Calculation of plasma current fluctuation under the effect of voltage variation with fixed temperature using double probe data

Rudainah Ali

Abstract

When the plasma particles posses a surplus energy, the plasma fluctuates to reduce this energy. Fluctuation may also occur as a result of density gradation or a temperature change due to the application of a magnetic field. Since the fluctuations are responsible of the particle loss, they may be considered as a great part of energy loss case. It has been found that the behavior of the probe characteristic curve of the current fluctuation dose not resembles that of the natural curve of the probe current. That means reading the fluctuation of current probe is influenced by fixing temperature.

Key words :Plasma, Current fluctuation, Double probe

حساب تراوح تيار البلازما تحت تاثير تغير الفولتيه بثبوت درجه الحراره باستخدام بيانات مجس مزدوج

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الخلاصة

عندما تمتلك جسيمات البلازما طاقه فائضه فان هذا يؤدي الى تراوح البلازما لتقليل هذه الطاقه وقد يحدث التراوح عند حدوث تدرج في الكثافه او تغير درجه الحراره او بتسليط مجال مغناطيسي وبما ان التراوحات مسؤوله عن قسم هام عن خساره في الجسيمات يمكن ان تعتبر جزءا كبيرا جدا من حالات خساره الطاقة وجد ان سلوك منحني خاصيه المجس المزدوج لتراوح التيار لا يماثل المنحني الطبيعي لتيار المجس وهذا يعني ثبوت درجه حراره تأثير ثبوت درجه الحرارة على تقليل تراوح تيار المجس

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Introduction

Any ionized gas can be called plasma, there is always some small degree of ionization in any gas. A plasma is a gas in which an important fraction of the atoms is ionized, so that the electrons and ions are separately free [1][2].

When the temperature is hot enough. A useful definition is: a plasma is a quasi neutral gas of charged and neutral particles which exhibits collective behavior. [1].

Fluctuation: the fluctuations are responsible for a signification part of the particle loss rate and many account for a large part of the anomalous energy losses [3]. The heave ion beam probe diagnostic permits the measurement of electron density and plasma potential as well as their fluctuations [4]. In order to make a complete estimation of the particle and heat transport, it is necessary to identify the fluctuations in density and temperature. In the case of plasma, the electrostatic fluctuations are responsible for the molecule transport [3].

Types of fluctuation

When the plasma particles possess a surplus energy, the plasma fluctuates to reduce this energy since fluctuation is always a motion that reduces energy. This fluctuation occurs either due to temperature or density increase or due to applying electric field to the plasma [5]. The fluctuation may be classified according to the types of the free energy available. There are four main categories:

1. Streaming fluctuation [1].
2. Rayleigh- taylor fluctuations [6][7].
3. Universal fluctuation.
4. Kinetic fluctuation [1].

Suppose that the probe current fluctuation is the result of plasma density and temperature fluctuation with the plasma potential then the current (I) flowing between two identical double probes may be represented by the following mathematical formula:

$I = I_{sat}\left[\tanh\frac{q.V}{2T_e} + \frac{F.V}{2T_e}\right]$ ……………..(1)

Where

V: Probe potential

$T_{e:}$ Electron temperature measured in (electron – Volt)

F: function of ${}^{r_p}/_{\lambda_D}$

Isat : The saturated current. It is given, as shown in figure (1), by the following relation: Chen (1984) [1]

$I_{sat} = n\ e\ A\sqrt{\frac{2T_e}{M_i}}$………………(2)

Where

(e) : electron charge

M_i) : ion mass(

A : The surface area of the probe

n : Plasma density

From figure (1) we found

S = (1/I_{sat}) Slope = F / 2T_e …………. (3)

Where slope = $\left({}^{dI}/_{dV}\right)V \to \infty$

+ F / 2T_e ………(4)   X = (1/I_{sat})

Slope = q / 2T_e

Where slope = $\left({dI}/{dV}\right)V \to \infty$

From S/X we get

$V = 2\,T_e / q$ ....(5)

For the nonzero slope in the saturation region, Swift and Schwar gave in (1970) [5] a correction of the electron temperature calculation as follows :-

$$T_e = \frac{V}{2}\left[\frac{1-0.85\ S\ /X}{1+0.5\ S/X}\right] \ldots\ldots\ldots\ldots\ldots(6)$$

