Exploration of Ohmic Plasma Current Control Strategies for the ADITYA-U Tokamak

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This work presents operation parameters exploration for plasma current control in ADITYA-U tokamak. The main objective of this study is to identify different parameters influencing the plasma flat-top duration in ADITYA-U tokamak. The profile of coil current in Ohmic transformer and vertical field play a vital role in the control of plasma current in ADITYA-U tokamak. A comprehensive consideration of various operational scenarios is carried out to verify the dependency of loop voltage profile on the plasma current temporal profile. This paper presents the different experiments cases using converter-based power supply and its operation strategies according to existing plasma operation in ADITYA-U tokamak.

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1. INTRODUCTION

In the ADITYA-U tokamak, plasma current is driven and controlled by the Ohmic Transformer Power Supply (OTPS) [1], which provides current to the Ohmic Transformer (OT) coils, consisting of the central solenoid and other compensating coils arranged in series. The plasma current in a tokamak is generated and sustained through flux changes in the OT coils, which function as the primary winding of an air-core transformer. The temporal variation in the current profile within the OT coils induces a toroidal electric field inside the vessel, which first ionizes the neutral gas into plasma and then accelerates ions and electrons. Additionally, the equilibrium vertical field (VFPS) is crucial for stabilizing the plasma in the horizontal direction by counteracting the plasma's expanding hoop force. A loop voltage of approximately 20 V is required to break down the neutral gas and form plasma, while a smaller loop voltage of around 1-2 V is needed to maintain a stable, flat-top plasma current. By swinging the OT current from +20 kA to -20 kA, the flux value is enhanced, ensuring a sustained plasma discharge with a consistent plasma current. An auxiliary converter, with a bi-polar current rating of +/- 3 kA, is employed during transitions between the positive and negative converters. The control of loop voltage is also influenced by regulating the VFPS current. The limits for the rise and fall of the VFPS are critical in controlling plasma current, as the ramp-up and ramp-down rates of VFPS directly impact plasma current stability. It has been observed that a decreasing VFPS current results in negative loop voltage, which leads to the de-acceleration of plasma current.

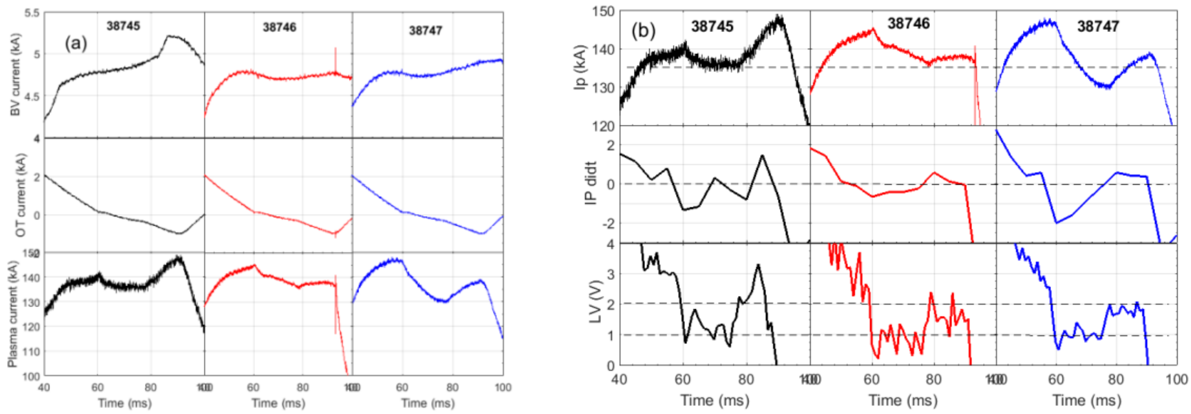

Fig. 1 (a) Temporal profile of OTPS and VFPS coil currents for different plasma current. (b) Dependence of plasma current profile on loop voltage for different plasma current.

