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1. Introduction

Why Ship Energy Management System in Need?

International Regulation Energy Management (SEEMP)

Ship Operational Cost Reduction Demand by Owner

* SEEMP: Ship Energy Efficiency Management Plan (2013. 01. 01)

FOC Difference for Voyage by Voyage

Current | Voyage1 | Voyage2 | Voyage3 | Voyage4
--- | --- | --- | --- | ---
6300 | 7200 | 6125 | 6750 | 5040

>30%

Ship Energy Management System Development
1. Introduction

Why “EN-SAVER” by SHI?

- Advanced Optimization Systems
  - Trim Optimizer: Advanced CFD/Towing Tank Test Technology
  - Route/Speed Optimizer: Smart/Accurate Generic Algorithms
  - G/E Load Optimizer: Non-Linear Equation Solver

- Accurate Ship Performance Evaluation (Case Study)
  - Weather Correction with Detail Analysis
  - Machinery Performance Evaluation

- SEEMP Based Software Philosophy
  - Systematic SEEMP Process in Software
  - Electronic Daily/Voyage Report Generation
2. ‘EN-SAVER’ Configuration

‘EN-SAVER’ – Functional Configuration

- Integrated Optimization Solution
  - Optimal Trim
  - Optimal Route & M/E Speed
  - Optimal G/E Load Allocation

- Advanced Ship Performance Evaluation
  - Weather Effect Analysis
  - Non Weather Effect Analysis
  - Machinery Performance Analysis

- Easy SEEMP Application
  - Embedded SEEMP Process
  - Automatic Daily Report Generation
  - Voyage Report with Performance Evaluation
2. ‘EN-SAVER’ Configuration

‘EN-SAVER’ – System Interface Configuration

Integrated Energy Management System

Onboard

Sub System

Equipment

Onshore

Real-time Information for M/E & G/E, Aux.
- Aux. Boiler, tank level, trim & draft, exh.
- Gas temp, fuel temp, SW temp

Real-time ship motion & fuel consumption
- Individual consumption for engine & boiler
- Roll & Pitch, Air temp & pressure

SVDR 3000/5000, VDR
(Information for GPS, Wind Speed/Direction, Rudder, Radar, Gyro, Water depth)

Internet

VPS 3000/5000, VDR
(Information for GPS, Wind Speed/Direction, Rudder, Radar, Gyro, Water depth)

VPS Server

Onshore

Owner’s Office

SSAS

LPMS

Power meter

Weather System

Loading Com.

VDR

ECDIS

Services

Fouling Effect

Rudder Effect

Drift Effect

Weather Effect

Non-weather Effect

EMISSION KPI’s

Previous OPTIMIZATION PLANS

Route / Speed

Trim Generator

Set

User

SEEMP 1

User

SEEMP 2

2. Estimated Time of Arrival

1. Estimated Distance of Arrival

3. Estimated Fuel Consumption

GOOD

98.7%

97%

Main Engine

SFOC

98%

Gen. Engine

SFOC

96%

Economizer Efficiency

P2P INFO

95%
3. ‘EN-SAVER’ Function Details

- **SEEMP Process**

Systematic Mechanism for Continuous Fuel Saving in ‘EN-SAVER’

- **Plan/Do**
  - Port
  - Opt. Trim
  - Opt. Route
  - Opt. Speed

- **Monitor**
  - Sea
  - Propulsion Monitor
  - Machinery Monitor
  - Weather/Non Weather

- **Evaluation**
  - Arrival
  - Voyage Analysis
  - SEEMP Report
  - Fleet Manage
3. ‘EN-SAVER’ Function Details

- **Trim Optimizer**

  - Optimal Trim Calculation Based on Model Test /CFD
  - Optimal Trim at
    - Equal Displacement
    - Equal Mid-Draft
  - Fuel Saving Calculation
  - Displacement Calc.
  - Propeller Immersion Calc.
3. ‘EN-SAVER’ Function Details

