Smart Engines Via Advanced Model Based Controls

Marc Allain, Yury Kalish, Nabil Hakim

Incorporating advanced control strategies during the engine development process and on-board is an inevitable consequence of modern-day advancements of the Information Technology age.

This presentation will provide Detroit Diesel's approach to the development of smart engine controls and will report on selected recent accomplishments.
Smart Engines Via Advanced Model-Based Controls

Marc Allain, Yury Kalish, Nabil Hakim

Acknowledgement: DDC’s MBC Expanded Team
Outline

• What is Model-Based Controls?

• Benefits of MBC

• Tools
  – Off-line simulation
  – Rapid prototyping
  – Hardware-in-the-loop

• Applications
What is Model-Based Controls?

• A “new” process for developing control systems
  – Less engine testing
  – More robust control system
  – Shorter development cycle time

• “Smarter” approach to engine control
  – On-board models describe engine behavior
  – Shorter, systematic calibration process
  – Customer and legislative requirements designed-in
What is Model-Based Controls?

TRADITIONAL PROCESS (SERIES)

Requirements

Write Software

Procure Hardware

Iteration

Design Freeze

Engine Tests

Engine Tests

Engine Tests

Strategy Development

Controller Development

Calibration Development
What is Model-Based Controls?

NEW PROCESS (PARALLEL)

- Procure Hardware
- System Analysis
- Strategy Development
- Software Testing
- Calibration Refinement
- Engine Tests
- Design Freeze

Virtual Lab
RPCS
HIL

CONTROLS PERFORMANCE ELECTRONICS

Requirements
Benefits of Model-Based Controls

- “Smarter” engine
- Better control
- More variables controlled

MODEL BASED CONTROLS

- Improved component protection
- Virtual sensors
- Cost savings

- Analytical Control development (off-line simulation)
- Rapid control prototyping
- Hardware-in-the-loop testing

Reduced software development time
Tools

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Off-line simulation

- Control strategy screening
- Sensor / actuator requirements
- Controls tuning
Off-line simulation

Real-time engine model

cycle-simulation code

actuator models

sensor models

engine model
Real-Time Engine Model

- **Map-based model**

- **Same engine model is used for**
  - Off-line simulation
  - Hardware-in-the-loop

- **Enables real-time evaluation of control strategies**
Off-line Simulation

- Example: Turbine inertia effect on turbine speed response
Off-line simulation

- Air-fuel ratio control over a load transient
Off-line simulation

- PID gain tuning for control of an advanced engine subsystem
  - Provides “virtual calibration”
  - Good initial set of parameters for engine calibration
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ECM: Electronic Control Module
Engine: Engine
Controls model: Controls model
Engine model: Engine model
Control Development Process

- Investigate control strategies

- Using same controls models as off-line
- Prototype C-code automatically generated

- Rapid controls prototyping

- Reduced algorithm development time
- Reduced risk of damaging prototype hardware
Off-line simulation & rapid prototyping

- **Turbine speed control**

**Model response**

**Engine response**

- + set-point
- + actual
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Hardware-In-The-Loop

actuator inputs

ENGINE MODEL

DDEC

torque
rpm
boost
etc.

engine outputs
Current Applications

- **Controls development**
  - Multi-variable air-system control
  - Aftertreatment control
  - Fuel delivery control

- **Incorporating model-based strategies**
  - Virtual sensing
  - On-board predictive algorithms (observers)
  - Investigation of advanced control schemes