UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR TÉCNICO

Università degli Studi di Padova

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

Doménica Corona Rivera

Supervisor:Prof. Horácio Fernandes
Co-Supervisor: Prof. Nuno Cruz
External supervisor: Prof. Alfredo Pironti

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ABSTRACT

Abstract en ingles

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

RESUMO

Abstract em tuga

Palavras-chave:

SOMMARIO

Abstract em italiano

Parole chiave:

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LIST OF ABBREVIATIONS

@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 - Instituto 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
- RFM - Reflective Memory
- SCD - Systéme de Contrôle Distribué
- XSC - eXtreme Shape Controller
- WO - Wiring Offset

LIST OF VARIABLES

@TODO: Review variable lists as writing the thesis

VARIABLES:

- I_p - Plasma current
- B_p - Poloidal magnetic field
- μ_0 - Vacuum permeability

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INTRODUCTION

1.1 TOKAMAK PLASMA CONTROL

1.2 BEHIND THE PLASMA CURRENT

1.3 THESIS OUTLINE

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PLASMA CONTROL SYSTEMS

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 [3, Chapter 8]. Currently different PCS's are use in the tokamaks around the world. In this chapter the "DIII-D-like" PCS, the Systéme de Contrôle Distribué (SCD) 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[1] 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 [1]. Figure 2.1 shows the block diagram of the DIII-D PCS 30 years ago.

Blablabla

2.1.2 *Systéme de Contrôle Distribué*

The TCV[2] distributed control system uses a modular network of real time PC nodes liken by a real time network to provide feedback control over all of the actuator systems. Each node consists of a Linux PC either embedded on a Compact-PCI module or as a desktop computer with Intel CPU. A fiber optic ring network links the reflective memory (RFM) network cards in each node [4]. The design of the diagnostic signal processing and control algorithms is performed in Matlab-Simulink software. During

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

2 The Tokamak à configuration variable (TCV) is a medium size tokamak localized in Laussane,Switzerland. It is characterized by a highly elongated, rectangular vacuum vessel.

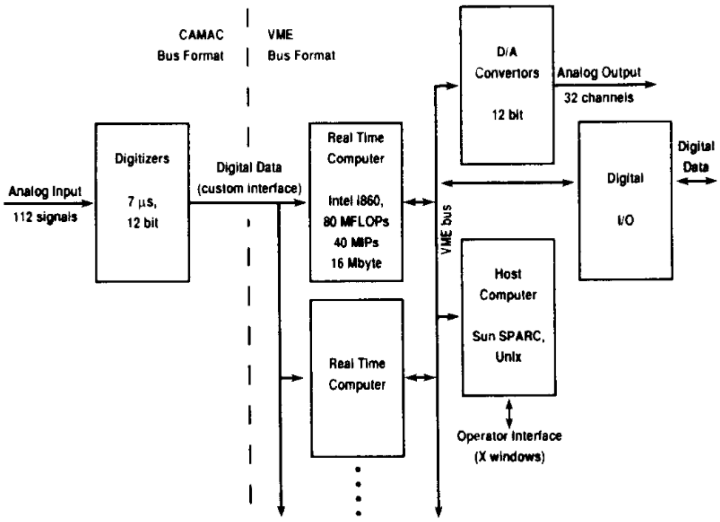

Figure 2.1.: DIII-D digital PCS in 1991 [1].

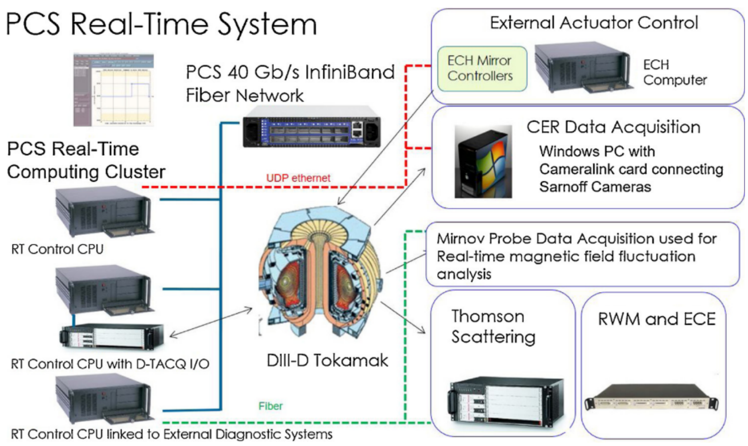

Figure 2.2.: [6].

the real-time execution C/C++ code is generated from the Simulink and compiled into a Linux shared library and distributed to target nodes providing the input/output interface to the control algorithm code [2]. Figure 2.3 depicts the TCV SCD layout with the connectivity to diagnostics and actuators.

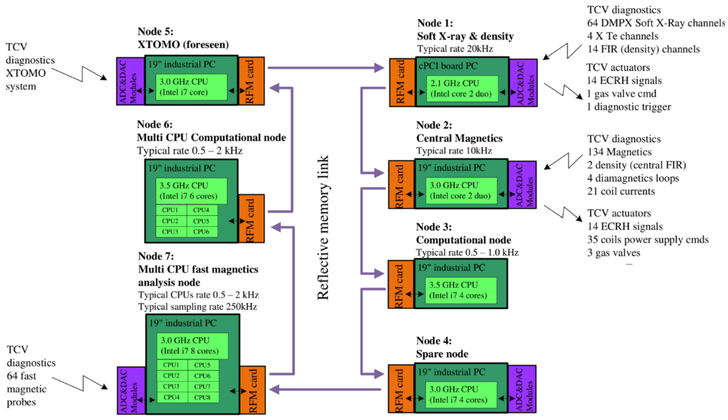

Figure 2.3.: TCV SCD. Real-time network nodes connection. The nodes configurations are shown together with the typical diagnostic and actuator systems to which they are connected [2].

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. [5]

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

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

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 PLASMA CURRENT MAGNETIC FIELD

Retrieving the contribution of the plasma current in tokamaks ...

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

5.1 IMPLEMENTATION OF THE GENERAL APPLICATION MODULES

5.1.1 *PID control implementation*

5.1.2 *Multiple-Input Multiple-Output control implementation*

5.2 RESULTS

5.2.1 *PID control and LQR control results*

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CONCLUSIONS

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DEMONSTRATIONS