INTERNATIONAL EDUCATIONAL APPLIED RESEARCH JOURNAL (IEARJ)
Volume 04, Issue 02, Feb 2020
E-ISSN: 2456-6713

REVIEW PAPER ON STABILITY AND HORIZONTAL POSITION CONTROL FOR ADITYA-U TOKAMAK

Riya Mittal[1], Ranjan Dubey[1], Navneet Gupta[1]

[1]*Arya Institute of Engineering and Technology, Kukas, Jaipur, India.*

Abstract: *To generate control system model for the horizontal position control for Aditya-U Tokamak. For position control of plasma, different tokamaks system has been studied and simulation-model has been designed. The Alcator C equilibrium is investigated from the standpoint of determining the plasma position. A review of equilibrium theory is presented, indicating that the central flux surfaces of the plasma should be displaced about 1-2 cm from the outermost. The stability of the feedback control system is improved by using an additional term which represents the shift velocity of the plasma column.*

1. INTRODUCTION:

Plasma is one of the four fundamental states of matter, and was first described by chemist Irving Langmuir in the 1920s. It consists of a gas of ions – atoms which have some of their orbital electrons removed – and free electrons. Plasma can be artificially generated by heating or subjecting a neutral gas to a strong electromagnetic field to the point where an ionized gaseous substance becomes increasingly electrically conductive.

The plasma in tokamak is mandatory controlled by the set of poloidal field (PF) coils generating magnetic fields to stabilize it and avoid striking at vessel. To provide protection of the tokamak during various discharging states, an accurate plasma position control should be guaranteed. Nevertheless, plasma in a magnetic field belongs to the class of plants with uncertainties. Until now, there are various kinds of approaches to solve this kind of control problems, which generally can be categorized into two groups: adaptive control and robust control.

The Alcator C Tokamak is designed to operate with near fusion-grade plasmas. In typical operation, the input power to the plasma is from 1 to 5 MW, resulting in average energy 2 flux at the surface of 20 to 100 W per cm^2. Local "hot spots" receive much greater energy concentrations. For protection of the interior of the vacuum chamber, and for minimum impurity influx from the walls, it is necessary to accurately control and maintain the plasma position. The classical method of horizontal plasma position control is to use a vertical magnetic field to act on the plasma current to create a transverse force. Most tokamaks have some sort of position feedback involving perturbations to a preprogrammed field.

For the tokamak having non-elongated plasma, horizontal position control is crucial for improved operation. There are many sources of horizontal forces on the plasma due to which plasma is displaced from the geometrical center of the tokamak and can even collapse on the wall of the vacuum vessel and results in sudden disruption of the operation and also damage to the wall. So it is required to control the horizontal movement of plasma.

In order to maintain the plasma column in the geometrical center of its vacuum vessel, the externally applied vertical magnetic field must be adjusted according to the changes in the plasma parameters such as the plasma current, the poloidal beta of the plasma and the inductance of the plasma column.

2. FEEDBACK SYSTEM IN ALCATOR:

An SCR power supply drives a set of four coils, which generate a vertical magnetic field. The J x B force of this field on the plasma current acts to position the plasma. The main components and interactions that are considered are:

a) The SCR power supply generates a current in the vertical field coils, which acts to position the plasma.

b) Variations in plasma parameters such as current, temperature, or profile represent disturbances which must be corrected. .

c) The product of position and current is measured, and forms the error signal in the feedback loop.

With an apparent frequency dependence of plasma response to the applied field, the plasma transfer function is proportional to Iv /(1+sp). This signal is the input to the feedback electronics, which then drives the SCR supply. The tokamak plasma is subjected to several forces in the major radial direction that must be dynamically counterbalanced by an appropriate magnetic Lorentz force in order to maintain equilibrium in the horizontal direction. The majority of these forces tend to cause the plasma to expand in the major radial direction and must be counteracted if the plasma is to be confined. Without frequency compensation, the closed loop system is unstable when the DC gain is high enough for accurate position control. Consequently, a lead network is included in the feedback loop. Lead compensation was chosen in order to achieve the fastest closed loop response to a plasma disturbance. The feedback circuit has a single pole-zero pair transfer function. With adjustable gain and lead, this transfer function is:

$$H(s) = Ho\left(\frac{1+s\tau 1}{1+s\tau 2}\right)$$

Where,

τ_1 = 5.2 ms (variable) , τ_2 = 1 ms , H_0 = 2.5 (variable).