And by substituting the equations (5) and (3), (4) in equation (6)

$$T_e = \frac{T_e}{q}\left[\frac{1-0.85\ (1+\frac{q}{F})}{1+0.5\ (1+\frac{q}{F})}\right] \ldots\ldots\ldots\ldots\ldots(7)$$

From this we get

q = 1 – 1.35 F

Eq (2) can be written

$$I_{sat} = n\ e\ A\sqrt{\frac{V.q}{M_i}} \ldots\ldots\ldots\ldots(8)$$

By differentiation to V with T_e fixed

$$\left[\frac{dI_{sat}}{dV}\right] = \frac{n\ e\ A}{\sqrt{M_i}}\ \frac{1}{2}\ (q.V)^{\frac{-1}{2}}\ (q)$$

$$= \frac{1}{2}\ \frac{n\ e\ A}{\sqrt{M_i}}\ \ \frac{1}{\sqrt{2T_e}}\ \ (q)$$

$$= \frac{1}{2}\frac{n\ e\ A}{\sqrt{M_i}}\ \frac{\sqrt{2T_e}}{\sqrt{M_i}}\ (V)$$

$$\left[\frac{dI_{sat}}{dV}\right] = \frac{1}{2}\frac{I_{sat}}{V}\ \ldots\ldots(9)$$

By returning to equation (1),(2) we can get the current fluctuation, according to the volts fluctuation with the density and temperature fixed, is as follows:

$$\left(\frac{dI}{dV}\right)T_e = I_{sat}\left[\sec h^2\ \frac{q.V'}{2T_e} + \frac{F.V'}{2T_e}\right] + \left[\tanh\frac{q.V}{2T_e} + \frac{F.V}{2\,T_e}\right] * \left[\frac{1}{2}\ \frac{I_{sat}}{V}\right] \ldots\ldots\ldots\ldots(10)$$

The table (1) represents the values used in equation (10) calculating the fluctuation of plasma [7]

