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First Ohmic Experiments On KTM Tokamak

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ABSTRACT

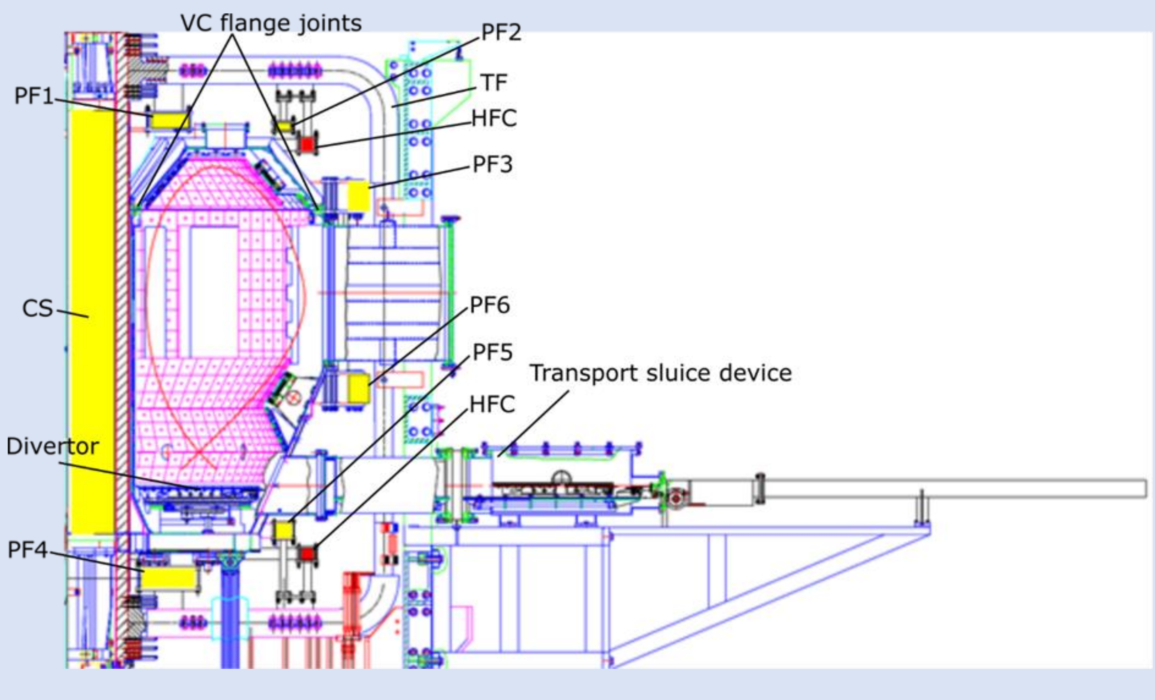
- KTM tokamak physical start-up was completed in November, 2019.
- Hydrogen plasma was obtained with a maximum plasma current of about 100 kA, a discharge duration of 65 ms, and an average electron plasma density of about $1.5{\cdot}10^{19}$ m^{-3} (the linear plasma density is not more than $8{\cdot}10^{18}$ m^{-2}).
- Plasma discharge was carried out in the ohmic regime without the additional methods of preionization and additional heating.

BACKGROUND

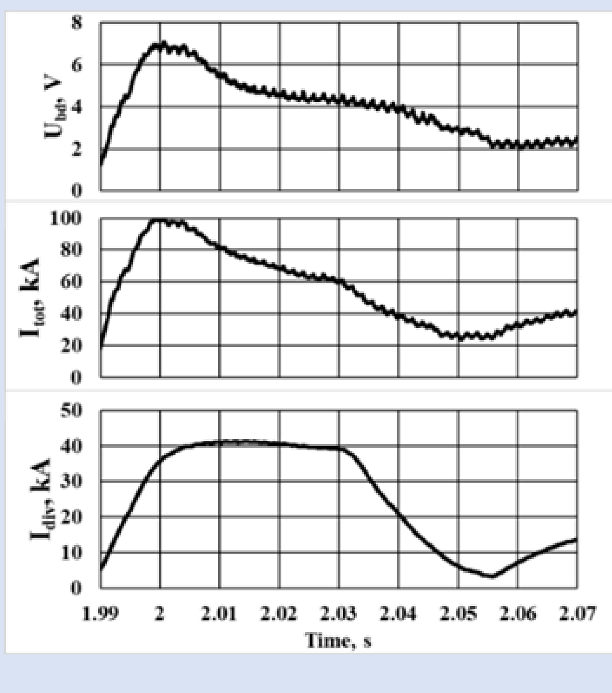
- KTM is the tokamak with aspect ratio equal to 2, single-null divertor plasma configuration, maximum plasma current of 750 kA, toroidal magnetic field of 1 T, and duration of an inductive discharge scenario with basic parameters of τpulse≤1 second, and up to 5 seconds using an additional RF plasma heating system with a maximum heating power of 5 MW. The maximum estimated heat load on the KTM receiving divertor plates is 20 MW/m2, which is comparable to the expected loads in the divertor area of ITER thermonuclear reactor.
- The primary task of a tokamak physical start-up is to breakdown, ionize the gas and achieve a plasma current of 50-100 kA.

