FEEDBACK LINEAR INDUCTION ACCELERATOR USING FUSION REACTOR EXHAUST PLASMA

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Abstract

Design of the feedback LINAC is centered on using the exhaust fusion reactor plasma at sustained pumping velocity to act as he moving core for the LINAC continuum, interacting with controlled pulsing current producing the exciting magnetic field. The continuous interacting will generate perturbations in the imposed magnetic field with subsequent formation of regional and intentional boundary layer separation. Electric accelerating field will be produced by the magneto-fluid interaction with effective dominant role along the downstream region of the divertor channel, overwhich the accelerating field is in action. The output accelerated plasma could then be recylced for either reacceleration or to serve as renewal medium for the acceleration core.

The new design concept of feedback LINAC will produce effective impact on the acceleration of heavy ion beam in fusion research as well as new operational design for linear induction accelerators.

1. Introduction (1-4,7,8)

Conventional designs of linear induction accelerators involve the utilization of ferromagnetic core or ferrites material, as well as effective control of the pulsing compensating network required in providing optimal acceleration for heavy ions beam.

Proposed modification in the design of linear induction accelerator, calls for the replacement of solid conventional core ionization and with low pressure such as the exhaust plasma of the Tokamak fusion reactor.

Previous work carried out by this author identified important steady-state characteristics of the fusion reactor exhaust plasma under the control of the divertor. Effectiveness of the divertor is based on he parametric level for the rate of impurity removal from the reactor main zone, tendency of ions return to the main reaction zone through diffusion and the divertor principal effectiveness role.

The indicated previous work secured solutions for the optimal concentration of Helium single ions and their transformation to Helium double ions with respect to the divertor effectiveness parameter. Conditions of optimal ions concentration include opposite equality between He^+ and He^{++} rate of ionization, opposite equality of He^{++} rate of ionization and the rate of impurity removal from the main reaction zone and for zero level of the parameter for the rate of impurity removal.

In this paper, the exhaust plasma of the Tokamak fusion reactor is considered as the operating core of the linear induction accelerator, interacting with an applied time varying magnetic field produced by a singularity pulsing current. The accelerated plasma could then be feedback to act as either a recycled moving core or to be used as working fluid for an AC-MHD induction generator.

2. Statement of The Problem (1-8)

Conceptual design of the linear induction accelerator with a moving hot conducting plasma as it core, will generate required accelerating field within the plasma boundary layer as well as self exhaust continuum from the Tokamak fusion reactor through the divertor channel. The accelerated plasma will be recycled or fed-back for a stable control system.

Required to determine:

1. Stability aspect for the field of acceleration on the single helium ions in the process of feedback, and identification of control parameters.
2. Stability aspect for the field of acceleration on he double helium ions in the process of feedback and identification of control parameters.
3. Role of the fusion reactor divertor to ensure stable field of acceleration.

3. Divertor Exhaust Plasma Characteristics (1, 2, 4)

Let,

n_1, n_2 = Concentration forHe^+andHe^{++}
α_1 = rate ofHe_+ions generation
α_2 = rate of transformation ofHe_+tohe_{++}
β = rate of impurity removal from the main reaction zone by diffusion
θ = divertor effectiveness parameter

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where

θ = 0, implies perfect divertor role
θ = 1, implies divertor role
X = space variable normalized with respect to reference diffusion length.

Solutions for n_1 and n_2 obtained earlier are:

$$n_1 = \frac{\alpha_1(\alpha_1+\alpha_2)}{[(\beta+\alpha_2-\alpha_1)(\theta\beta-2\alpha_1-\alpha_2+\beta)+(2\alpha_1-\beta-\theta\beta)\alpha_1]} \quad (1)$$

$$n_2 = \frac{\alpha_1+\alpha_2}{\theta\beta-2\alpha_1-\alpha_2+\beta} - \frac{2\alpha_1-\beta-\theta\beta}{\theta\beta-2\alpha_1-\alpha_2+\beta}X$$
$$\frac{\alpha_1(\alpha_1+\alpha_2)}{(\theta\beta-2\alpha_1-\alpha_2+\beta)(\alpha_1-\alpha_2-\beta)+\alpha_1(2\alpha_1-\beta-\theta\beta)} \quad (2)$$

constraints for optimal levels for n_1 and n_2 are:

