EMMA™ Ship Energy Manager

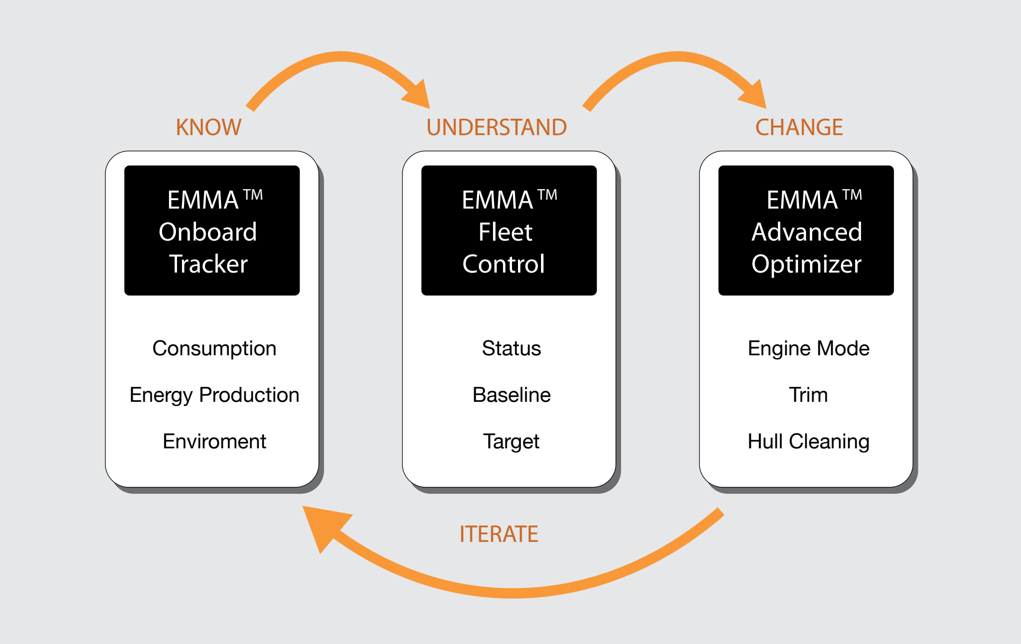
Know, understand and change

JUKKA IGNATIUS, JAN-ERIK RÄSÄNEN, KALEVI TERVO, OLLI HUTTUNEN **– There is considerable potential for today's vessels to improve overall energy consumption. This can be done by, for instance, changing the engine configuration, operating profiles or the fuel used; or by recovering waste heat or optimizing trim. EMMA™ offers integrated solutions for decision support in the search for optimal energy management.**

To improve operations, owners need to identify and understand the weakest parts of their existing performance. Understanding is developed by measuring the key performance indicators (KPIs) of each and every vessel in the fleet.

With such progressive improvement in mind, ABB has developed the EMMA Advisory Suite, which offers a range of products designed to take an iterative approach to ship performance benchmarking.

1 Benchmarking process with EMMA Advisory Suite



The EMMA product portfolio consists of onboard modules for energy monitoring and optimization and office tools for fleet-wide data analysis (Figure 1). The EMMA Suite aims to look at the vessel as a whole, instead of providing separate decision support tools for different problem areas.

Relationship to SEEMP

The International Maritime Organization's Marine Environment Protection Committee (MEPC) describes the Ship Energy Efficiency Management Plan (SEEMP) as a four-step cycle of planning, implementation, monitoring, self-evaluation and improvement. In combination with EMMA and energy coaching services, a shipping company can implement a full SEEMP which will be mandatory as of Jan. 1, 2013.

The SEEMP requires ship and company-specific measurements to be determined. EMMA has a good set of proposed KPIs including the Energy Efficiency Operational Indicator (EEOI). Using ABB's energy coaches, the most appropriate KPIs can be selected to fit the operations in question.

Voluntary goal setting for the selected measures is also part of the process. The MEPC states that the goal may take any form, fitting well with the various KPIs that EMMA presents. Depending on the operational profile, a suitable target can be set either qualitatively or quantitatively.