**Optimal Route & Speed**

- Optimal Route Finding with Given ETA Limit
- Route Evaluation
  - Minimum Distance Route FOC
  - Actual Route FOC
  - Optimal Route FOC

- Optimal Speed Allocation by GA
- Optima RPM waypoint by waypoint

[Optimized RPM profile]
3. ‘EN-SAVER’ Function Details

- **Optimal Generator Load Allocation**

  - Optimal Generator Operation
  - How many generator?
  - How much power for each G/E?
  - Calculation based on SFOC Curves for each G/E Sizes & Numbers

![Image showing fuel consumption and load allocation comparison between normal and optimized conditions](image-url)

<table>
<thead>
<tr>
<th>G/E Load [kW]</th>
<th>Avg. SFOC [g/kWh]</th>
<th>Baseline</th>
<th>Deviation [MT/day]</th>
<th>Ratio [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No1 496</td>
<td>212.8</td>
<td>21</td>
<td></td>
<td>96.8</td>
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<tr>
<td>No2 G/E</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>No3 G/E</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>No4 G/E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Specific Fuel Oil Consumption (SFOC)**

- **Daily Fuel Oil Consumption (DFOC)**

Normal condition

Optimized condition
3. ‘EN-SAVER’ Function Details

- **Machinery Performance – Main Engine**

  - SFOC Curve Analysis: Shop Test SFOC vs. Actual SFOC in ISO condition
  - Energy Flow Analysis: Shaft/ Heat Recovery/ Exhaust Gas/ Air Cooler Power
3. ‘EN-SAVER’ Function Details

- **Machinery Performance – Generator Engines**
  - SFOC Curve Analysis: Shop Test SFOC vs. Actual SFOC in ISO condition
  - Electricity Consumption Profile: Essential/Bow Thruster/ Lighting/ HVAC, etc.
3. ‘EN-SAVER’ Function Details

- **Machinery Performance – Economizer**
  - Boiler Fuel Consumption Profile

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### Economizer Steam Mass Flow

<table>
<thead>
<tr>
<th>M/E Load [kW]</th>
<th>ECN. Steam [MT/day]</th>
<th>Baseline [MT/day]</th>
<th>Deviation [MT/day]</th>
<th>Ratio [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>12989</td>
<td>14.0</td>
<td>13.3</td>
<td>0.7</td>
<td>105.2</td>
</tr>
</tbody>
</table>

### Boiler Steam Flow / Fuel Oil Consumption (DFOC)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>12989</td>
<td>7.6</td>
<td>5.9</td>
<td>19.0</td>
<td>2.8</td>
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</tbody>
</table>

### Steam Usage

<table>
<thead>
<tr>
<th>Steam Type</th>
<th>Current (MT/day)</th>
<th>Previous (MT/day)</th>
<th>Deviation (MT/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Steam</td>
<td>33.0</td>
<td>41.0</td>
<td>-8.0</td>
</tr>
<tr>
<td>ECN Steam</td>
<td>14.0</td>
<td>19.7</td>
<td>-5.7</td>
</tr>
<tr>
<td>BLR Steam</td>
<td>19.0</td>
<td>21.3</td>
<td>-2.3</td>
</tr>
</tbody>
</table>
3. ‘EN-SAVER’ Function Details

- **Weather Effect Analysis**
  - Power Increase due to Current/Wind/Wave/Sea Water Temperature
  - P2P Comparison of Each Weather Effect

![Diagram showing time history and P2P trend analysis of weather effects]

- **Time History**
  - Components: Weather, Current, Wind, Wave, S.W Temp
  - Energy Loss [%]: Weather -0.20, Current 1.41, Wind -2.92, Wave 0.36, S.W Temp 0.95

- **P2P Trend**
  - Components: Current, Previous, Deviation
  - Energy Loss [%]: Weather 10.22, 4.92, 5.30, Current 4.98, 1.98, 3.00, Wind 1.63, 1.37, 0.26, Wave 2.64, 1.53, 1.11, S.W Temp 0.97, 0.04, 0.93
3. ‘EN-SAVER’ Function Details

