Saving energy the efficient way

ABB's products are energy efficient helping to reduce energy wastes around the world.

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Electricity is increasingly important in today's modern society. Most primary energy sources are converted into electricity to meet relentless demands. The inefficient use of energy means that three-fifths of our energy capacity is lost. Greater energy efficiency not only helps to conserve limited fossil-fuel resources but also helps to reduce carbon emissions.

The efficient use of energy is regarded as a solution to the energy crisis. From producer to consumer, there is great potential to save energy. ABB's profolio of products and services can contribute to greater energy efficiency from power generation and transmission to distribution and consumption.

Powering the economy

Energy losses due to inefficiency are huge. Needless wasted energy could be prevented by increasing the efficiency of all aspects of power production right through to consumption. By installing energy efficient equipment, countries with rapidly expanding economies, like China, could reduce their demands on world resources and reduce harmful emissions 1. In China, coal is by far the largest contributer to electric power generation, accounting for 65 percent of China's energy consumption. This amounts to 28 percent of the world's total coal consumption. Clearly, by encouraging the use of the most efficient methods of power generation in China and around the rest of the world, the impact of thermal power generation plants on fossil-fuel reserves and the environment will be significant.

ABB's combustion management software optimizes the combustion process in thermal power plants to improve efficiency.

Power generation

By optimizing the energy conversion process, huge savings in energy losses can be made. Since such large quantities of fuel are used in this process, even minor improvements in efficiency can have a dramatic overall effect.

One of the most important processes in a thermal power plant is combustion. Water is heated to produce steam, which drives steam turbines linked to electric generators. The control of this process is very complicated, yet improvements made here are critical to the efficiency of the power plant. ABB's combustion management software package improves boiler control; allows the flame quality to be monitored; and measures and controls the flow of fuel and air to increase combustion efficiency, reducing nitrogen and carbon monoxide production.

The heart of the combustion management system is the Optimax® combustion optimizer. For closed-loop combustion optimization of coal-fired boilers, the ABB Neural Net modeler replicates the multivariable, nonlinear relationships of the combustion process. This approach is especially suited to the complex combustion process, which cannot easily be described in mathematical terms. The model predictive control (MPC) in combustion management is a generated multivariable, dynamic controller and optimizer that uses dynamic feedback to update the models. A unique characteristic of the software is its ability to learn and predict trends so that response times to changing conditions can be reduced, resulting in greater efficiency.

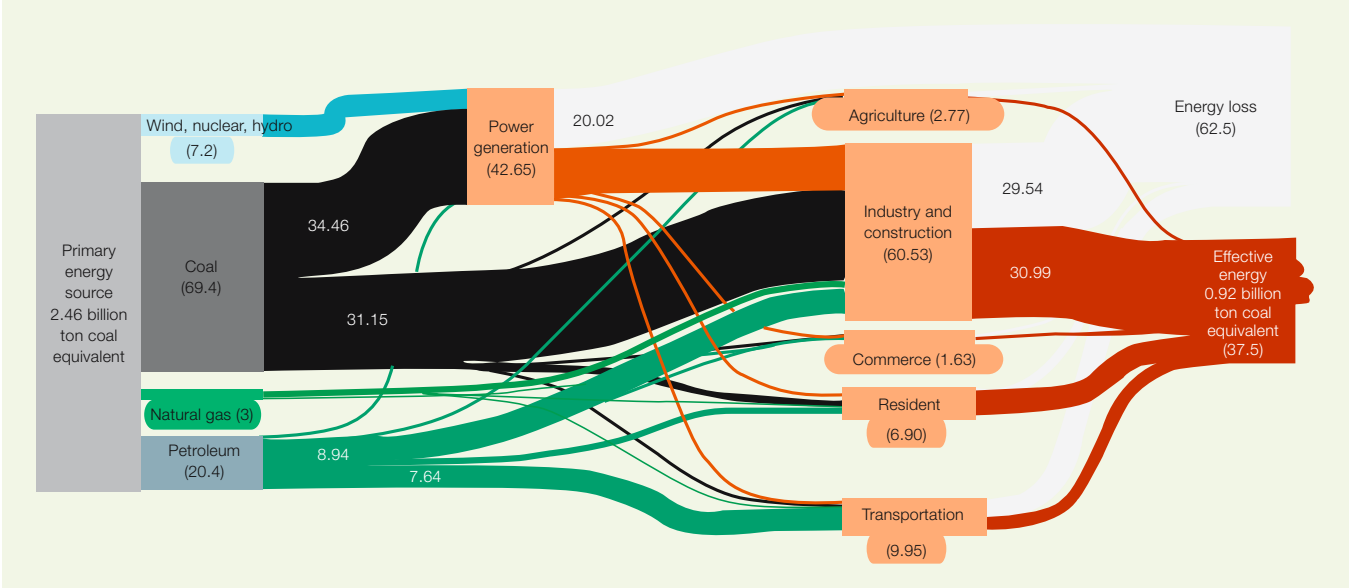
Taking an optimized 600 MW unit in the European Union as an example, the benefits can reach:

