OFF-NORMAL AND FAILURE CONDITION ANALYSIS OF THE MITICA NEGATIVE-ION ACCELERATOR

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MITICA Goal:
P = 16 MW
I = 40 A
V = 1 MV
\( t = 3600 \) s

MITICA (Megavolt ITER Injector & Concept Advancement) is the full-scale prototype of ITER NBI.

The negative ion (D) accelerator design is based on Multi Aperture Multi Gap concept (7 grids, 1280 apertures).

Main design issue: keep the thermo-mechanical stresses in the materials below the tolerable limit for the required pulse duration and fatigue life

Achieved by: (a) reducing and uniforming heat loads caused by electrons and secondary particles
(b) improving heat removal capability of the water cooling channels inside the grids

Aim of this work: analyse and identify the "off-normal" operating conditions of MITICA accelerator.

Condition #1: demagnetization of permanent magnets
• \( B_{r} \), reduced from 1.1 T to 0.5 T for all the magnets contiguous to one beamlet
• Heat load increased by a factor of 2.5 on AG2 (due to co-extracted ions)
• Could lead to damages if a large area (tens of beamlets) is affected

Condition #2: PG current failure
• PG current is necessary for generating long-range magnetic field for electron deflection
• Partial (75%) and total (0%) failure considered
• Major effect: increase of transmitted electrons

Condition #3: non uniform extracted current/gas density
• Non uniform extraction observed in large ion sources
• Both reduced extracted current (+20%) and increased gas density (+20%) lead to higher heat loads on the grids
• Heat load on last grids probably underestimated due to lack of realizable model of halo region

Condition #4: breakdown between grids
• Modeled considering zero voltage across one of the acceleration gaps, and the voltage on the other gaps unchanged
• Breakdown PG-EG and EG-AG1 not considered as the accelerator operation would be interrupted
• Optics quality deteriorated, total beam energy decreased by 200 kV

Condition #5: variation of extraction gap
• Heat loads lead to out-of-plane grid deformation
• Variation of extraction gap between 5 and 7 mm has been investigated
• Resulting divergence of 0.5 mrad has been obtained (acceptable)

Condition #6: effect of grid misplacement
• Misplacement due to grid deformation caused by heat loads, wrong mechanical tolerances and over-constrained thermal expansion
• Final deflection range [-1.6, 2.4] is slightly larger than the requirement on beamlet alignment (±2 mrad)

Detection and protection strategies
• Faults having purely electric nature: easy detection
• Other faults: temperature measure of cooling water combined with other diagnostics:
  • Beam Emission Spectroscopy (BES)
  • Beam tomography
  • Secondary emission imaging on the calibrator
  • Data cross-checking could be complex and time-consuming

Conclusions
• Off-normal operating conditions cause a degradation of performances but do not constitute immediate risk
• Detection requires processing and cross-checking data from different diagnostic systems

REFERENCES