Model-Based Development of Waste Heat Recovery Systems for Container Ships
Added customer value through integration, intelligence and IoTSP
ABB Marine
Drivers and risks

Key drivers
- Energy efficiency,
- Safety and environmental sustainability
- Information technology

Risks and safety
- Lots of people onboard (up to 8000)
- Lots of cargo onboard (18000 containers, hundreds of thousands tons of oil)
- Big size up to 160000 DWT
- Large investment (up to 1 billion USD)

ABB Guarantees reliability, safety, and energy efficiency through high quality products, high expertise, and thorough testing of the solutions
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Motivation
Hero Story
Traditional way of working
Transportation of Fresh Goods
Huge electrical energy consumption

- Transportation of fresh goods is growing
- Reefer containers require a lot of electrical power
  - Typically auxiliary power plant > 10 MW
  - Diesel generators supplying 10 MW consume > 2000 kg/h of marine diesel oil
Waste Heat Recovery System
Power Turbine Generator (PTG) Application

WHRS Schematics

ABB Marine scope

Savings

Shaft power output 49%
Increase in efficiency with WHRS

Energy in fuel 100%

1. Main Engine
2. Turbo Generator
3. WHRS
4. Main Electrical Grid

40-80 MW

1,5-3,5 MW electrical power

Waste Heat Recovery System

Quick Closing
Control Valve
Exhaust Gas
Steam Turbine
Power Turbine

Annual emissions with and without WHRS

w/
28848 t
91880 t CO₂/year

w/o
29200 t
93000 t CO₂/year

Annual savings with WHRS = 352 t 1121 t CO₂/year
The Challenge
The Challenge
Tight schedule

• Customer project of 14 ships
  • 1.6 MW electrical power from exhaust gas waste heat

• Functionalities that has not been done by any other company
• New product for ABB
• Less than two years development time
• 14 deliveries within 1 year
The Solution
Development process
Model-based development

- Simulation model development
  - Concept development
    - Function description
      - Implementation on PLC
        - HIL testing
          - Mechanical FAT tests
            - Harbor and sea acceptance tests
              - Plug-and-play data acquisition
                - Real-time simulation
                  - Desktop simulation
                    - Physical modeling
Simulation model
Systems and toolboxes

WHRS simulator
- Exhaust gas system, Power turbine
- Gearbox and generator, braking resistor unit
- Three-phase network with varying loads
- Diesel generators
- Main switchboard, synchronizers and circuit breakers

Simulated 3rd party control systems
- Power Management System
- Engine Control System
- Diesel engine governor

Electrical system
- SimPowerSystems (2nd generation / Specialized technology)
- Synchronous generator, AVR (Excitation system), measurements, loads, circuit breakers

Other toolboxes
- Signal processing toolbox
- Control systems toolbox
Development and test platform
Real actuators

Pneumatic control valve
Fast closing ESD valve

Instrument air 8 bar

Actual pos.

Valve cmd.

Cmd.

Act.

~50 IOs

Permanent setup with simulated actuators

Modbus TCP/RTU, Profibus DP

1 MW Braking resistor unit

Electrical power

Speedgoat Performance real-time target machine

IO

EtherCAT

Modbus RTU

IO

Modbus RTU

Modbus TCP

Profibus DP

WHRS Local Control Unit

Modbus TCP

cpmPlus RTDB

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Results
Results

- More than 60% of the development cost were used for simulation and testing at the laboratory
- >85% of the control software issues fixed before the first handover of the system, >95% of the critical issues
- Many of the issues would not have been found during sea trials
  - Require certain sequence of events to happen
- >1000 operation hours for control system before first delivery
- Software updates were tested at laboratory before updating the software onboard

- Cargo ships travel around the world with tight schedules
  - WHRS system cannot be tested at dock
  - → Minimum time onboard is one voyage (3-30 days)
  - Total costs of one service trip onboard > 10000 USD
What’s Next?
Ongoing work
Integrated Marine Systems Laboratory

ABB Steps Up Marine R&D with New Lab

2015-10-27 - Next generation of maritime technology will be developed with ship owners at high technology facility in Helsinki, Finland.

Zurich, Switzerland, October 27, 2015 - ABB, the leading power and automation group, has strengthened its commitment to research and development in the marine sector by opening a new laboratory. Situated in Helsinki, next to the Azipod® factory, it will bring together all ABB’s offerings for the shipping industry under one roof. ABB has invested significant funds in the scheme, which will be used by the 30 ABB engineers dedicated to marine research in Helsinki as well as to demonstrate products to customers.
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