE mode growth rate similar to the experiment (3d and e).

EPM/GAE STABILIZATION IN HELIOTRON J

- The \( \vec{v} \) profile is deformed by the ECCD injection. The EPM/GAE growth rate and freq. change (7a to d).

- A-Co ECCD increases \( \vec{v} \) and a c-toroidal decreases \( \vec{v} \) (7a and b).

- Co- and c-toroidal increase the magnetic shear in the inner-outter plasma.

- A c-toroidal with \( \vec{v} = [0.4, 0.56] \) further destabilize the EPM/GAE, because the 1/2 radial resonance enters in the plasma. If \( \vec{v} < 0.4 \), the 1/2 is located at the plasma periphery where the magnetic shear is stronger, so the EPM/GAE growth rate decreases.

- The continuum damping is enhanced as the \( \vec{v} \) decreases (7 e and f).

CONCLUSIONS

- A set of linear simulations are performed by the FAR3D code studying the effect of the ECCD injection on the Heliotron J and LHD plasma stability. The simulation results are compared with the experimental data showing a reasonable agreement.

- The simulations for Heliotron J show an improvement of the EPM/AE stability if the magnetic shear is enhanced as \( \vec{v} \) increases (co- ECD injection), although only below a given threshold if \( \vec{n} \) decreases (c-toroidal injection). The \( \vec{n} \) threshold is linked to the destabilizing effect of the 1/2 radial resonance, entering in the plasma and overcoming the stabilizing effect of the magnetic shear. A further decrease of the \( \vec{n} \) leads to a 1/2 radial surface located at the plasma periphery where the magnetic shear is strong enough to stabilize the EPM/AE. In addition, the application of ECCD also adds a stabilization of the continuum damping. The simulations of LHD discharges with ECCD indicate the further destabilization of EPM/AE in the cases with co- ECD injection and stabilization in the cases with c-toroidal injection. The EPM and TAE observed in the experiment are destabilized in the inner plasma region where the continuum damping is enhanced as the \( \vec{n} \) decreases due to the c-toroidal.