DOI: 10.34854/ICPAF.51.2024.1.1.069

APPLICATION OF NEURAL NETWORKS TO THE TASKS OF RECOVERING THE PLASMA EQUILIBRIUM IN A TOKAMAK *)

[1]Scopintsev D.A., [1,2]Dokuka V.N., [1,2]Khayrutdinov R.R., [2]Andrianova R.R., [2]Khayrutdinov E.N.

[1]*Troitsk Institute for Innovation and Fusion Research, Troitsk, Moscow, Russia, scopintsev.d.a@triniti.ru*

[2]*National Research Centre Kurchatov Institute, Moscow, Russia, khayrutdinov_rr@nrcki.ru*

Standard methods for reconstruction the equilibrium of a plasma plasma shape in a tokamak [1], as well as the presented method, assume that the values of currents in plasma and coils of a poloidal magnetic field, also the values of magnetic fields in sensors of a poloidal magnetic field and fluxes in poloidal magnetic loops are known from experiment.

Currently, many researches are being carried out on tokamaks to keep plasma of various cross sections, circular, elongated vertically and divertor, with positive and negative triangularity. The task of reconstruction equilibrium according to magnetic sensors can be divided into two parts. The first is the reconstruction after the experiment, and the second, in real time during the discharge.

In the first task, different complicated codes are usually used, in which the two-dimensional nonlinear Grad-Shafranov equation is solved in iterations, and current density profiles are determined. This task requires significant computational time. The second task uses less accurate methods based on the representation of plasma by several current filaments, which allow to determine the plasma boundary with less accuracy than in the first task and with a large error of the magnetic axis coordinates.

The main task of real-time control is to mapping the necessary signals from the nonlinear representation of magnetic signals in to the values of geometric parameters [2]. The neural network enables us to quickly and efficiently determine the parameters of the plasma boundary shape.

In this article, a multi-layer neural network with a back propagation algorithm is used. In the process of training a neural network, calculations of direct equilibrium with a change in established range of geometric quantities and current density parameters are applied as input data of the neural network, and the calculated values of magnetic sensor signals are fed to the output of the neural network.

The training set of parameters used as the desired position and shape of the plasma boundary is calculated using the DINA code [3], which makes possible to obtain an equilibrium configuration of the tokamak plasma in specified magnetic fields, provided that the plasma boundary pass through the points fixed in the plane of the poloidal cross section of the tokamak.

References

[1]. Bishop C.M., Haynes P.S., Smith M.E.U., Todd T.N., Trotman D.L., Real-time control of a tokamak plasma using neural networks // Neural Computation, V. 7, No. 1 (1995), P. 206–217.

[2]. Dokuka V.N., Khairutdinov R.R., Kavin A.A. Synthesis and modeling of the magnetic plasma control system in a tokamak KTM // VANT. Thermonuclear synthesis, 2008, Issue 1, P. 12–20.

[3]. Khayrutdinov R.R., Lukash V.E. Studies of Plasma Equilibrium and Transport in a Tokamak Fusion Device with the Inverse-Variable Technique. // J. Comput. Physics, V. 109 (1993), P. 193–201.

*) abstracts of this report in Russian