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The Basic Components of Software-Hardware System for Modeling and Control of the Toroidal Plasma by Epsilon-Nets on Heterogeneous Mini-Supercomputers

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Abstract. A significant step towards the comprehensive solution of the important new fundamental control problems of high-temperature plasma of toroidal configuration is made by utilizing heterogeneous mini-supercomputers of NIISI RAS (Scientific Research Institute of System Development, Russian Academy of Science). The basic components of hardware and software modeling system and automatic real-time plasma feedback control are developed and implemented. The system is named HASP CS (Hardware-Software Plasma Control System). It is based on a fundamentally new, more accurate and reliable control algorithm using a solution with a given accuracy of a number of inverse diagnostic problems by ϵ-nets. The possibility of an application of the proposed technique during discharge time to provide feedback control of the boundary and internal plasma parameters is demonstrated. It is shown that the complex allows investigating the processes in currently operated and designed fusion devices and solving problems of fusion application for energy production. The recommendations to the engineering implementation of plasma control systems are made. The directions for further research are formulated.

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1 Introduction

The leading world countries carry out intensive research on the transition to fusion power generation based on a secure, virtually inexhaustible source of energy.

The international thermonuclear tokamak reactor ITER (`www.iter.org`) is built by China, European Union, India, Japan, Korea, Russia and USA. The world's largest tokamak JET (`www.euro-fusion.org`), where in 1991 the first reaction of controlled thermonuclear fusion was carried out operates in EU. In the UK record plasma parameters were obtained on a large spherical tokamak MAST (`http://www.ccfe.ac.uk`). In Germany ASDEX tokamak (`http://www.ipp.mpg.de/16195/asdex`) which has a well-developed plasma diagnostics operates. T-15 tokamak (National Research Center "Kurchatov Institute", `http://www.nrcki.ru/pages/main/6015/8698/7145/index.shtml`) is being built in Russia. The international community plans to construct the first fusion power plant DEMO in Japan.

Countries that possess the technology of controlled thermonuclear fusion (CTF) will be out of competition. The main difficulty in CTF study is a large range of temporal and spatial scales of the existing phenomena, as well as multi-dimensional dependency of process' characteristics on phase variables. It requires detailed study of plasma diagnostics and control systems, of engineering solutions in terms of accuracy, reliability, efficiency, safety and durability. Complete solution of these problems is impossible without the use of high-performance computing.

Plasma dynamics control is one of the main fundamental problems of theoretical and experimental study of fusion and of transition to the thermonuclear fusion power generation. However, control methods, especially for internal plasma parameters are poorly developed due to the need of using comprehensive mathematical models that address a number of complex ill-posed inverse problems of plasma diagnostics, development of massive knowledge-intensive software and application of high-performance computing. In practice, when constructing the controllers the semi-empirical greatly simplified approaches or prescribed (program) mode are commonly used, which lead to the bulk expensive work on the experimental choice of the parameters of control systems and to a large number of premature discharge disruptions during the research companies.

The basic components of system HASP CS (Hardware-Software Plasma Control System) were developed for comprehensive modelling of toroidal plasma control problems and support of real plasma operation. Here details of HASP CS are fully described for the first time in an easy accessible journal in English language.

The main objectives of this paper are: presentation of the concept and the main components of the new hardware and software system HASP CS, which allows modeling and control of the toroidal plasma by ϵ-nets on heterogeneous mini-supercomputers; description of the new boundary and internal plasma parameters real-time feedback control algorithms; a brief summary of the advanced graphical user interfaces; an example of system prototype operation.

Ongoing studies are focused on the creation of fundamentals of advanced technolo-