Model-Based Development of Waste Heat Recovery Systems for Container Ships
ABB Marine
Main offering

Online Advisory, Integrated Operations, IoTSP

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
Contents

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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

능력: 40-80 MW

Savings
Shaft power output 49%
Increase in efficiency with WHRS

49%

Energy in fuel 100%

1,5-3.5 MW electrical power

ABB Marine scope

WHRS Schematics

Main Engine
Turbo Generator
WHRS
Main Electrical Grid

Annual emissions with and without WHRS
w/

w/o

28848 t
91880 t CO₂ /year

29200 t
93000 t CO₂ /year

Annual savings with WHRS = 352 t
1121 t CO₂ /year

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May 3, 2016
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
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

Options:
- Physical modeling
- Desktop simulation
- Plug-and-play data acquisition
- Real-time simulation
## Simulation model

### Systems and toolboxes

<table>
<thead>
<tr>
<th>WHRS simulator</th>
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<tbody>
<tr>
<td>• Exhaust gas system, Power turbine</td>
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<td>• Gearbox and generator, braking resistor unit</td>
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<tr>
<td>• Three-phase network with varying loads</td>
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<td>• Diesel generators</td>
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<tr>
<td>• Main switchboard, synchronizers and circuit breakers</td>
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<tr>
<th>Simulated 3rd party control systems</th>
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<tr>
<td>• Power Management System</td>
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<td>• Engine Control System</td>
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<td>• Diesel engine governor</td>
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<tr>
<th>Electrical system</th>
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<tr>
<td>• SimPowerSystems (2nd generation / Specialized technology)</td>
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<tr>
<td>• Synchronous generator, AVR (Excitation system), measurements, loads, circuit breakers</td>
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<th>Other toolboxes</th>
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<tr>
<td>• Signal processing toolbox</td>
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<td>• Control systems toolbox</td>
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Development and test platform
Real actuators

Pneumatic control valve
Fast closing ESD valve

Instrument air 8 bar

Permanent setup with simulated actuators

1 MW Braking resistor unit

Electrical power

~50 IOs

Speedgoat Performance real-time target machine

IO
EtherCAT
Modbus RTU

Modbus TCP

IO
Modbus RTU
Modbus TCP

Profibus
DP

WHRS Local Control Unit

cpmPlus
RTDB

Act.

Cmd.

Actual pos.

Valve cmd.

Controller

Power and productivity
for a better world™
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 Azpilco 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.
Hero Story
Revised