Integrated Design and Implementation of Performance Regulation and MHD Stability Control Algorithms for KSTAR


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US-Korea Workshop on Opportunities for Expanded Fusion Science/Technology Collaboration with the KSTAR Project

General Atomics, San Diego, CA

19-20 May 2004
Overview of Talk

• Proposed task: advanced, integrated plasma control design for KSTAR
  – Advanced shape/stability control
  – Operating point, profile control

• Proposed task is a natural extension of the KSTAR Day One Plasma Control System (PCS) development effort, now underway (with funding ~0.4 FTE DOE, ~0.25 FTE KSTAR, + KBSI collaboration support)
  – Basic R, Z, Ip, coil current control; infrastructure derived from DIII-D PCS
  – Uses DIII-D integrated plasma control tools

• The Integrated Plasma Control approach
  – Used in both Day One PCS task and advanced control task

• Task sequence/schedule: FY2006-2010 (extension to 2011-2014)

• Summary and Conclusions
Proposed Task: Integrated Performance and Stability Control Design for KSTAR

• Upgraded KSTAR PCS to include advanced equilibrium and MHD stability control in close collaboration with KBSI

• Model-based design and simulation tools; simulations to test implementation
  – Implementation in KSTAR PCS based on DIII-D PCS

• Advanced shape control:
  – Full isoflux scheme from DIII-D
  – Realtime EFIT
  – Model-based multivariable controllers
  – Nonlinear (saturation proximity avoidance) algorithms

• Operating point control algorithms:
  – Density control (fueling/pumping)
  – Plasma beta control

• MHD stability control:
  – High performance digital vertical stability control
  – RWM, NTM control algorithms

• Off-normal supervisory/response algorithms
Proposed Task is Natural Extension of Present Day One KSTAR PCS Design Task

- **Goal of Present task is to design “Day One” KSTAR PCS with basic plasma control**
  - KSTAR Day One PCS is based on and developed from the DIII-D PCS infrastructure
  - Strong collaboration with KBSI personnel
- **Model-based design and simulation tools; simulations to test implementation**
- **Basic position, vertical stability control:**
  - R, Z position; velocity-based vertical stability algorithm
  - Model-based PID controllers
- **Operating point control algorithms:**
  - Coil current control
  - Breakdown algorithm
  - Plasma current control
- **KSTAR PCS and algorithms designed to be extendable to full advanced, integrated plasma control**
KSTAR Tasks Follow Integrated Plasma Control Approach to Ensure High Reliability, High Performance in Final Implementation
Present KSTAR Simulation Includes Power Supplies, Plasma-Conductor System, Filters, Noise Sources

KSTAR R,Z,Ip Controller

KSTAR Plasma-conductor system
The **KSTAR PCS** is Based on and Developed from the **DIII-D PCS**

- **KSTAR/DIII-D PCS** provides completely general computational environment for implementing complex algorithms of any type (mathematical operations, logic, waveform programs)

- **KSTAR Day One PCS** contains basic set of control categories
  - Equilibrium
  - PF coil control
  - Vertical stability

- DIII-D PCS now used as basis for PCS systems at NSTX, MAST, EAST
Demonstration of KSTAR PCS Controlling Simulation

- Simulation of KSTAR major radial position command following
  - KSTAR PCS based on DIII-D PCS; presently configured for R, Z, Ip control scheme
  - Command following simulation with fast internal coil control (no integral error reduction)
  - Controller design functions well with saturation, delays, rate limits, anti-alias filters, actual PCS response
KSTAR Simulation Modules for MHD Physics and Control Design Will be Based on DIII-D Modules

Model of plasma/island response to ECCD

NTM Control Algorithm

Modified Rutherford Equation

Core Plasma Model

NTM Physics Model

Last modification: Thu Dec 20 22:48:04 2002
The Vision of Integrated Plasma Control Includes Modeling and Simulation of all Key AT Elements

Many of these elements have already been developed, validated, and applied to DIII-D designs, simulations, and experiments.
Strawman Task Sequence/Schedule

Strawman KSTAR Advanced Control Task Sequence/Schedule 2006-2014

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Annotations: v1.5, v2.0
Summary and Conclusions

• The proposed KSTAR Integrated Plasma Control design task will extend present Day One PCS design efforts to provide coordinated, high performance, high reliability control for KSTAR

• Key elements of Integrated Plasma Control include:
  – Model-based control design, using models validated by experiment
  – Multivariable design techniques which include performance optimization
  – Realistic, accurate simulations for systematically confirming control performance, both offline and with actual control computer hardware/software

• KSTAR advanced control elements to be designed and implemented in the proposed task in close collaboration with KBSI
  – KSTAR PCS developed to support new advanced control elements
  – Advanced shape control (isoflux, rtEFIT)
  – Advanced operating point control (beta, density, profiles)
  – MHD control: high performance vertical, NTM, RWM

• Proposed Task execution over FY2006-2010 (optional extension to 2011-2014)
• Level of effort ~0.8 FTE over duration of task (~0.8 Man-Year per year of task)
Simulations Allow Testing of KSTAR Control Algorithms Before and After Implementation

“Hardware-in-the-Loop” simulation uses the KSTAR Simulator to verify actual implementation in KSTAR PCS