2. PLASMA CURRENT PROFILE CONTROL

The OT coil current was manually adjusted using a trial-and-error method based on experimental requirements. If the OT current increases more slowly than a certain threshold, the plasma current begins to decrease, which can potentially lead to unwanted plasma disruption. Optimizing the loop voltage profile helps maintain the plasma current at a constant value. To better understand this, plasma discharges with varying VFPS current profiles were evaluated to determine their dependency on plasma current, as shown in Fig. 1(a). The temporal profiles of loop voltage and plasma current changes are presented in Fig. 1(b). A comparison of discharges with both plasma current ramp-up and ramp-down was conducted to examine the relationship between loop voltage, peak plasma current, and plasma current changes as shown in Fig. 2(a) and Fig. 2(b).

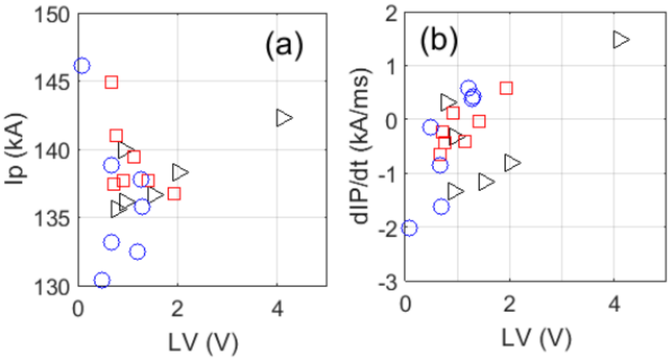

Fig. 2(a). Dependency of plasma current on loop voltage magnitude. (b) Dependency of plasma current rate change on loop voltage.

The maximum plasma current rise rate is observed to be 0.5 to 1 kA/ms, while the ramp-down rate is between -1 and -2 kA/ms. A sudden decrease in plasma current is observed when there is an abrupt drop in loop voltage, which forces the plasma current into disruption mode. These limits were determined through experiments, and the rates of plasma current rise and fall in different discharges are shown in Fig. 3. This paper will provide a detailed analysis of the plasma current behaviour when using the negative converter of OTPS, without the auxiliary converter of OTPS. Additionally, the boundaries of the various coil currents will be determined to effectively control the flat-top phase of the plasma current.

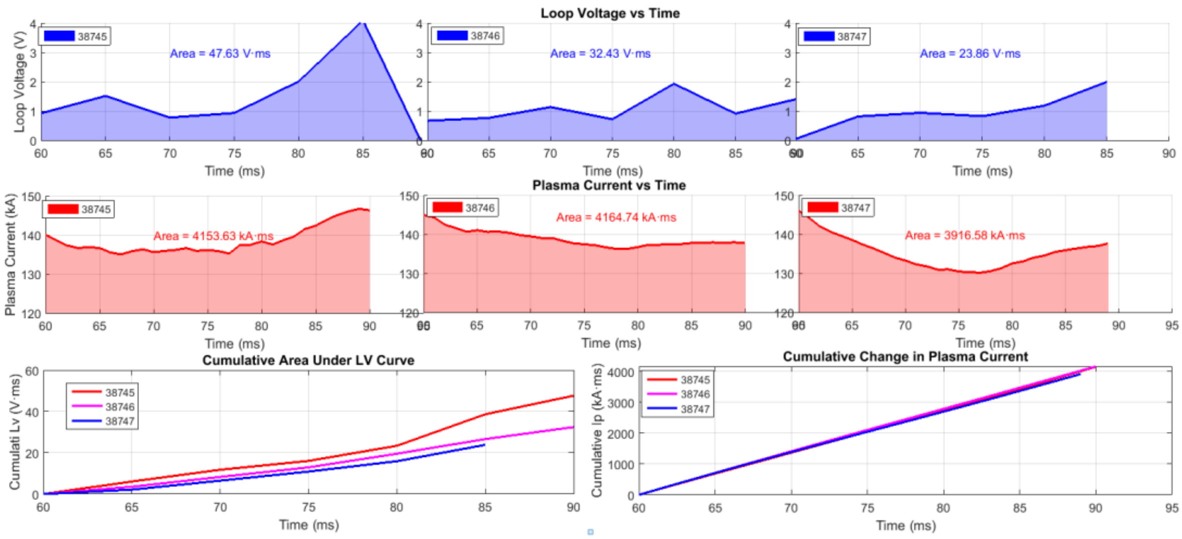

Fig. 3. Evaluation of plasma current dependency on loop voltage profile during flat-top phase.

3. REFERENCES

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