Inductive Start Up of NSTX and DIII-D Without the Use of a Central Solenoid

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Motivation:

- Spherical Torus reactor designs do not include a central solenoid:
  --Plasma start up is a critical issue

- AT reactors also benefit from reduction in V-S capacity of central solenoid

- Limited data in literature on initiation and ramp-up using induction available from poloidal field coils
  --Recent experiments on JT-60U, soon to be published, are a very good start on PF coil start up research.

- Experiments on NSTX and DIII-D are needed to explore possible scenarios

Summary of Proposed Scope of Work

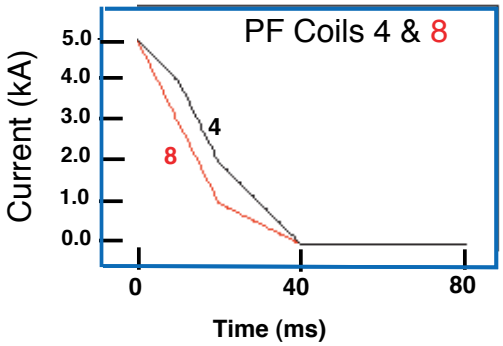
- Support existing NSTX XP's on PF coil start up with DINA code modeling
  - DINA is a time dependent resistive MHD and transport modeling code using real device coil and vacuum vessel geometry and power supply characteristics.
  - NSTX and DIII-D device characteristics are already available in DINA
  - Pre-experiment modeling useful for scenario development and control system setup.
  - Post-experiment modeling to assist analysis.

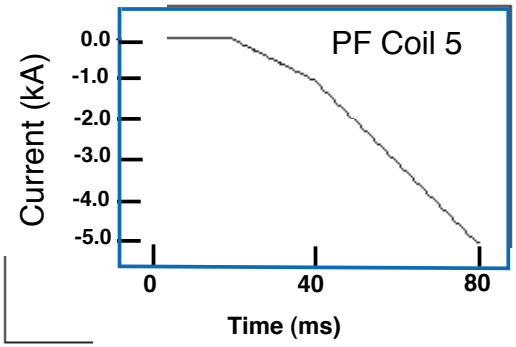
- Model and Perform PF coil start up experiments on DIII-D
  - Previous DINA modeling of PF coil start up on DIII-D is very promising
  - Recent upgrades to DINA will allow more detailed modeling of plasma initiation
  - Some control system modifications are needed for these experiments

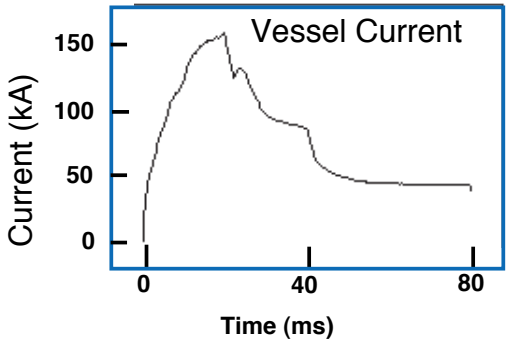
Modeling Indicates PF Coil Ramp Up of Plasma Current to 200 kA on DIII-D

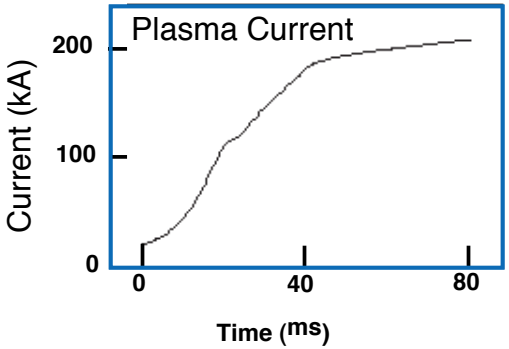
Brief Description of DINA Model:

- Massless, resistive, axisymmetric plasma MHD model
- Free boundary 2-D equilibrium is solved on a rectangular grid
- 1-D flux surface-averaged transport of energy, density of plasma components and poloidal magnetic flux
- "Inverse variable" equilibrium technique is used for mapping between equilibrium flux coordinates and rectangular grid
- Effects of eddy currents included: PF coils, passive structure (e.g. vacuum vessel) are represented by a set of inductively coupled filements









Recent Upgrades to the DINA Code by the TRINITI Group

1. Plasma current on both closed and open magnetic surfaces
2. Adaptive (moving) grid method for very small plasma size up to standard size, important for the modeling of PF coil startup when the initial plasma current channel is small and control of plasma position is difficult.
3. Modeling of pre-breakdown null formation and breakdown phase. For breakdown and startup cases, transport equations, including balance of neutrals, are solved self-consistently with 2D equilibrium.
4. Implementation under Matlab/Simulink for detailed control simulations

Extensive Benchmarking and Use of DINA:

1. Correctly simulates plasma shape, position control and disruptions on DIII-D, TCV and JT-60U devices.
2. Used for control system development on DIII-D and other tokamaks
3. DINA/Simulink model extensively applied and validated in control studies on DIII-D and TCV
4. Used for ITER scenario simulations.

Expected Outcome

1. Support of scenario development for NSTX XP.
2. Support of scenario development and control system modifications for DIII-D
3. Post experiment analysis support for both NSTX & DIII-D.
4. Contributions to publications on the experimental results.
5. Independent paper on modeling of PF coil startup