- Equivalent to $80 million CO_2 certificates over a lifetime[1)]
- Increased plant output of more than 15 MW
- Plant efficiency increases of 1.5 percent

ABB built a district heating system in Harbin, China that uses the heat normally wasted in a power station's cooling tower to heat homes in the district.

Optimizing the combustion process is one step towards increasing energy efficiency, but often thermal power plants simply vent the heat generated for steam production through cooling towers into the environment once it has passed through the turbines. This heat is a huge source of wasted energy. In 2007, ABB built a large district heating system in Harbin, China, creating a new central combined heat and power (CHP) plant that uses the heat normally wasted in a cooling

1 Energy flow chart in China 2006 (Data source: National Bureau of Statistics of China)



tower to heat homes in the district. Such cogeneration plants and district heating networks help reduce energy consumption and overall emissions, since they eliminate the need for individual boilers in the home and reduce the wasted energy from conventional power plants.

Power transmission and distribution

Today, electric power is frequently transported long distances from its source of generation to the consumer. High-voltage direct current (HVDC) is the most energy-efficient technology available for long-distance bulk power transmission, losing less electricity than conventional AC transmission systems. The existing three ±500 kV HVDC lines used to transport electricity from the Three Gorges hydroelectric power generation plants to consumers in eastern China have already saved sufficient energy to avoid the construction of a further 300 MW power station that would be required if the transfer capability was through AC transmission. A conventional 800 kV AC circuit loses about 7 percent of its electricity over 1,500 km, while only 6 percent is lost over the same distance with a ±500 kV HVDC circuit. An even greater saving with losses of only 5 percent can be made with a ±800 kV ultra-high-voltage direct current (UHVDC) circuit carrying 6 GW.

To develop 800 kV UHVDC technology all equipment had to be redesigned and tested to ensure reliability at higher voltages.

