§20. Analytical Studies on a Traveling Wave Direct Energy Converter for D-³He Fusion

Momota, H., Tomita, Y.
Miley, G.H. (Univ. of Illinois)

Analytical studies on a traveling wave direct energy converter (TWDEC) [1,2] for D-³He fueled fusion are carried out. The TWDEC consists of a modulator and a decelerator both of which consist of an array of metallic grid meshes and a transmission circuit.

The applied traveling wave potential to the modulator modulates the velocity of fusion proton beams. This modulation makes a form of bunched protons at a down stream of the modulator:

$$n_p(x, t) = n_{p0} \left[1 + \frac{4\pi e V_{m0}}{m v_t^2} \sin(k_m x - \omega_m t) \right], \quad (1)$$

here, V_{m0} , k_m and ω_m are the potential, wave-number and frequency of the applied wave, respectively, and v_t corresponds a Doppler spread at the birth of fusion protons. The second term indicates the spatial bunching at the down stream of the modulator field.

At the decelerator, the wave number k_d of the potential wave V^e due to bunched protons is changed spatially by the coupling to the excited traveling wave on the transmission circuit (Fig.1). From this circuit the potential V_n is governed by a forced oscillation due to the potential of bunched protons:

$$\left(2 + \frac{C_s}{C}\right) (\ddot{V}_n + \frac{R}{L} \dot{V}_n) + \frac{V_n}{LC} - [\ddot{V}_{n+1} + \ddot{V}_{n-1} + \frac{R}{L} (\dot{V}_{n+1} + \dot{V}_{n-1})] = \frac{C_s}{C} (\ddot{V}_n^e + \frac{R}{L} \dot{V}_n^e). \quad (2)$$

In this transmission circuit, the form of the potential wave can be transmitted is given by :

$$V_n(t) = f_p(t) \cos(\theta_n - \omega_d t), \quad (3)$$

here θ_n is the phase of n-th grid and the function f_p changes much slower than the traveling wave. Under this situation we have a non-trivial solution, provided that the resonance condition:

$$\Omega^2 - \omega_d^2 - \frac{v^2}{4} = 0, \quad (4)$$

is satisfied. Here Ω is the characteristic frequency of the transmission circuit:

$$\Omega^2 \equiv \frac{1}{LC[2(1-\gamma) + C_s/C]}, \quad (5)$$

and $v \equiv R/L$. The potential V_n of n-th grid is obtained:

$$V_n(t) = [V_n(0) \frac{\exp(-vt/2)}{\cos \Psi_n(0)} - \frac{\varepsilon}{v\omega_d} (1 + \frac{v^2}{16\omega_d^2})^{-1/2} (1 - \exp(-vt/2))] \times \cos \Psi_n(t), \quad (6)$$

here,

$$\varepsilon \equiv \omega_d^2 \frac{C_s}{C} \tilde{V} \sqrt{1 + \frac{v^2}{\omega_d^2}} \frac{1}{2(1-\gamma) + C_s/C},$$

$$\Psi_n(t) \equiv \int_{x_n}^{x_n} k_d d\xi - \omega_d t - \phi + \tan^{-1} \frac{4\omega_d}{v},$$

$$\phi \equiv -\cos^{-1} \frac{1}{\sqrt{1 + R^2/L^2}}, \quad \gamma \equiv \cos(\theta_{n+1} - \theta_n).$$

As a result the power obtained from the decelerator is given by using the steepness of resonance Q ($\equiv \omega_d L / R$) :

$$P_{out} = \frac{8\varepsilon^2}{\omega_d^5 L} \frac{Q^5}{(16Q^2 + 1)(Q^2 + 1)}. \quad (7)$$

Fig.1 The transmission circuit in the decelerator, consists of a inductance L , a capacitor C , and a register R . The stray capacitance between proton beams and grid meshes is denoted by C_s .

Reference

- 1) Momota, H., LA-11808-C, Los Alamos Natl. Lab., New Mexico, (1989) 8.
- 2) Shu, L.Y., Miley, G.H., Tomita, Y., and Momota, H., Trans. Fusion Technol., 27 (1995) 551.