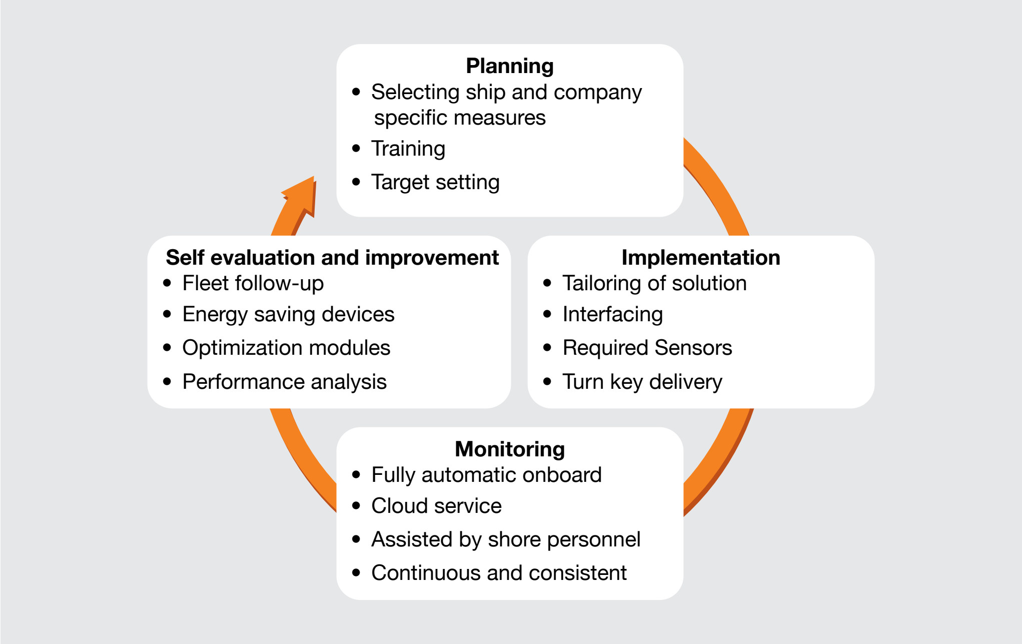
Measures that can be taken towards better energy management practices depend on vessel type. ABB offers the following as a turnkey delivery:
- Optimum trim
- Hull and propeller condition maintenance
- Energy management and waste heat recovery
- Propulsion system optimization
- Pump and fan operation

Planning – optimum trim

The EMMA solution is based on the principle of easy-to-use optimization modules for even the most complex onboard processes. This principle requires smart algorithms and the latest available design and operating guidelines. Trim optimization is a good example of this. The operator can see from a distance of about 3 meters a clear presentation of the current trim of the vessel, the optimum trim and the potential savings available.

The algorithm used is based on effective machine learning methods and real-time sensor fusion algorithms of real, full scale, measurements instead of

2 SEEMP process



merely being inferred from computed fluid dynamics (CFD) or towing tank tests. The model can also include prior information based, for example, on the propeller's properties, and certain key variables that affect the vessel's resistance and propulsion power loss.

This type of approach will find the optimum trim for any given operating condition. The model uses data collected from several sources on board, such as an integrated automation system, an integrated navigation system and ABB's attitude sensors that measure ship movements.

Typically, after installing the system on board, measurements are recorded over a 1-2 month period to ensure that the parameters of the trim optimization model are supported by sufficient statistical data drawn from normal operational conditions. In addition, trim sweep tests are performed with the help of ABB's Energy Coach to complete model construction.

