Abstract

In the MITICA research program for the construction of the ITER Neutral Beam Injector prototype, a Laboratory for the investigation on high voltage holding in vacuum has been set up. This Laboratory - HVPTF: High Voltage Padova Test Facility - is presently capable of experiments up to 300 kV dc, and planned for the upgrade to 800 kV. The specific mission for this ancillary lab is the support to the electrostatic design and construction of the MITICA analyzer and the development and testing of HV components to be installed inside the MITICA accelerator during its operation.

The paper describes the structure of the lab, characterized by a high degree of automation and reports the results of the commissioning at 300 kV and the first results of voltage holding between test electrodes.

The 300 kV setup

- **Objectives**
  - Breakdown Predictive Model Valuation*
  - HV lab to develop and test components for MITICA
  - Clean electrostatic configuration
  - High vacuum quality
  - Precise control of Power Supplies

- **Structure**
  - Symmetric
  - Air-to-vacuum feedthrough
  - Movable electrodes
  - \( E_{\text{em}} < 0.01 \text{ MV/m} \)

- **The Vacuum Tank**
  - \( D=960 \text{ mm}, D=759 \text{ mm}, s=5 \text{ mm}, V=0.5 \text{ m}^3 \)
  - AISI 304L
  - 3 CF100 for diagnostic
  - 1 CF200 for the connection to the Vacuum System
  - Upper lid sealed by Viton® oring and clamps; covered by 5 mm lead for X screening
  - Inner surface satin finished and ethanol cleaned
  - Provided of PID controlled 9 kW heating cables system for speed up outgassing (Tmax 120 C)
  - Global flow rate, \( Q_{\text{tot}} = 5.9 \times 10^4 \text{ mbar/l/s} \)

- **The HV Feedthroughs**
  - Developed by Kyocera in cooperation with Consorzio RFX
  - Rated voltage 150 kV dc
  - Insulation Alumina A-479 (99%)
  - Metallic parts AISI 304L
  - Max \( E = 6.7 \text{ MV/m} \)
  - \( E \) triple junction <0.5 MV/m @ ground flange
  - \( E \) triple junction <2.6 MV/m @ High Potential
  - Translator 50 mm ± 0.2 mm (upper)

- **Vacuum system**
  - Conceived for easy transportation from 300 kV to 800 kV setup
  - Main components
    - S1-S2 Rotary and Scroll pumps
    - T Turbo-molecular pump, 1000 l/s
    - CR Cryopump, 1500 l/s
    - P1 Penning (cold cathode) pressure gauge
    - P2-P3 Pirani pressure gauges
    - P4 Ionization head pressure gauge
    - RGA Residual Gas Analyzer
    - G1 Ga ionization valve
  - Minimum pressure <10⁻⁹ mbar
  - Vacuum recovery after air venting <15 hrs @100 C

- **Control System**
  - Conceived to guarantee the highest flexibility, in view of the 800 kV step-up
  - Hierarchical structure
    - Vacuum control system, based on dedicated PLC NC-CRIO 9400
    - S&I system, controlling the access inside the HV area and level of X-ray. Inhibit power supplies. Based on hardwired logic
    - Supervisor System, interacting with Vacuum control, interacting with S&I system, and Power supplies. Based on LabView.

Electrodes

- Three sets of Rogowski profile - parallel plane electrodes (D=100, 180 and 300 mm)
- AISI 304L
- Thermal treatment (4 hrs ramp-600 °C for 1 hr- 20 mins ramp - 950 °C for 2 hrs)
- Surface roughness Ra<0.1-0.15 μm
- Planarity adjustment

Electrical Configuration

- Independent polarization of the two electrodes
- Two HV – single pole Power supplies (positive and negative)
  - Type: SPELLMAN SL150
  - Output Voltage: 0 to 150 kV
  - Output Current: 9 mA
  - Voltage Regulation: 0.01% of rated voltage
  - Current Regulation: 0.01% of rated current
  - Voltage Ripple: 0.1% peak to peak
  - Temperature Coefficient 100 ppm/°C
  - Stability: 100 ppm/hr

Commissioning and first operations

- **Commissioning**
  - Individual voltage conditioning of the feedthroughs up to full voltage (150 kV)
  - Pressure 5.10⁻⁷ mbar
  - Main problem encountered: EMI produced by breakdown to ground. Countermeasures adopted so far:
    - Improved grounding connection
    - 3.7 MD resistor insertion in series to each Power Supply

- **First operations**
  - Test carried out on 180 mm electrodes
  - Obtained 195 kV @ 10 mm gap and 230 kV up 15 mm gap (19.5 MV/m and 15.3 MV/m)
  - After some uncontrolled breakdown a glow discharge appeared; current increase to pre-set limit (200 µA)
  - Now moving to 108 mm electrodes