Number diagram	T_e (electron-volt)	I (n.Am)	F
1	2	6.8	0.1
2	2	18	0.2
3	2	29	0.3

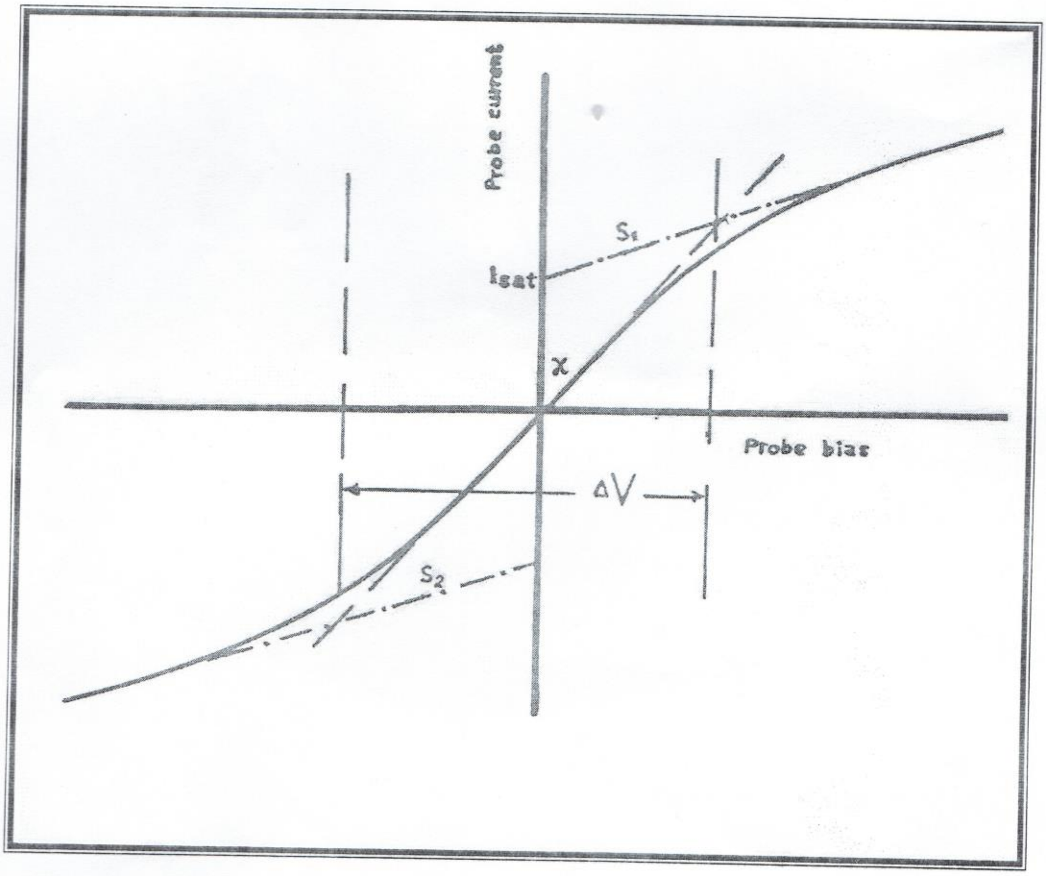
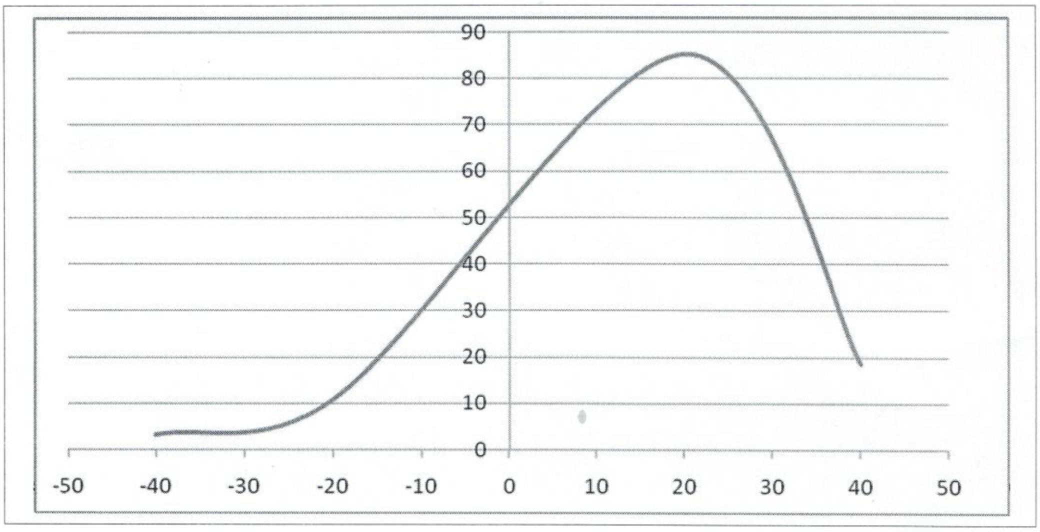


Figure (1) Double probe characteristic

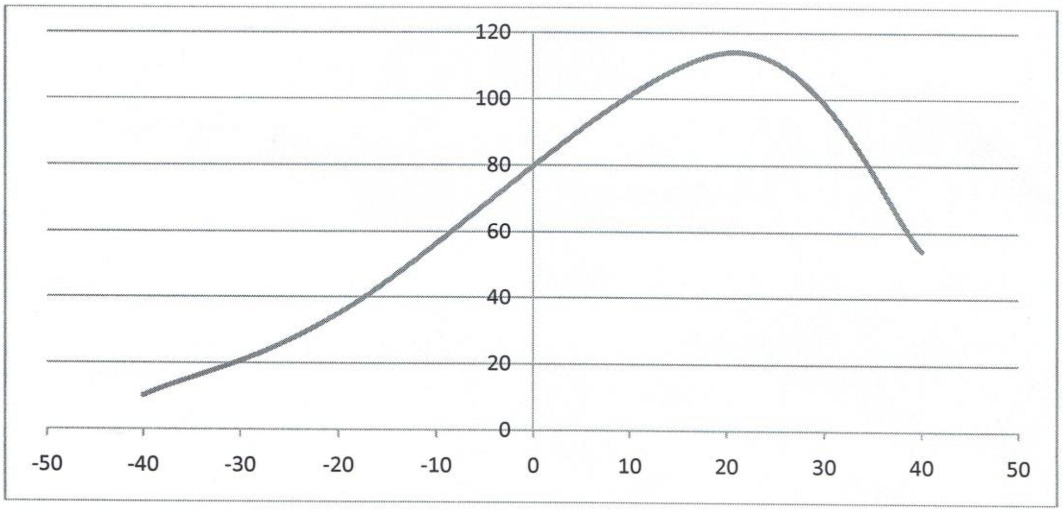
$\left(\frac{\partial I}{\partial V}\right)_{Te}$



