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# Tokamak Magnetic Control Simulation: Applications for JT60-SA and ISTTOK Operation.

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## ABSTRACT

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Abstract en ingles

**Keywords:**Real-time control, plasma current, centroid position, state-space



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## RESUMO

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Abstract em tuga

**Palavras-chave:**



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## SOMMARIO

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Abstract em italiano

**Parole chiave:**





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Figure 2.1      DIII-D digital PCS in 1991 [3].      6



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## LIST OF ABBREVIATIONS

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@TODO: Review variable lists as writing the thesis

- AC - Alternating Current
- ADC - Analog to Digital Converter
- ATCA - Advanced Telecommunications Computing Architecture
- CREATE - Consorzio di Ricerca per l'Energia, l'Automazione e le Tecnologie dell'Elettromagnetismo
- DAC - Digital to Analog Converter
- EO - Electronic Offset
- IST - Istituto Superior Técnico
- LQR - Linear Quadratic Regulator
- MARTe - Multi-threaded Application Real-Time executor
- MIMO - Multiple-Input Multiple-Output
- PCS - Plasma Control System
- PF - Poloidal Field
- PID - Proportional - Integrative - Derivative
- XSC - eXtreme Shape Controller
- WO - Wiring Offset



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## LIST OF VARIABLES

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@TODO: Review variable lists as writing the thesis

VARIABLES:

- $I_p$  - Plasma current
- $B_p$  - Poloidal magnetic field
- $\mu_0$  - Vacuum permeability





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## INTRODUCTION

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1.1 TOKAMAK PLASMA CONTROL

1.2 BEHIND THE PLASMA CURRENT

1.3 THESIS OUTLINE



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## PLASMA CONTROL SYSTEMS

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### 2.1 OVERVIEW OF CONTROL SYSTEMS

The control of plasma position, shape and current among other parameters is one of the crucial engineering problems for present and future magnetic confinement devices. The Plasma Control Systems (PCS) lead with the overall control of fusion devices being responsible also for the plasma configuration and scenarios algorithms [1, Chapter 8]. Currently different PCS's are use in the tokamaks around the world. In this chapter the "DIII-D-like" PCS and the Multi-threaded Application Real-Time executor (MARTE) will be approach, this last one being of special interest due to its extensive utilization in this work.

#### 2.1.1 *DIII-D Plasma Control System*

Early documentation regarding the PCS in DIII-D<sup>1</sup> reefers to digitalization of analog signals transmitted to a high speed processor executing a shape control algorithm and then writing the result to a digital to analog converter for driving the controlled systems . The real-time computer used allowed to performed operations with vectors and matrices required for the plasma shape control algorithm [3]. Figure 2.1 shows the block diagram of the DIII-D PCS 30 years ago.

### 2.2 MARTE FRAMEWORK

MARTE was developed in order to standardize general real-time control systems for the execution of control algorithms. MARTE framework is based on a multiplatform C++ library. [2]

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<sup>1</sup> DIII-D is a D-shape tokamak operated by General Atomics in San Diego, California.



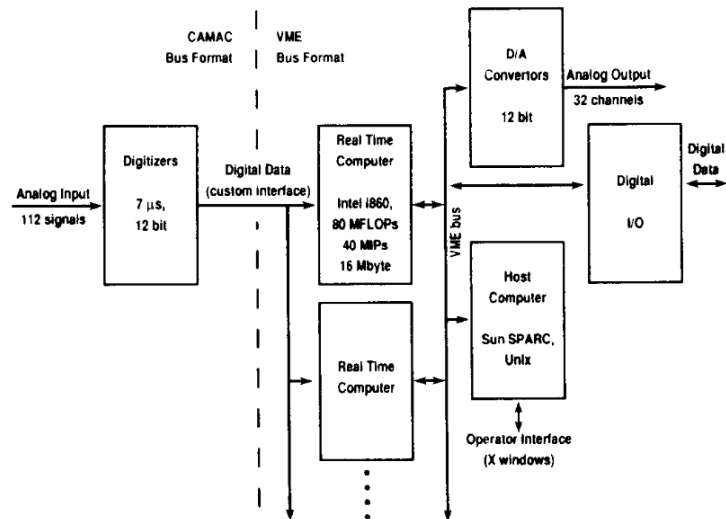


Figure 2.1.: DIII-D digital PCS in 1991 [3].

### 2.2.1 *MARTE architecture*

### 2.2.2 *Hardware containers*

### 2.2.3 *MARTE 2.0*

## 2.3 EQUILIBRIUM AND CONTROL ALGORITHMS

### 2.3.1 *PID control*

### 2.3.2 *Multiple-Input Multiple-Output control*

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## JT60-SA CONTROL DESIGN

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### 3.1 MACHINE DESCRIPTION

### 3.2 CREATE TOOLS

### 3.3 CONTROLLER DESIGNS

### 3.4 QST TOOLS IMPLEMENTATION

### 3.5 SIMULATION RESULTS



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## ISTTOK

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### 4.1 MACHINE DESCRIPTION

### 4.2 DIAGNOSTICS AND ACTUATORS

### 4.3 ATCA-MIMO-ISOL BOARDS

#### 4.3.1 *Hardware layout*

#### 4.3.2 *Real-time integration software*

### 4.4 RETRIEVING THE CONTRIBUTION OF PLASMA CURRENT

The methods of correction of the magnetic error fields due to inaccuracies of tokamak manufacturing and assembly are considered. The problems of the plasma position and shape reconstruction based on magnetic field measurements are discussed.

### 4.5 PLASMA CENTROID POSITION DETERMINATION



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## ISTTOK RESULTS

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### 5.1 GENERAL APPLICATION MODULES IMPLEMENTATIONS

### 5.2 PID CONTROL IMPLEMENTATION

### 5.3 MULTIPLE-INPUT MULTIPLE-OUTPUT CONTROL IMPLEMENTATION



## CONCLUSIONS

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bla bla bla





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DEMONSTRATIONS

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