❖ Non-Weather Effect Analysis

• Power Increase due to Fouling/Rudder/Drift

• P2P Comparison of Each Non-Weather Effect

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### Time History

<table>
<thead>
<tr>
<th>Components</th>
<th>Energy Loss [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Weather</td>
<td>0.21</td>
</tr>
<tr>
<td>Drift</td>
<td>0.08</td>
</tr>
<tr>
<td>Rudder</td>
<td>0.13</td>
</tr>
<tr>
<td>Fouling</td>
<td>0.00</td>
</tr>
</tbody>
</table>

- 49.3% Non-Weather
- 0% Fouling
- 0.13% Rudder
- 0.08% Drift
- 0.2% Weather

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### P2P Trend

<table>
<thead>
<tr>
<th>Components</th>
<th>Current</th>
<th>Previous</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Weather</td>
<td>0.84</td>
<td>0.67</td>
<td>0.17</td>
</tr>
<tr>
<td>Drift</td>
<td>0.38</td>
<td>0.41</td>
<td>-0.03</td>
</tr>
<tr>
<td>Rudder</td>
<td>0.46</td>
<td>0.26</td>
<td>0.20</td>
</tr>
<tr>
<td>Fouling</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
3. ‘EN-SAVER’ Function Details

- Ship Performance Evaluation after Power Correction
  - Ship Performance Evaluation in Calm Sea Condition
  - Overall Weather/Non-Weather Effect Analysis

![Propulsion Diagram]

- RPM vs Power
- Speed vs Power
- P2P Trend

- RPM: 75.6
- Power [kW]: 12523.9
- Speed [Knot]: 16.9
3. ‘EN-SAVER’ Function Details

- Ship Motion Monitoring by Roll/Pitch/Bow Sensors and Ballast Tank Status
- Key Performance Index Monitoring such as EEOI, FOC, SFOC, Emission, etc
- Emission Monitoring: CO2, NOx, SOx, EEOI
4. Case Study 1 – Busan to Canada

4-1. Accuracy Test Index

• Objective: Optimal Route Algorithm Verification
• Test Period: 2014.03.02. 08:00 ~ 03.12 21:35
• Port Information: Busan to Prince Rupert
• Verification Index: Fuel Consumption/ GPS Speed
• Verification Method (Case 1 vs. Case 2)
  1) Measured FOC/GPS Speed (Every 5 min)
  2) Simulated FOC/GPS Speed (Every 5 min)
4. Case Study 1 – Busan to Canada

- Route Case Study: 1) Min. Dist. Route, 2) Actual Route, 3) Optimal Route
4. Case Study 1 – Busan to Canada

1) GPS Speed/FOC Estimation Accuracy (Measured vs. Calculated)
   > GPS Speed Calculation Accuracy: 97 %
   > FOC Calculation Accuracy: 95 %

2) Machinery Performance Estimation Accuracy (Measured vs. Shop Test)
   > Calculation Accuracy: 95 ~ 99% (ME 99%, GE 95%, ECN 95%)

3) Energy Saving Potential
   > Total Potential: 9.7 %
     ▶ Optimal Route (7.8%) + Optimal Speed (1.1%) + Optimal Trim (0.8%)
   > Considering Error: 4.7 ~ 9.7% Saving Possible
5. Case Study 2 – Vancouver to Busan

1) GPS Speed/FOC Estimation Accuracy (Measured vs. Calculated)
   > GPS Speed Calculation Accuracy: 95 %
   > FOC Calculation Accuracy: 91.6 %

2) Machinery Performance Estimation Accuracy (Measured vs. Shop Test)
   > Calculation Accuracy: 95 ~ 99% (ME 99%, GE 96%, ECN 95%)

3) Energy Saving Potential
   > Total Potential: 12.8 %
     ▶ Optimal Route (10.9%) + Optimal Speed (0.8%) + Optimal Trim (1.1%)
   > Considering Error: 4.4 ~ 12.8% Saving Possible