

Low-density Start-up

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Historically, fueling and heating help avoid MHD during start-up

- Long experience with goal of achieving long, stable, high-performance discharges has led to the present prescription
 - both low-field and high-field side gas puffing
 - Rapid I_p ramp-rate
 - Low I_i used
 - High dI_p/dt
 - large aperture start-up
 - early heating
- Most of these also increase the plasma density

New approach is needed for low density

- Simply turning off gas and/or heating does not work to produce stable plasmas
- Partial existence proof: CHI initiated discharges had low density, low I_i , larger R, OH(0)=0 and were stable (but no flattop and L-Mode)
- Error fields are more likely to cause locked modes (or other MHD?) at low density (does low I_i help?)
 1. Use zero OH precharge to minimize error fields
 2. Use high V_{loop} like CHI did
 3. Try low voltage start-up and low dI_p/dt
 4. Use RWM coils early to correct for error fields

(In H-Mode, $n_e I$ increases about $1 \times 10^{15}/\text{cm}^2$ per 0.1s)

Strategy

- Use zero OH precharge to investigate if OHXTF is source of error fields
 - This at least starts with only eddy currents contributing to error (ramping coils, ramping errors?)
 - If this is successful, investigate error –field reduction with RWM coils next (if not try this later)
- Try high initial V_{loop} , with larger R and kappa with low gas fueling, like the low I_i , low n_e CHI shots
- Try low voltage start-up with slow dI_p/dt with low gas fueling and low NBI
- Attack early error field correction
- In all cases, compare n_e evolution to a 2 NB source, 700 kA fiducial plasma to evaluate success

Zero OH pre-charge

- Starting up is straight-forward, plasma shape like fiducial
- Goal 600 or 700 kA (to have a bit of flattop)
- Use only prefill, early NBI timing like 2-source fiducial
- Introduce flat spot in I_p ramp to get H-Mode
- Add some LFS gas if needed to get H-Mode
- If LFS gas does not work add some HFS gas
- Compare to same I_p , shape and gas programming, but with full OH precharge

High loop Voltage (low early I_i)

- Try about 4V/turn, about double standard
- Use lower PF5 to get larger R
- Reduce PF3/PF5 ratio like CHI case (taller plasma)
- Will require tweaking of PF1AU&L to avoid hitting top
- Make R 10cm bigger in first 70 ms
- Flattop at 600-700 kA
- Use only prefill, early NBI timing like 2 source fiducial
- Introduce flat spot in I_p ramp to get H-Mode
- Add some LFS gas if needed to get H-Mode
- Add blip of 3rd NB source
- If that does not work add some HFS

Low loop voltage

- During the slow ramp-up ($\sim 5 - 7$ MA/s), we normally use ~ 2 V/turn for L-Mode or ~ 1.5 V/turn in H-Mode.
- Try to use < 1.5 V for breakdown (will require lower prefill and PF5). Ramp to 700 kA at ~ 0.6 s
- Larger plasma size at start-up generally leads to lower I_i ; May need this to offset the faster current penetration due to lower T_e from lower input power. Start with the usual PF3/PF5 ratio and lower it as needed to get lower I_i
- Use only prefill, use plasma shape similar to fiducial, but taller early on
- Inject beams early similar to 2 source fiducial
- Use usual tricks of flat-spot in I_p ramp, LFS gas, 3rd NB source, or some HFS gas to get H-Mode

No LFS gas - early H_{α} spikes and higher I_i , then shorter duration