V/volt

Diagram (1) represents the relation between $\left(\frac{\partial I}{\partial V}\right)_{T_e}$ and V/volt

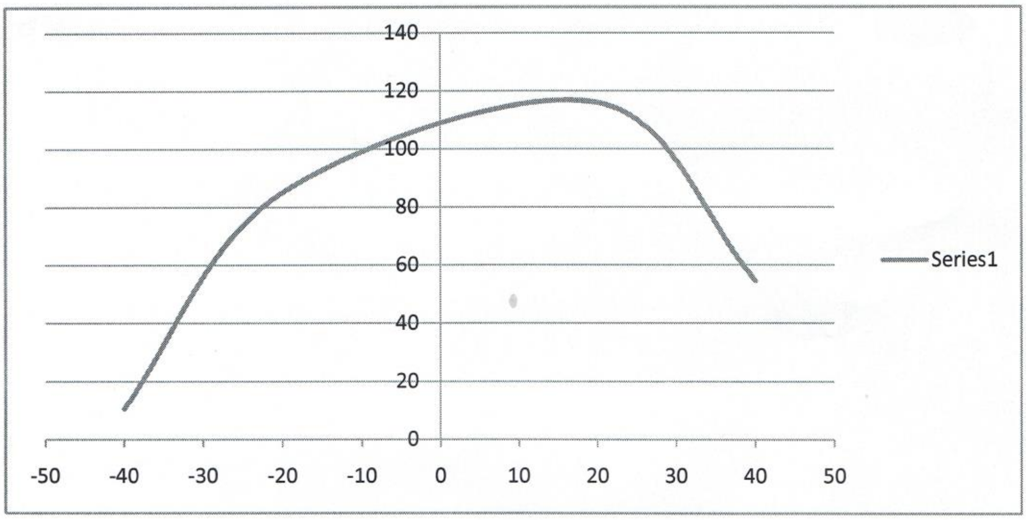
$\left(\frac{\partial I}{\partial V}\right)_{Te}$



V/volt

Diagram (2) represents the relation between $\left(\frac{\partial I}{\partial V}\right)_{T_e}$ and V/volt

$\left(\frac{\partial I}{\partial V}\right)_{Te}$



V/volt

Diagram (3) represents the relation between $\left(\frac{\partial I}{\partial V}\right)_{T_e}$ and V/volt

Results and discussions

Table (1) shows the values used in equation (10) which is employed to calculate the fluctuation of plasma current with fixed temperature and varying voltage. These values are taken from previous studies. When the relation between $\left(\frac{\partial I}{\partial V}\right)T_e$ and V/ volts has been plotted, it has been found that the fluctuation curve dose not resemble the natural characteristic curve of the probe illustrated in fig (1). This proves the importance of temperature variation on the fluctuation of probe current in that the fluctuation in the current increases proportionally with the temperature.

Diagrams (2,3,4) represent the current fluctuation with the temperature fixed for different (r_p) Values which lead to the change of F values (because F is a fluctuation $\left({}^{r_p}/_{\lambda_D}\right)$ From 0.1 to 0.3 at equal increase of 0.1 each. The values of variables taken from a previous study [8].

Diagrams (1,2,3) represent the current fluctuation with the temperature fixed for different r_p Values which lead to the change of F values (because F is a function to $\left({}^{r_p}/_{\lambda_D}\right)$from 0.1 to 0.3 equal increases of 0.1 each. The values of variables taken from a previous study [8].

Conclusions

1. After calculating the plasma current fluctuation depending on the change of V and the probe radius, it has been found that the plasma current fluctuation is not resembles that of the natural curve of probe current.
2. When the probe dimensions are chosen to be less than the length of the collision free path, F (saturated slop function) becomes less than 0.5 and more than zero.
3. The fluctuation of plasma current is influenced by temperature variation.

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