$$\alpha_2 = -\alpha_1 = -\beta \quad (3)$$

$\beta = 0$

4. Field Aacceleration on n_1 (1, 2, 4)

Let
a_x = acceleration along the x orientation direction

$$= [\frac{\delta n}{\delta x}\frac{\delta^2 n}{\delta t^2} - \frac{\delta n}{\delta t}\frac{\delta^2 n}{\delta x^2}][\frac{\delta n}{\delta x}] \quad (4)$$

and
$n = n_1 + n_2$

Taking the Laplace transform of equation 4 with zero initial conditions and rearranging, resulting,

$$\frac{n_1(s)}{a_1(s)} = \frac{G_1}{(1-G_1H_1)} \quad (5)$$

where

$$G_1 = \frac{-1}{(k_1n_1+k_2)(\frac{\delta n_1}{\delta x})^2} \quad (6)$$

$$H_1 = \frac{-s}{(\frac{\delta n_1}{\delta x})^3} \quad (7)$$

$$\frac{\delta n_1}{\delta x} = (k_1n_1+k_2)x + N_1 \quad (8)$$

N_1 is the value of n_1 at $x = 0$
From equation (5) the steady-state level of $\frac{a_1}{n_1}$ found equal to:

$$\frac{a_1}{n_1} = -(k_1n_1+k_2)[N_1+(k_1n_1+k_2)] \quad (9)$$

The control feedback system for and is shown below in Fig. 1 also

$$k_1 = (\alpha_1-\alpha_2-\beta) + [\frac{\alpha_1(2\alpha_1-\beta-\theta\beta)}{\theta\beta-2\alpha_1-\alpha_2+\beta}] \quad (10)$$

$$k_2 = \frac{\alpha_1(\alpha_1+\alpha_2)}{\theta\beta-2\alpha_1-\alpha_2+\beta} \quad (11)$$

5. Field Acceleration on n_2 (1, 2, 4)

Similar to the procedure of securing the transform function the counter part function of is expressed below:

$$\frac{n_2(s)}{a_2(s)} = \frac{G_2}{(1-G_2H_2)} \quad (12)$$

where

$$G_2 = \frac{-\beta}{[n_1\alpha_2+n_2(\alpha_2-\beta)][\frac{\delta n_2}{\delta x}]^2} \quad (13)$$

$$H_2 = -s[\frac{\delta n_2}{\delta x}]^3 \quad (14)$$

$$\frac{\delta n_2}{\delta x} = \frac{x}{b}[n_1\alpha_2+n_2(\alpha_2-\beta)] \quad (15)$$

and the steady-state level of $\frac{a_2}{n_2}$ is:

$$\frac{a_2}{n_2} = \frac{x^2[n_1\alpha_2+n_2(\alpha_2-\beta)]^2}{\beta^3} \quad (16)$$

The feedback control system for He^{++} is shown below in Fig. 2.

6. Conclusion (1-8)

With the field of acceleration as the input signal and the concentration function of Helium ions as the output response in a control system with feedback function, resulting models indicate the following:

1. Control models for both He^+ and He^{++} linking their concentration with respect to the respective acceleration represent systems of the first order.

2. Both control system models are physically realizable with an eventual finite steady-state ratio of acceleration with respect to corresponding concentration function.

3. Although the feedback function for the He^+ and He^{++} control models indicates apparent negative value, the constraints governing optimal ions concentrations, will eventually ensure stable first order control system.

4. The feedback control function for both He^+ and He^{++} systems is in the first order and proportional to the respective 3rd order of the concentration gradient.

5. Three alternative specific control systems could emerge for the ultimate goal of optimal levels of concentration for He^+ and their transformation to He^{++} depending upon which constraint from the fusion reactor divertor may be selected, namely

$$\alpha_2 = -\alpha_1 nonumber \quad (17)$$

$$\alpha_2 = -\beta$$
$$\beta = 0$$

6. Effective direct and feedback control systems for the acceleration and concentration of He^{++} ions in a linear induction acceleration will ensure controlled field of conventional accelerators) and smooth operation of the pulsing network.

7. Controlled field of acceleration in a linear induction accelerator with hot conducting plasma acting as the core with feedback, will enhance effective work on heavy ions beam encountered in fusion research.

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