Planning – hull and propeller condition maintenance

The EMMA optimizer gives accurate predictions of the propulsion power required, taking into account operating conditions such as wind, sea state, speed,

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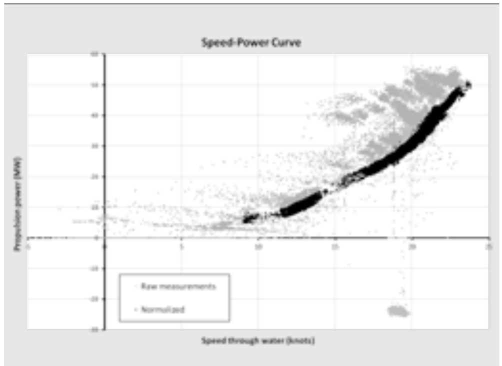
3 Example of EMMA Advanced Optimizer Trim

4 Speed-power curve as raw data, and filtered and normalized (except the trim)



Typical sensors required in SEEMP implementation

Torductor: shaft torque meter - a proven product for shaft torque measurement for any size of propeller shaft. The technology used is based on measurement of the magnetic characteristics of the shaft.

CoriolisMaster: mass flow meter operating on the Coriolis principle - included in the ABB portfolio. It can measure mass flow, volume flow, density, temperature and concentration simultaneously without moving parts.

Attitude sensors: needed for accurate dynamic trim measurements. ABB uses military grade attitude sensors. Depending on the size of the vessel, two to three sensors are installed to measure the attitude.

currents, etc. Therefore the model gives a benchmark for the propulsion system's performance and the hull condition. One interesting by-product that can be built on these measurements is a hull maintenance planning aid.

The typical problem in interpreting full-scale speed-power measurements is visible in Figure 4. The grey dots indicate raw data, as received from the automation and navigation systems. This raw data includes approximately 112,000 measurements. The black dots represent the measurement set once the obviously erroneous and low speed values are removed and the data is normalized for weather and floating positions effects using the EMMA method. Curve fitting using raw data results in 0.706 as the coefficient of determination. The filtered and normalized values put this at 0.992, which is a remarkable improvement (see Figure 4).

Calculating these normalized figures over time shows the hydrodynamic performance of the vessel. The effect of hull and propeller conditions is evident from these figures, and the shipping company can use this data in correctly scheduling hull cleaning or even dry-docking.

Planning: energy management and waste recovery

The EMMA power plant optimizer employs a physical model (including, for example, specific fuel oil consumption curves) that is adjusted using statistical data from real-life measurements. This combination gives a definite advantage to plain power plant physical modeling, since any energy producer will not be the same throughout its life cycle.

5 Example of EMMA Advanced Optimizer Power Plant

6 Example of EMMA Onboard Tracker main dashboard

Decision support for the user is given in a simple way, observing the power plant as a whole. This is important, especially with more complex configurations. The example in Figure 5 is from a large container vessel with two main engines, two shaft generators/motors, four auxiliary engines and a large 20 MW waste heat recovery (WHR) unit.

Optimizing such power plant requires extensive knowledge, and the number of permutations is beyond possible real-time human interpretation. The EMMA user interface (UI) clearly indicates the overall status, as can be seen from Figure 5. Each energy producer is listed, and the UI uses color codes to indicate the running status, current and optimum load and the advice for the user.

The optimizer allows the user to determine and change the necessary spinning reserve, as well as the operating limits for each power producer. Moreover, the user can exclude some of the power producers from the optimization model in real time. The model is also able to take into account the maintenance cycles of power producers.

The optimization model can also easily be enhanced if a forecast for power demand can be added. This will allow the system to use the model predictive control (MPC) philosophy. The MPC is based on the idea that the optimization algorithm uses the existing model of the system and forecast inputs to simulate the consequences of actions taken now.

Planning - propulsion system

If the vessel is equipped with two or more Azipod® propulsion units, ABB offers an Azipod Dynamic Optimization (ADO) tool addressing the towing angle of the Azipods. This is a problem of a dynamic nature and requires constant measurement of real conditions. The system does not require any user interference and is totally automatic, providing continuous optimum vessel thrust.

