Development of Online Plasma Edge Density and Temperature Measurements using MATLAB Module

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Abstract

Ion Cyclotron Resonance Heating (ICRH) is a very prominent auxiliary heating system for Tokamaks. ICRH heating experiment needs many diagnostics like Langmuir probe, Magnetic loop, electric dipole, capacitive probe etc. One of the important diagnostics extensively used for plasma edge density and edge temperature measurement is Langmuir probe. Normally Langmuir probes are installed near the SOL region close to ICRH antenna in tokamaks. Signals are taken through electrical feed through and coaxial cable which is connected to the front end electronics for further processing.

In this paper we describe the module(program) that has been integrated on SST-1 main control system for displaying the density and temperature after processing the signals obtained from Langmuir probe.This module has been developed by considering the error bar in the measurement of the signals for Langmuir probes installed in magnetically confined devices. Our program gives us an average edge density of $5x10^{11}$ per cm^3 and an average temperature of 12 to 14 eV for a plasma current of around 65 kA. This paper describes the Matlab module and the experimental results.

1. Introduction:

ICRH DAC designed for auxiliary heating system on tokamak. RF generator used to produce power on required frequencies for the tokamak [1]. There are several diagnostics installed in antenna where Langmuir probes are one of the important diagnostic. Of all the ways to measure plasma, the Langmuir probe is probably the simplest, since it consists of inserting a wire or a disc into the plasma and measuring the current to it at various applied voltages. It is determined by observing the moving peak by varying the emission [2]. However, it is an intrusive, not remote, technique and the probe must be carefully designed so as not to interfere with the plasma nor be destroyed by it.

Figure 1 shows the idealized I-V curve obtained by biasing the probe at different voltages. The flat region of the curve represents the ion current. The floating potential V_f is where the ion and electron currents are equal and the net current is zero. The space potential V_s is near the knee of the curve. When V_p reaches V_s all of the random thermal flux of electrons is collected. From the I-V curve the plasma density n, electron temperature KT_e and plasma potential V_s can be determined but not the ion temperature. The exponential part of the I-V curve, when plotted semi-logarithmically vs. the probe voltage V_p, should be a straight line if the electrons are Maxwellian. The inverse of the slope of the straight line gives the electron temperature. The equations governing the temperature and density are given below:

$$I_e = I_{es}\exp\left[e(V_p - V_s)/\,KT_e\right] \qquad (1)$$

$$I_{es} = eAn_e v/4 \; = en_e A\left(\frac{KT_e}{2\pi m}\right)^{1/2} \qquad (2)$$

Where A being the exposed area of the probe tip. Here I_{es} is the saturation electron current, or

random thermal current to a surface at V_s. Eq. (1) shows that the slope of the (ln I)−V_p curve is exactly $1/T_eV$ and is a good measure of the electron temperature.