τ_1 is the lead parameter, while H represents the DC gain of the circuit.

3. CONTROLLING OF POSITION OF PLASMA:

The horizontal displacement of plasma can be balanced by externally applied **JXB** force, where **J** is the plasma current density and **B** is the externally applied magnetic field. For balancing horizontal displacement, vertical field is required from external or any internal (passive) source and for balancing vertical displacement, radial field is required. Control system should be applied to the tokamak system. Closed loop feedback system is installed for the horizontal position control. For controlling the transient response and steady state error, tuning of PID controller is required, which is performed in MATLAB-SIMULINK.

3.1 Expansion forces in major radial direction:

The tokamak plasma is subjected to several forces in the major radial direction that must be dynamically counterbalanced by an appropriate magnetic Lorentz force in order to maintain equilibrium in the horizontal direction. The majority of these forces tend to cause the plasma to expand in the major radial direction and must be counteracted if the plasma is to be confined. With plasma column being modeled as a conducting ring, inductance of plasma tends to be increased due to radial forces on it. In order for the position of the plasma in equilibrium, the Lorentz force which is induced by the net vertical field should counterbalance this force:

$$F_R = 2\pi R I_p B_V \quad N$$

The net vertical field which is required for the equilibrium of the plasma in the horizontal direction is given by

$$B_V = \frac{\mu_0 I_P}{4\pi R}\left[\ln\left(\frac{8R}{a}\right) - \frac{3}{2} + \left(\beta_\theta + \frac{l_i}{2}\right)\right] \quad T$$

Outward radial force simply doesn't depends upon I (plasma current) only, it also depends upon other parameters like β and l_i. In order to stabilize plasma in horizontal direction vertical field has to be controlled, which simply doesn't only depends upon I. Due to dynamic evolution of plasma, different parameters will change with time. The temporal variation of the plasma parameters demands continuous and dynamic regulation of the net vertical field that is required for equilibrium. This is a very difficult technical problem, particularly if the parameters of the plasma column change quickly.

For horizontal stabilization, vertical field is required which counterbalances the outward radial displacement. There are many ways by which this stabilizing vertical field is provided. These are called passive stabilization and active stabilization. Due to horizontal shift of plasma, flux associated with vacuum vessel and other conducting structure changes and results in generation of eddy current, these eddy currents are generated with different mode numbers. These different modes have different magnitude and different decay index of current which decay at L/R time constant. Normally P.F coils made up of copper is installed in tokamaks with different time constants. P.F coils are provided to satisfy flux conservation for which continuous vertical field is provided , but due to poor response time an extra set of '*fast feedback*' coils are provided from which minor change in vertical field is provided within given duration. Hence results in improved position control.

4. CONCLUSION:

In this paper, we had studied about the stability of the feedback control system for several kinds of control equation. For stability of the system, we compute time response of the displacement of plasma to the desired position. We also investigated the controlling of position of plasma by using control system. It is important for tokamak to control the plasma position during routine discharge. However, model contain some uncertainties. So, the robust control theory is suitable to deal with this problem. It had strong impact and developing intensively worldwide. It provide large stability margin which deals with different disturbances and uncertainties without resetting controller.

REFERENCES:

1. Japanese journal of applied physics (vol. 19, No.8, August 1980).
2. Freidberg, J. P. Notes from course 22.615 at MIT (1979).
3. Shafranov, V. D. Reviews of Plasma Physics Vol.2, Consultants Bureau, New York (1966) p. 103.