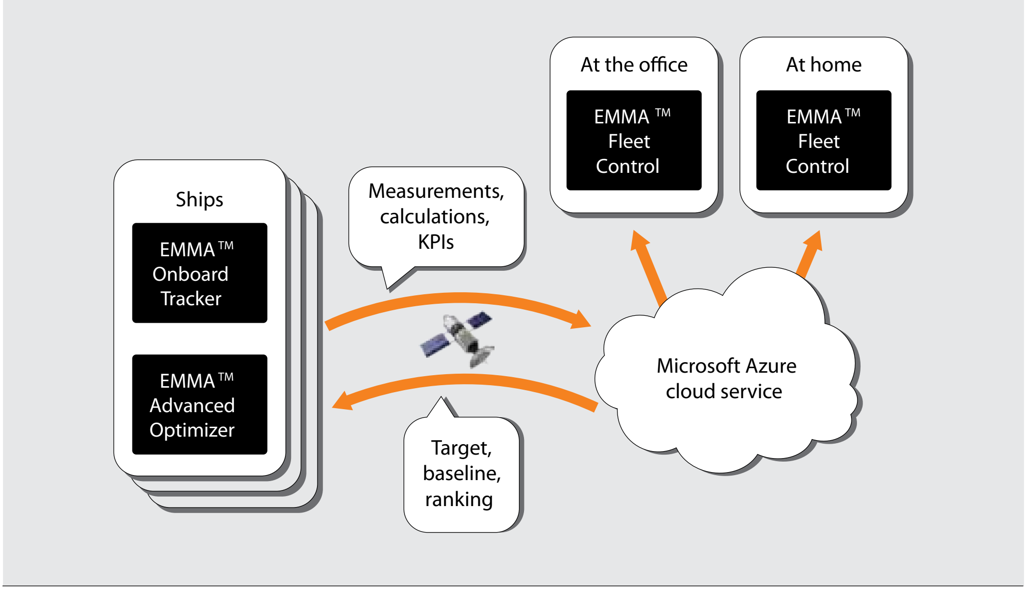
Planning – pump and fan operation

Until recently, energy efficiency in auxiliary systems was not taken into account during the design process or construction of marine vessels. For this reason, systems on existing ships are not energy efficient and have not been fully optimized in terms of overall fuel consumption. The onboard ship systems most suitable for improving energy efficiency are those with large pumps and fans, which are not required to run continuously and at full capacity. When applicable, electric motors can be fitted with variable frequency drives (VFD) to operate pumps and fans more efficiently under partial loads during slower sailing speeds or when ventilation requirements are reduced. The electric power consumption of a pump is related to its volumetric flow. As an example, a reduction of the pump speed by 10 percent will save 27 percent of the power consumed.

Implementation

The MEPC guidelines state that the selected measures for energy management have to be implemented by defining tasks and assigning them to qualified personnel. ABB can implement a project as a complete turnkey delivery, thus minimizing the shipping company's risk and involvement in possible installations and modifications. Naturally, tasks are assigned to the personnel operating the vessel.

7 EMMA data transfer principles



Depending on the measures selected, installation of sensors might be required. For example, dynamic trim optimization requires attitude sensors and propeller shaft torque measurement. Power plant optimization requires power measurements and fuel flow meters that are as accurate as possible. If these are required but not available, ABB offers a package including all required hardware in the same turnkey project.

Monitoring

SEEMP guidelines state that onboard monitoring should be quantitative, assisted by shore personnel, consistent and continuous, and should involve the crew as little as possible. The EMMA Advisory Suite handles the monitoring automatically on two levels - on board the vessel with the EMMA Onboard Tracker and for the office personnel with EMMA Fleet Control.

Monitoring – EMMA Onboard Tracker

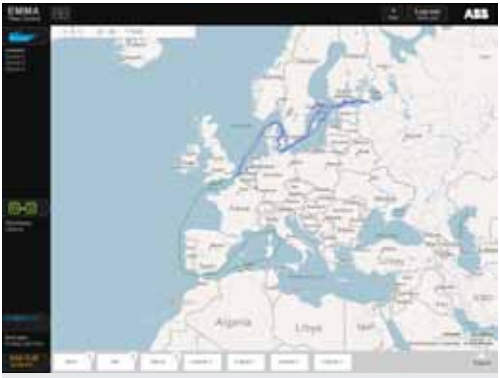
The EMMA Onboard Tracker is a fully automatic tool for onboard KPI calculation, display and recording purposes. The user interface is heavily implemented on the "3-meter-screen" ideology, which simply means that the overall status is visible from a distance without the need for making a detailed study. Figure 6 shows an example of the main dashboard.

