IMAPCT OF RUNAWAY ELECTRON ON PLASMA INITIATION OF ADITYA-U TOKAMAK AS INVESTIGATED VIA OBSERVED HARD X-RAY SPECTRUM

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The plasma start-up phase is one of the key areas of tokamak research considering the challenges associated with it. A high externally applied electric field, high neutral density, and non-existent flux surface are the typical characteristics of a typical ohmic start-up scenario [1-2]. The initial seed electrons / stray electrons are subjected to the high electric field which facilitates the collisions and initializes a chain reaction of ionization. This avalanche of ionization leads to plasma breakdown. The next phase of this start-up phase is the burn-through, when ionization continues, as long as the heating overcomes losses due to ionization and radiation from the fusion fuel and impurities [1]. If the operating parameters are not chosen appropriately, plasma start-up can occasionally generate non-thermal electrons (NTE), which sometimes convert to runaway electrons (RE). These REs interact with the vessel wall/plasma-facing components (PFC) and deposit their energy. This energy deposition generates high-energy X-rays as high as a few MeV and melting/sputtering of the PFC material leading to the increase of overall impurity content in the plasma. Then RE strongly affects the efficiency of burn-through the presence of runaway electrons affects the plasma conductivity and the ionization rate of atoms. In the present days tokamak, although the RE generation during the start-up phase has been controlled by the proper tuning of operational parameters, it is not clear how the parameter will be chosen in the case of the reactor-grade tokamak, such as ITER. Considering the devastating effects associated with RE a study has been conducted on the ohmic plasma start-up for ADITYA-U tokamak [4]. The main objective of this study is to understand the RE dynamics with the plasma and machine parameters.

The ADITYA-U tokamak is a mid-sized device having a large aspect ratio (R/a= 0.75m/ 0.25m = 3) equipped with a toroidal belt limiter at the inboard side and 2 poloidal limiters at the outboard side. Plasma is usually produced and maintained by a toroidal electric field provided by ohmic coils and with the help of position feedback control. The impact of RE at the ohmic plasma start-up (OPS) is generally realized by measuring the changes in the REgenerated hard X-ray (HX) emission and it is usually monitored temporally by NaI/CsI detector operated in the current mode. These measurements are employed for temporal correlation studies, however, these observations do not have any information about the RE energy or the HX spectra. Instead, the scintillation detectors operated in pulse mode offer energy and flux information which is very valuable. A single-element LaBr3 (Ce) detector (1.5-inch x 1.5-inch size), based on hard X-ray spectroscopic diagnostic (pulse mode), capable enough to measure the temporal evolution of HXR spectrum has been operational for the ADITYA-U experimental campaign at different configuration, ADITYA-U Hard X-ray Spectrometer's (AUHXS) operating energy ranges from ~ 80 keV to a few MeV with a good energy resolution of ~ 3 % at 662 keV of 137Cs. The diagnostic is viewing the plasma tangentially having the toroidal limiter in the field of view. The PMT is connected with a data acquisition system (DAQ) signal conditioning system, a Multi-channel analyzer (MCA) integrated into a single unit, Canberra OSPREY, and is capable of handling 250-kilo counts per second with a remote operation via GENIE 2000 DAQ software[3-6]. This diagnostic enables us to estimate the temporal evolution of average RE energy (T_{eRE}) and the HX energy having maximum count (E_{peak}). The E_{peak} is employed to qualitatively study the improvement in the thermal character of the plasma [5-6].

A statistical analysis of the HXR spectral emission from the start-up phase of ADITYA-U discharges has been carried out through the estimation of the average RE energy of the HX spectral peaks and evaluated for different plasma and machine parameters. Here, average runaway energy has been investigated with the ratio of toroidal electric field and pre-fill pressure (E/p), which is a crucial parameter for plasma start-up by regulating the electron avalanche and the ratio of B_v/B_T, which influences the drift of non-thermal electron during the burn-through phase. The discharges are considered at three different B_v/B_T values, 2%, 2.5%, and 3 %. As the ratio rises a strong vertical field appears which serves as a twist to the magnetic field lines. Referring to figure 1, the left-to-right ratio is increasing in the first row the plasma pre-filled pressure is kept constant at $2x10^{-4}$Torr, and only the applied electric field is increased (higher E/p higher electric field). In the discharges presented in the second row, the applied electric field/loop voltage is kept constant and the pre-filled pressure is changing smaller E/p at higher pre-filled pressure. All the configurations suggest that at a higher E/p ratio, the average RE energy rises and can be as high as 400 keV during the start-up phase, observed by the AUHXS. It can also be observed that as the B_v/B_T ratio increases the RE temperature increases as seen through the change in the fitting slope. These observations and their consequence will be discussed to understand the role of RE in the start-up phase. It is also observed that plasma having higher RE energy has delayed burn-through as monitored through time differences between breakdown time and plateau time of C^{2+} emission after its first peak.

The key findings provide an understanding of the impact of magnetic field geometry over the RE generations and their behavior at the ohmic plasma start-up phase. The relationship between the burn-through and the RE temperature is explored, It is observed that plasma with higher RE energy is having delayed burn-through.

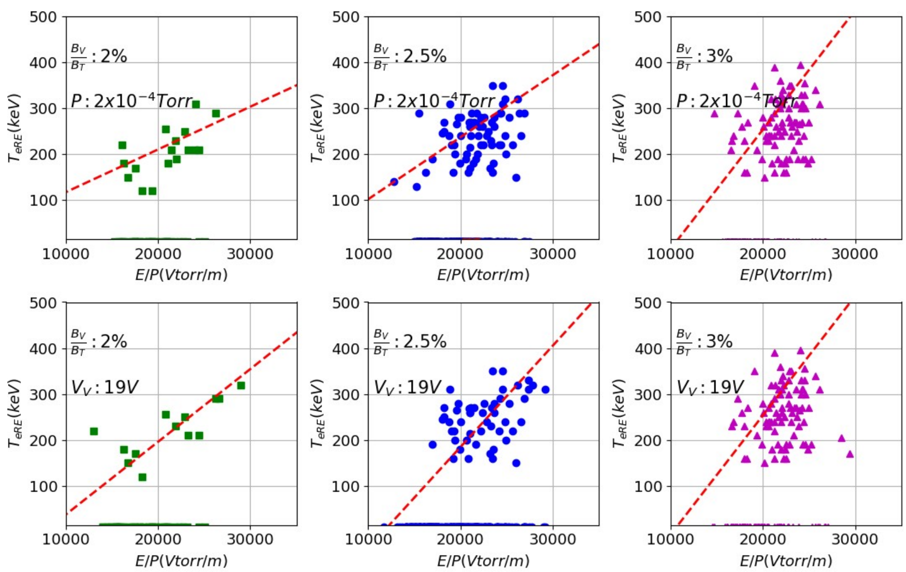

Fig 1: The Average RE energy as a function of the applied E/p ratio for different B_v/B_T.

References

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