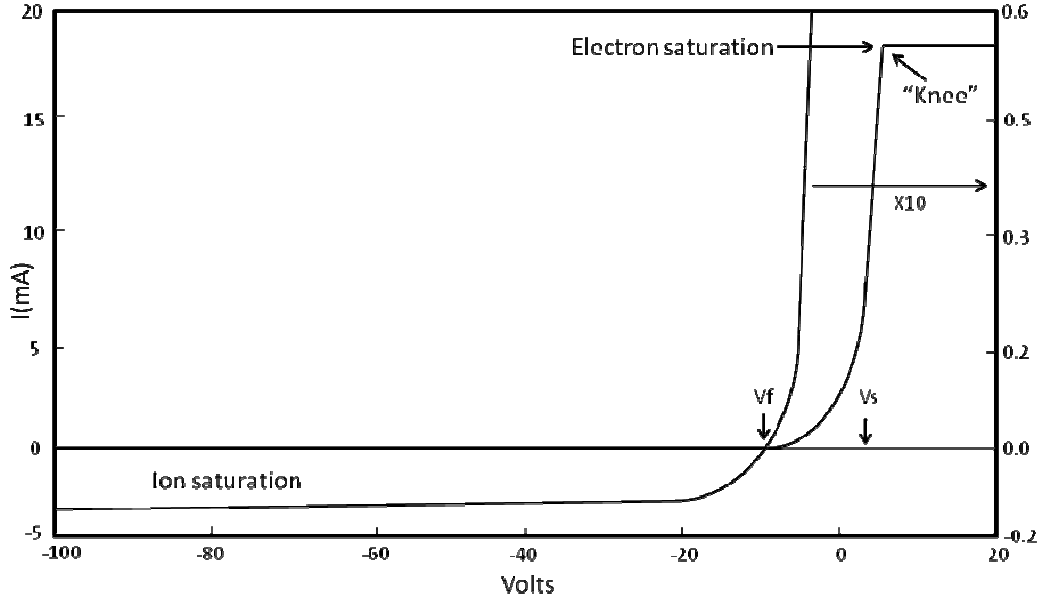

Figure 1 An idealized I-V curve

2. Experimental Procedure

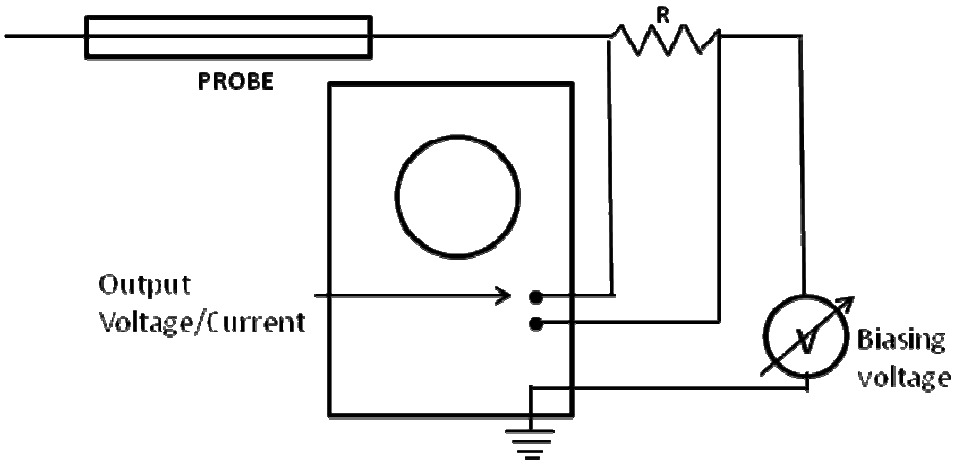

Figure 2 Configuration of Probe circuit

In order to obtain the I-V characteristics using Langmuir probe the probe has to be properly biased using the sweeping ramp voltage [3]. Figure 2 shows the schematic of ramp circuit used in the experiments. Ramp Circuit that has been used to bias the Langmuir probes uses 2 PA 85 power mosfets to generate the sweeping voltage. The applied voltage to the Langmuir probe is around 80 volts on the negative side and +30 volts on the positive side. The frequency of the circuit can be varied from 10 Hz to 1 kHz. The options of gain, offset and amplitude management are implemented in the circuit. Reference ramp of +-5 Volts and the current obtained from the Langmuir program are fed to the central data acquisition system.

