Synopses

Performance MT-I spherical tokamak with upgraded power supplies system

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Nuclear fusion energy is the ultimate solution of the ever-increasing energy requirements of the world due to industrialization (1). The fusion community has investigated tokamak physics for the last 50 years and found that tokamak has the potential of being a successful contender for nuclear fusion power plants in which high- temperature plasma is created and confined by a magnetic field. The magnetic field is produced by different coils that play a major role in the confinement of hot plasma. Metallic Tokamak-I (MT-I) is a modified version of GLAST-II and GLAST-III (2). The difference between GLAST-II and MT-I is that the vessel of prior is made of Pyrex glass whereas the MT-I's vessel is made of non-magnetic stainless steel (304L). It has a major radius (R) = 0.15 m, minor radius (a) = 0.09 m, aspect ratio (A) = 1.67, total diameter = 0.5 m, wall surface area = 0.785 m^2 and total volume = 59 L. The vessel consists of two semi- half spheres joined together through Viton O-ring to introduce the toroidal break and having total fourteen multipurpose ports of different sizes. MT-1 has several sub-systems like pre-ionization system, diagnostic system, triggering system, vacuum system, magnetic coil system and power supply system. An electron cyclotron resonance heating (ECRH) system is developed using magnetron to produce a microwave pulse of about 5 ms at 3 kW with a frequency of 2.45 GHz.

Most of the small tokamaks like SUNIST, SMART, Alborz, VEST, QUEST, Taban, ETE, NanChang and STOR-M (3), where energy requirements are in the range of kJs to MJs, the use of capacitor banks is more economical. The peak energy requirement per shot in MT-I is approximately 35 kJ. Power supplies for MT-I consist of capacitor banks and switching circuits. Energy stored in capacitor banks is delivered to coils through controlled switching of thyristors and ignitrons. Capacitor bank capacity, charging voltages and switching time play an important role in achieving the required pulse shapes.

The CS of MT-I is made up of 128 turns of a copper strip of cross-section 2×5 mm^2 having resistance =278 mΩ, inductance =138 μH and current density = 0.7 kA/mm^2. Two pairs of compensation coils (CC) and a 14-turn decoupling coil (DC) is also connected in series with CS. The presence of an unwanted magnetic field (error field) in the region of plasma formation increases the loop voltage requirement during start-up. CC helps in the extenuation of this error field and generates a null field region inside the chamber. DC helps to increase the pulse length of loop voltage and reduces the unwanted coupling between CS and VF coils.

TF power supply for MT-I is designed to generate a flat top of about 10 ms maintaining 0.1 T for the whole duration of the operation. To achieve the required current in TF coils (I_{TF}), a combination of slow-fast capacitor banks is used. The fast capacitor bank is selected for a quick rise of 4.5 kA current in TF coils, then slow capacitor bank is discharged through a diode to provide a flat top of TF current with minimum variation. The energy required to generate a toroidal magnetic field of 0.1 T is 649 J. For this, the minimum capacity of the fast capacitor bank is found to be 2.3 mF with a charging voltage of 750 V. To meet these requirements, the fast capacitor bank is selected having a capacity of 4.3 mF with a maximum voltage rating of 3 kV. It is charged up to 750 V which provides an initial rise time of 800 μs with a rate of rise of 5.625 A/μs. A slow capacitor bank with 600 mF was in operation previously which is now upgraded to 1 F to give a longer flat top with reduced variation.

VF coil system consists of six coils making three symmetrically arranged pairs. Each coil has 30 turns with resistance = 1.15 Ω and inductance = 3.42 mH. All these coils are connected in series and powered by a common power supply. Similarly VF power supply of MT-I consists of a single capacitor bank. The capacitor bank (17.2 mF, V_{max} = 3kV) is charged up to 200 V in this experiment and discharged through a thyristor.

TF and ECRH are launched together for pre-ionization and the requisite magnetic field to make effective absorption of microwave power under resonance conditions. After a delay of 1 ms, CS and VF are triggered. Loop voltage builds up in the presence of pre-ionization and plasma current is initiated. A plasma current of 12 kA is recorded for about 0.5 ms at 2×10^{-4} mbar and a loop voltage of about 10 volts as shown in Figure 1a. With the addition of second capacitor bank in CS power supply, the loop voltage is maintained above a critical value for longer period and as a result, plasma current is increased up to 15 kA with a pulse length of almost 1.2 ms as shown in Figure 1b. The pulse length of plasma current is significantly improved with the addition of second capacitor bank in CS power supply as compared to the single bank configuration.

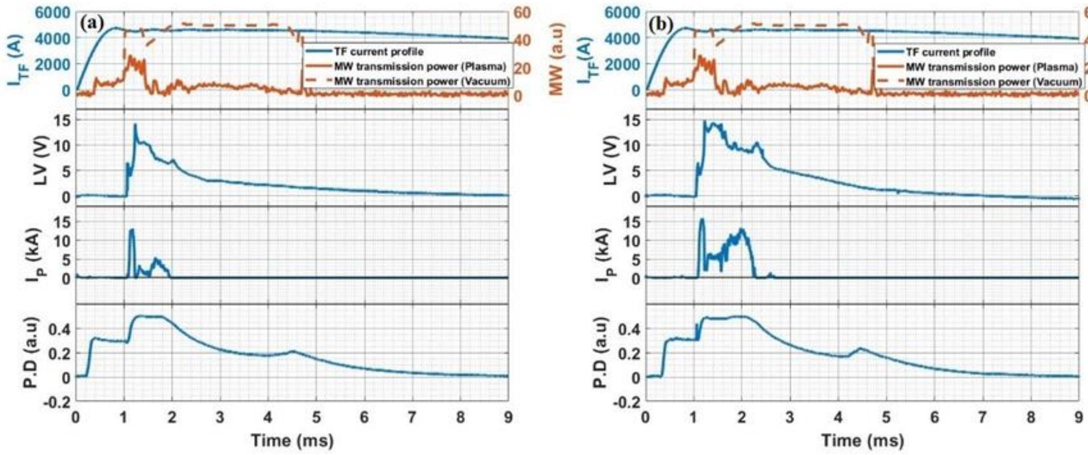

Figure 1. Results at 2×10^{-4} mbar pressure: **a** TF current waveform with microwave absorption, loop voltage waveform, plasma current and light intensity recorded by photodiode single capacitor bank-based power supply; **b** the same with upgraded double capacitor bank-based power supply

References

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