The UI in this example is divided into four segments presenting different type of KPIs:

- Upper left: cost of operation
- Upper right: energy production/consumption
- Lower left: navigational aspect, in this case consumption per nautical mile
- Lower right: overall optimization status

The large dials are visible from a long distance. If all of the segments are lit up, the vessel is performing well in the specific area, taking into account prevailing environmental conditions. The more segments are missing, the greater the potential for improvement. Trend presentation of history data is also available.
It is typical for marine applications that the performance of some equipment varies more as a result of operating conditions than it does as a result of substandard operation. For example, in deep sea operations, the variation in the vessel's propulsion power is set by the desired speed in the context of wind, weather and waves. These operating conditions need to be taken into account when evaluating performance.

The EMMA Onboard Tracker addresses this issue by employing the ABB self-learning model to provide adaptive dynamic targets for each power producer. The model can learn the interdependence in play between a consumer and the operating conditions automatically without any human effort.



8 Example of EMMA Fleet Control view

Once the model can predict behaviour of the consumer to the required level, it starts to provide the adaptive dynamic KPI value for the consumer. By normalizing the effect of operating conditions generated by the consumer measurements, performance degradation that is directly due to equipment wear or poor operation can be spotted easily.

Monitoring – EMMA Fleet Control

All of the data collected and calculated on board is automatically transferred to EMMA Fleet Control, which is a modern business intelligence data analysis tool. EMMA Fleet Control operates within the high cyber security Microsoft Azure cloud service. This enables secure data access from any location. This centralized EMMA database is used to form the baseline and ranking of fleet performance. The benchmarking data is replicated back to the vessels so that the fleet-wide performance is visible for users on board without a broadband connection. See Figure 7 for data transfer principles.

All collected and calculated figures are available for access in graphical and numerical forms. EMMA Fleet Control uses predefined views for ease of use. As an example, weekly fuel oil consumption is visualized using bar charts, fleet positions on an interactive map (Figure 8), and the speed-power curve as a scatter chart with curve fitting. The user can benchmark and rank data collected from the fleet.

As in any benchmarking process, the MEPC describes the last step of SEEMP as the one that should produce “meaningful feedback for the coming first stage, ie, planning stage, of the next improvement cycle.” All of the measures documented in the SEEMP are documented and quantitatively recorded using the onboard and office tools. It is even advisable that all the possible measures are not included in the first implementation of SEEMP. Having the EMMA system implemented for a couple of months provides excellent information on current vessel status and additional measures can be chosen more wisely using this baseline.

Unleash the power of integration

As described, the existing fleet can easily be retrofitted with a custom EMMA Advisory Suite, thus significantly improving the performance. However, the full power of the approach is only unleashed when a complete ABB solution is implemented. Such an integrated approach would see the ship equipped with an ABB automation system, power management and decision support tools so that the information flow is not only enabled but significantly simplified. The more the system “knows,” the more it is able to offer advice on optimizing operations.

ABB believes that an integrated solution is not only preferable, but critical in ensuring an efficient and eco-friendly fleet. Only through integrated approach can an owner harmonize what may be conflicting advice affecting different parameters. For instance, a voyage optimization tool should be connected to live data drawn from power plant performance. ABB’s integrated solution makes sure that the vessel is observed as a whole.

As well as heightening awareness of decision support tools themselves, an integrated solution minimizes hardware and the number of interfaces. This naturally increases the system’s availability and robustness. Again, the integrated approach should mean that software tools are more easily updated throughout the ship’s life cycle.

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