§4. Numerical Simulation of Large-Scale TWDEC and HelmholtsDEC Devices

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The self-excitation processes of commercial-scale traveling wave direct energy converter (TWDEC) are analyzed, where the real size is treated, although the previous studies could treat only reduced sizes because of limitation of capability of available computers. Then separation capability of charged particles in the Helmholts type direct energy converter device (HelmholtsDEC) is analyzed.

(1) Self-excitation Processes of Commercial-scale TWDEC

An optimization has resulted in the cross-section of 25 π m^2 with 5 m radius and the period of the traveling wave of 0.12 μs when the energy input from a fusion reactor is 272.5 MW. The modulator has five electrodes, whereas the decelerator has 25 electrodes with four cycles of the traveling wave. A few million numerical time steps are required for the self-excitation process and therefore one-dimensional analyses has been used, although we have developed two-dimensional codes.

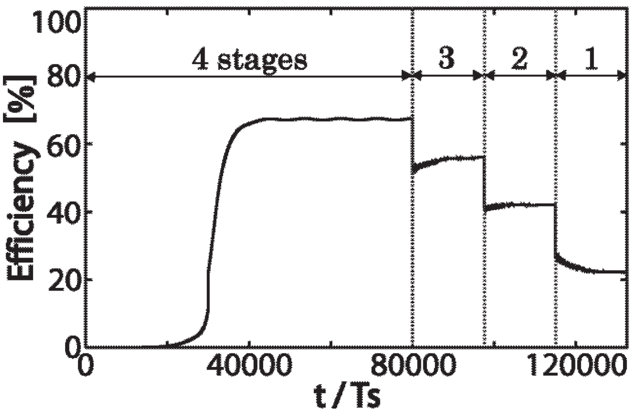

Fig. 1. Capability of Fast Control of Large-Scale TWDEC. (switching time of about 0.23 ms)

Figure 1 shows the time variation of the efficiency of the TWDEC, which corresponding to the ratio of the electric power of the full design power. The operation of TWDEC is changed from four to three, two, one with about 0.23 ms, where the electric power becomes 84 %, 63 % and 33 % by decreasing the number of active stages.

It has been shown that the electrode voltage (operation voltage) is self-excited and becomes about 1.0 MV at about 7 milliseconds by switching the load resistances. About 65 % energy conversion efficiency is obtained, and that the TWDEC has the capability of fast control of the electric power when required by the commercial grid.

(2) Separation Capability of Charged Particles in HelmholtsDEC

The separation capability of charged particles is one of the most important requirements for direct energy converters. Time-dependent axisymmetric two-dimensional analyses have been carried out for a commercial-scale HelmholtsDEC with the energy input of 250 MW. A series of optimization of the design of the HelmholtsDEC results in a shape shown in Fig.2, where trajectories of the fusion protons and the fast electrons are depicted. It has been demonstrated that the fusion protons can pass the HelmholtsDEC and reach the TWDEC as designed, whereas the fast electrons can reach the cathode. The separation of the fusion proton and the fast electrons is almost perfect.

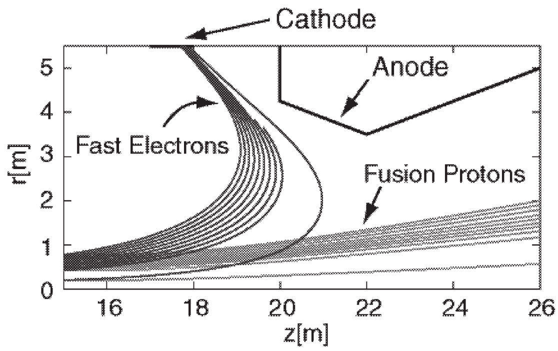

Fig. 2. Separation of fusion protons and fast electrons in Helmholts type DEC (anode and cathode earthed).

Figure 3 shows the trajectories of the thermal ions and the slow electrons, indicating that the separation is relatively good with 61 % of ions to cathode.

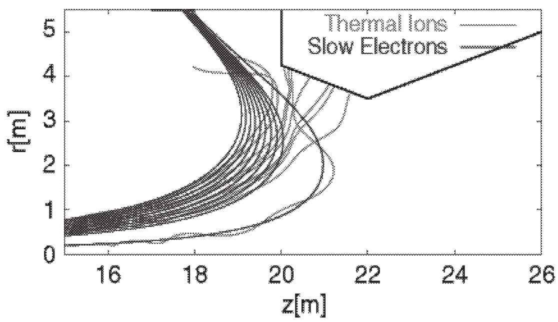

Fig. 3. Separation of thermal ions and slow electrons in Helmholts type DEC (anode with 10kV and cathode with 100 kV).

Reference

1) Kobayashi, T., Nemoto, T. and Ishikawa, M.: AIAA 2004-2168, pp.1-10, 35th AIAA Plasmadynamics and Lasers Conf., 2004.
2) Kawana, R. and Ishikawa, M.: Proc. 15th Int. Conf. On MHD Energy Conversion, Vol.2, pp.302-130, 2005.