CHALLENGES / METHODS / IMPLEMENTATION

- In KTM tokamak, due to the technical capabilities, the maximum value of the electric field intensity is limited to 1.6 V/m. This imposes a limit on the minimum value of the toroidal field and the region with the minimum poloidal magnetic field, which are required to achieve an avalanche breakdown in an eddy electric field.
- The design of KTM vacuum chamber has a number of technical features (vacuum chamber asymmetric design and the presence of massive conductive elements, such as massive movable divertor table, electrically closed in the toroidal direction, vacuum chamber flanges, etc., where significant eddy currents are induced) that complicate the simulation and calculation of the breakdown scenario. In this regard, the preliminary work was carried out on the measurement of poloidal magnetic fields and the corresponding verification of the calculation model.
- The analysis of the plasma initiation stage in the KTM tokamak was performed using TRANSMAK code, developed in JSC “Yefremov NIIEFA” (Russian Federation) specifically for the purpose of modelling the discharge initial stage in tokamaks.



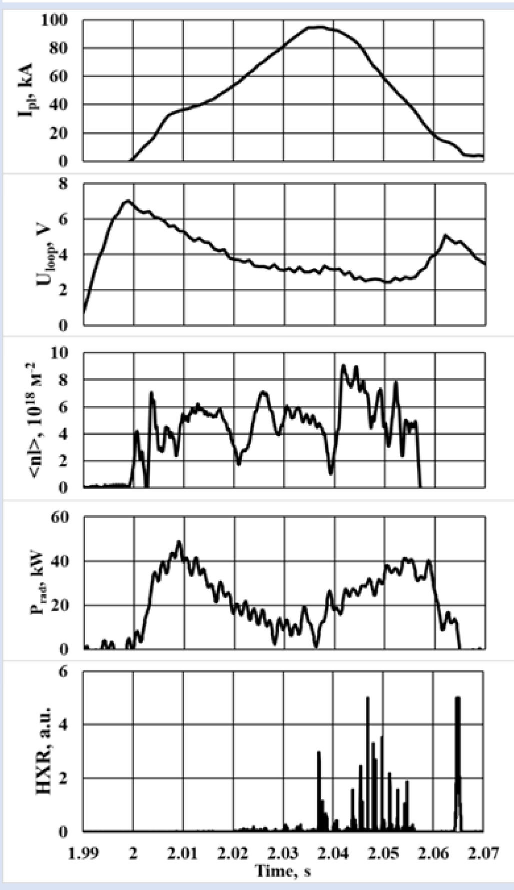
KTM tokamak cross section (CS – central solenoid, PF1-F6 – poloidal field coils, TF – toroidal field coil, HFC – horizontal field coil)



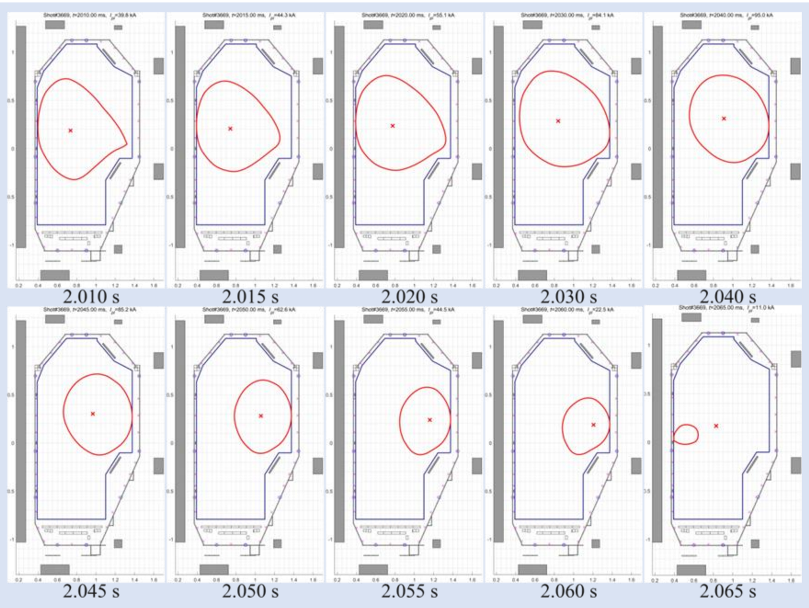
The induced currents on the VC of the KTM tokamak (discharge without plasma). Itot – total current, Idiv – divertor current, Ubd – loop voltage in the VC center

