Research Milestone R(18-X) Assess Transient CHI Current Start-up Potential for a ST-FNSF

Description: Solenoid-free plasma initiation is likely required in future ST devices such as a FNSF/CTF facility to enable operation at low aspect ratio with minimal inboard neutron shielding. Transient Coaxial Helicity Injection (CHI) is a leading candidate method for solenoid-free plasma initiation in the ST configuration and has already demonstrated 100-200kA of closed-flux plasma current generation in present STs. The present understanding of the current scaling for transient CHI suggests that the current generation potential is directly proportional to the device's injector flux capability. At present there does not seem to exist a physics limit to the amount of poloidal-injected flux that could be used for start-up. Simulations using the TSC and NIMROD codes will be performed to assess the maximum injector flux that could be used in a ST configuration. The resulting increases to the electron temperature, and the dependence of 3-D reconnection processes on injector parameters as the amount of injector flux and the toroidal field is increased to levels capable of generating multi-MA level start-up currents will be examined. In particular, the 3-D MHD physics modeling is critical for investigating whether all of the needed current required for plasma sustainment could be generated by transient CHI alone. Using 3-D simulations, the feasible maximum injector flux will be determined.

Another aspect that may be important for the implementation of CHI in a FNSF is the use simpler electrode structures, such as for example biasing an electrode with respect to a grounded vessel component. Scoping design studies for a ST-FNSF suggests that with the use of biased electrodes, the insulator could be easily protected from neutrons and that the insulator would maintain its integrity for the lifetime of the reactor. To test if such an electrode configuration is compatible with transient CHI operations, supporting experiments will be conducted on the QUEST ST in Japan to establish transient CHI capability in this, recently installed, alternate electrode configuration, using metal electrodes. An initial test of electron heating due the application of high-power electron cyclotron heating in QUEST may also be conducted. The NSTX-U device is also capable of supporting such an electrode configuration, for example by placing an insulated electrode below the inner upper divertor plate. Scoping studies would be conducted to investigate the design of such an alternate electrode configuration for NSTX-U. A design based on biased electrodes will be developed for a CHI system for PEGASUS that is capable of generating 200 – 300kA start-up currents, to the maximum levels that could be supported by the existing PF coils on PEGASUS. A feasibility study for the installation of a point source helicity injection on NSTX-U will also be conducted.

What will be done?

1) In the NSTX geometry (but we are not using the word NSTX or NSTX-U, we are calling it a ST configuration) we will increase the injector flux to very high levels to see if there is a fundamental physics limit to the maximum amount of flux that can injected, and if a stable configuration continues to be generated or if there are some new instabilities that develop that reduces the amount of closed flux current at high levels of injector flux.
2) At fixed injector flux, the effect of increasing the toroidal field would be studied.
3) For the modeling study, a generic ST configuration is needed. We have working versions of the codes for the NSTX/NSTX-U geometry. There is nothing new to be gained by adopting a new vessel configuration. If we use a new vessel configuration a lot of time is needed to just get the model working in this new configuration, but the end result would be the same. A Postdoc will be developing a QUEST vessel configuration for TSC, but we do not want to promise this for 2018, so it is not mentioned. The progress made with the QUEST TSC simulations will be reported in the milestone summary report.
4) Experimental CHI plasmas would be generated on QUEST and diagnosed and ECH will be injected into these plasmas.
5) We will design the CHI configuration for Pegasus.