3. Calculation Module

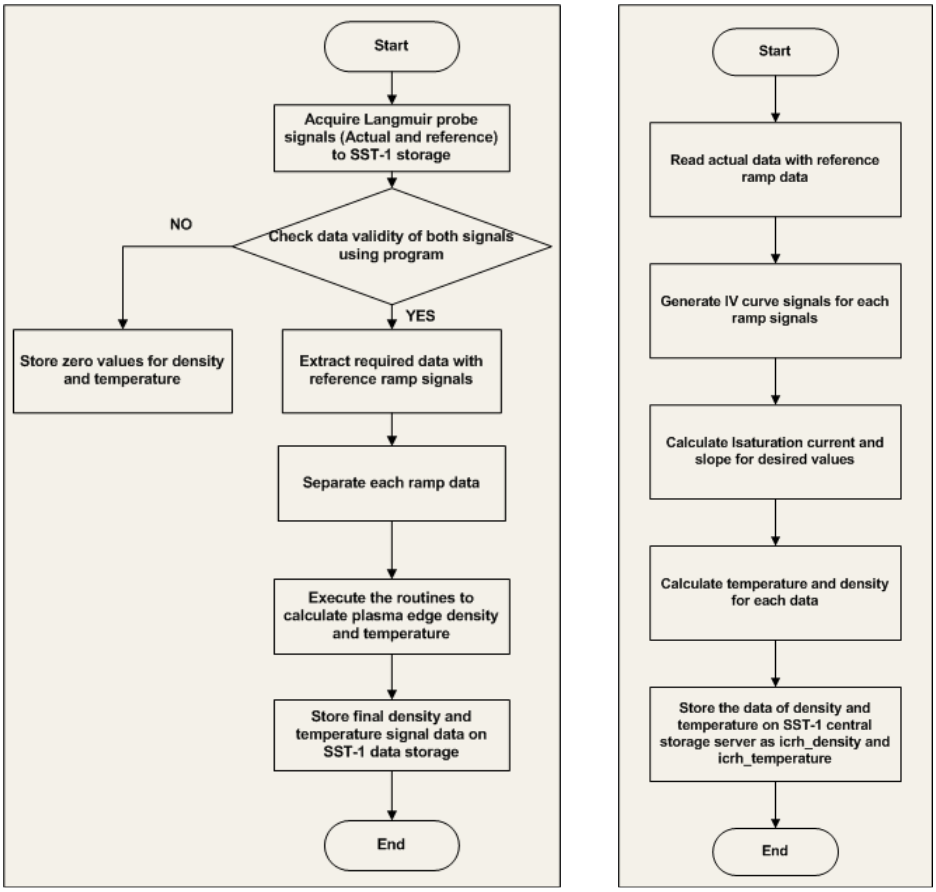

Figure 3 flowchart of program for calculation of density and temperature

Figure-3 shows the design flowchart of program for density and temperature calculation. Module has been developed using MATLAB [4]. The first step consists of acquiring Langmuir probe data from the plasma. Acquired data is sent to central storage. The second step includes the data validity which ensures the acquired data is correct sometimes the acquired data may have a higher noise level or in absence of plasma there may be a false signal. If the amplitude of the signals is below the defined value in the program it is considered as noise and hence no further processing of the data is done. Density and temperature are displayed as zero values.

Depending upon the frequency set by the electronics user in the electronic circuit there may be several ramps for a particular plasma shot. Accordingly the density signals corresponding to each ramp is calculated by the module. The I-V curve for each ramp is plotted by the program and smoothing of the curve is done to calculate Ion saturation current. After the calculation of ion saturation current the floating and plasma potential in the graph is determined by the use of equations mentioned above.

The data points between the floating and plasma potentials are taken into account for calculating the electron temperature. Density corresponding to each temperature is calculated using the formula mentioned above. Thus in a single plasma shot the density and temperature values corresponding to the time axis of plasma current is displayed as the end result in the SST-1 data plotting software.

4. Test Results:

A typical plasma shot in which density and temperature are plotted using the calculation module is shown in figure 4 with respect to plasma current.

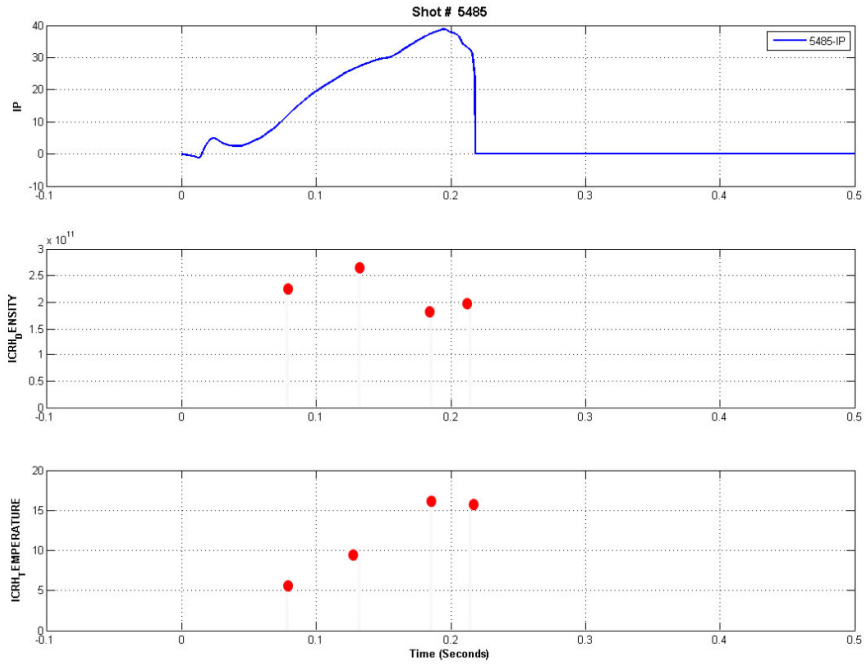

Figure 4 Edge Density and Temperature plot for shot no. 5485

Conclusion:

The results obtained using the module developed to calculate density and temperature are in agreement with our expected values. Since very few shots have been analysed using the module mentioned herewith there is a necessity for further evaluation of the module with more plasma shots. Effectively using the module has led to a faster processing of calculation of density and temperature obtained with Langmuir probes.

References:

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