OUTCOME

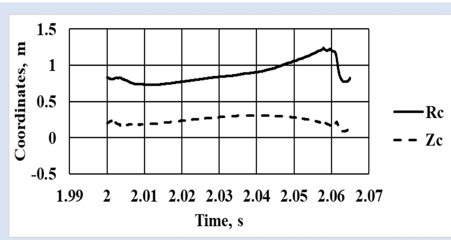
- The plasma current growth rate in discharge No. 3669 was about 2.5 MA/s (the plasma current reached about 100 kA within 38 ms). The loop voltage at the time of plasma breakdown was 7 V. The plasma current started to grow after 2.015 s and the plasma column began to move to the outer edge and touched the outer wall of the VC at approximately 2.02 seconds, at the same time a small level of HXR appeared. The intensity of HXR increased by 2.035 s, which was due to the further departure of the plasma cord to the outer wall and the simultaneous increase in radiation losses.
- The plasma linear electron density on average was (4-5)·10^{18} m^{-2}, with the maximum value of $8{\cdot}10^{18}$ m^{-2}.
- During the breakdown, the two brightest lines were observed in the spectrum, which corresponded to H_α 656.3 nm and H_β 486.1 nm hydrogen radiation lines. At the breakdown moment, there were several radiation lines with much lower intensity in the spectrum that corresponded to the nitrogen lines NII: 500.2 nm and 568.6 nm. After the breakdown, the radiation intensity of the Hα and Hβ lines quickly decreased, which indicated the hydrogen ionization. After the breakdown, oxygen and carbon lines appeared in the radiation spectrum.



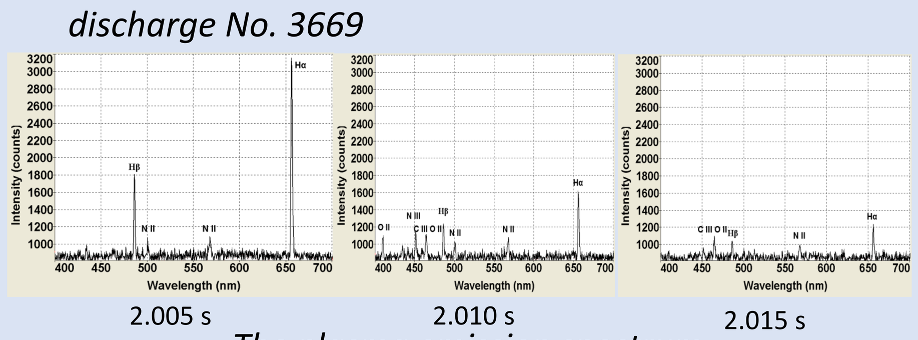
The plasma parameters evolution in discharge No. 3669.



The plasma shape reconstruction frames, discharge No. 3669



The plasma column center position evolution in discharge No. 3669.



The plasma emission spectrum.

CONCLUSION

- The experiments on clarifying the distribution of poloidal magnetic fields in the VC allowed us to verify and optimize the KTM VC and EMS calculation model. This work made it possible to calculate currents in CS and PF1-PF6 coils which allows creating the necessary conditions for creating a poloidal magnetic null field. In experiments, the avalanche ohmic breakdown was achieved in the range of voltages at a bypass of 1.4-1.6 V/m with a toroidal field of 1.14 T in the breakdown area at a radius of R=0.7 m and the pressure range from $4{\cdot}10^{-5}$ to $6{\cdot}10^{-5}$ Torr.
- In November 2019, an experimental campaign was conducted on KTM to implement its physical start-up and the following hydrogen plasma parameters were achieved: plasma current of about 100 kA, discharge duration of 65 ms, average electron density of plasma not more than $1.5{\cdot}10^{19}$ m^{-3} (on the chord of the interferometer measurement, ρ=0.5).
- The physical start-up has demonstrated the main KTM tokamak systems performance and the possibility of obtaining plasma.

ACKNOWLEDGEMENTS

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