Centralised Coordinated Control to Protect the JET ITER-like Wall.

Adam Stephen and JET-EFDA Contributors*

ICALEPCS, 2011.

*See the Appendix of F. Romanelli et al., Proceedings of the 23rd IAEA Fusion Energy Conference 2010, Daejeon, Korea.
Acknowledgements

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  - Peter Lomas and Plasma Ops Group
  - Paul McCullen – JET Level-1.
  - CODAS
  - Diagnostic/Camera systems team.
  - Funded by EFDA & RCUK Energy Programme.
- MARTe

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The Joint European Torus (JET)

Plasma physics closest to ITER

- Torus radius: 3.1 m
- Vacuum vessel: 3.96m high x 2.4m wide
- Plasma volume: 80 m³ - 100 m³
- Plasma current: up to 5 MA in present configuration
- Main confining field: up to 4 Tesla

Unique technical capabilities:
- Tritium
- Beryllium

⇒ Optimise the use of JET in support of ITER by making use of its unique capabilities
JET vessel 2005
Material for Plasma Facing Components

Carbon Fibre Composite Tiles (CFC)

- Low atomic number (minimise radiation losses)
- High power handling capacity (sublimation 4000K)
- Absorbs deuterium/tritium fuel.

Design for ITER: all-metal wall with Beryllium

ITER-like Wall project for JET: 4000 new tiles

Beryllium Tiles

- Low atomic number (minimise radiation losses)
- Reduced power handling capacity (melting pt 1560K)
- Reduced retention of fuel

Implications for the JET protection systems…
Detection Systems

- Plasma Fault Protection System (PFPS)
- Plant Enable Windows System
- Real-Time Plasma Protection (RTPP)
- Real-Time Central Controller (RTCC)
- Plasma Wall Load System (WALLS)
Detection Systems
• Plasma Fault Protection System (PFPS)
• Plant Enable Windows System
• Real-Time Plasma Protection (RTPP)
• Real-Time Central Controller (RTCC)

Real-time Controllers (local managers)
• Fuelling/Density (PDLM)
• Additional Heating
  • Neutral-Beam (NBLM)
  • Radio Frequency (RFLM)
  • Lower-Hybrid (LHLM)
• Plasma Position & Current Control (PPCC)
Protection Response

- Pulse Termination Network
- Global STOP to all systems
- System stops fixed in time
- No variation according to plasma state
- Possibility of high heat fluxes to wall components
• New Diagnostic Systems to detect faults
  – Pyrometers, IR Cameras + Real-time image processing (See M.Jouve, WEPMU018, this conference).
  – Vessel Thermal Map (See D.Alves, WEPMN014, this conference)
  – Walls plasma load upgrade

• Update real-time controllers to accept protection override commands, including PPCC (See A.Neto, MOPMU035, this conference)

• Real-Time Protection Sequencer (RTPS) – new system to adapt experimental controls to implement hotspot avoidance or else achieve a “soft landing”

• Separation of control (RTCC)/protection(RTPP) diagnostics and related central servers (RTGS E/P)
New Protection Logic

Stop Triggers link to Configurable Stop Responses

• Identify classes of protective response:
  – (A) Overheating (local/walls/divertor/global)
    • Reduce the heating, but avoid turning it off.
    • Move/shrink the plasma.
    • Adjust heating/fuelling `as required’.
  – (B) Magnetohydrodynamic (MHD) Instabilities.
    • Change plasma control scenario to avoid disruption
  – (C) Improved programmable ‘Fast’ and ‘Slow’ stops

• Link fault alarms to response actions.
• Allow for local protection, plus two escalated responses.
Local Protection

- Localised overheating?
- Known culprit? (1 PINI, 1 Antenna, 1 Klystron)

✦ Inhibit & continue

Local managers will rebalance the power demand.

If things get worse, stop safely.
Global Stop Response

2. Type of risk

1. Time / phase.

RTPS protection varies according to:

2. Class of response; PTN/RTPS/JTT

The MHD Stop Response is not a primary RTPS stop in this Pul.
1. Scenarios for each stop type.

2. Stop response = set of controls.

3. Controls define stepped transitions.
Plan:
Steady-state
52.5-57.4
Termination:
57.4-62.0
If event occurs any time in steady-state phase jump to 57.4
Secondary Stop Transitions

Some stops may `accelerate`, others continue to completion.

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See A. Neto, THDAULT06, *this conference.*

1. Reusable modules for standard control application (state machine, data collection). Highly data driven application structure. Sophisticated object oriented/component based framework with 10+ years of control system experience.

2. Proven real-time performance.

3. Portable and highly modular: run unit tests on Linux, pluggable simulated inputs, rapidly evolve the design.

4. Strong interface to Level-1 MMI. Decouple compiled code from configuration programming. Strong authorisation and validation checks on changes. Highly visible parameters.

5. Application configuration ➔ Documentation

6. Growing community of MARTe experts – a very knowledgeable and helpful group.
RTPS Block Diagram

2ms cycle
RTPS Hardware Architecture

- VME system
- MVME5500 1GHz PowerPC 512MB RAM
- Digital IO
- Watchdog monitoring via pulse train
- Ethernet for slow control/data collection
- Real-time communication:
  - ATM segregated network for RT control
  - Low latency, high reliability
  - Fixed connections (permanent virtual circuits)
  - Fixed size datagrams with controlled version ID.
RTDN / MARTe
Same pattern.

• Functional blocks
• Smart Bus
  • Synchronisation
  • Data Coherency
• Commissioning/Campaigns interleaved.
• Logic tests with dry runs
• Ohmic plasmas
• Plasma light used to simulate high temperatures.
• Vessel Thermal Map alarms checked.
• RTPS stop responses demonstrated.
• Jump To Termination in plasma control JPN 80500.
Future Work

• Full commissioning and calibration of camera systems.
• Integrate control of heating systems.
• Expanded local protection.
• ‘Alternative control’?