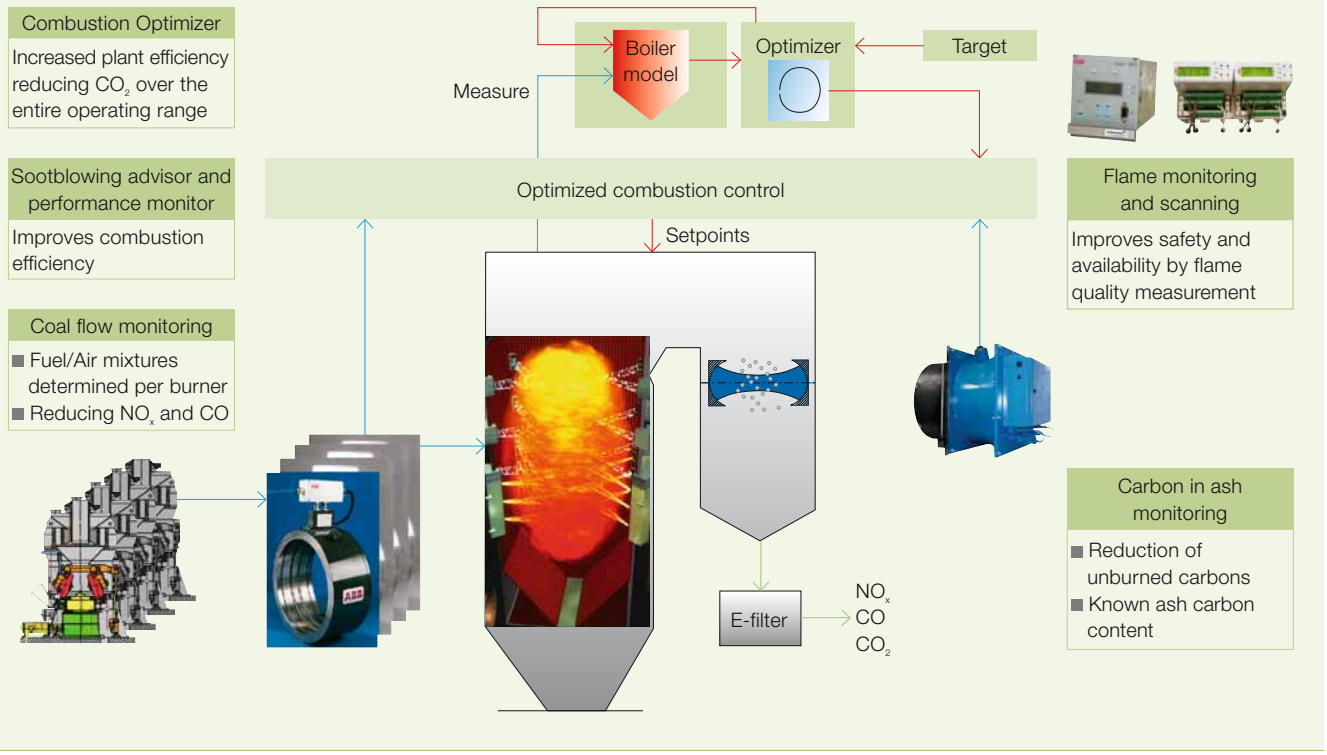
The key to the development of ±800 kV UHVDC technology is the insulation and the design of the main circuit for high reliability.

To produce a ±800 kV UHVDC transmission system, ABB has designed, manufactured and tested transformers, transformer bushings, wall bushings in the valve hall, thyristor valves, arresters, voltage dividers, DC filter capacitors and support isolators specifically able to withstand such high voltages.

For higher reliability, the main circuit of the converter station was specially desgined 3. Two 400 kV 12 pulse converters are connected in series. When one converter is tripped, another converter can continue to transmit half-rated power. The forced availablility of ±800 kV UHVDC can reach 99.9 percent.

The world's first ±800 kV UHVDC transmission system is under construction in China and will be operational in 2010, transporting electricity from the huge Xiangjiaba hydroelectric power plant in southwest China 2,000 km to Shanghai in the east.

2 Combustion optimization



Footnotes

[1] CO_2 certificates allow emissions trading supported by the Kyoto Protocol. A ton of CO_2 is given a trading value (eg, 20 euros) so that 230,000 tons of CO_2 emissions are worth about 4.6 million euros or $5.5 million.

[2] Reactive power describes the loss of power in a system resulting from the production of electric and magnetic fields within it. Reactive loads in a power system drop voltage and draw current, which creates the impression that they are using up power, when they are not. This "imaginary" or "phantom" power is measured in Volt-Amps-reactive (VAr).

HVDC Light®

One of the main obstacles to large-scale offshore wind-park power utilization is reliably and efficiently connecting the electricity generated to the power grid, especially if the grid is weak. HVDC Light® is a power-transmission system that enables such reliable long-distance electricity delivery from offshore wind farms to distant population centers. This helps provide sustainable energy solutions to the ever-increasing demand for electricity without contributing to further CO_2 emissions. The capability of HVDC Light comes from voltage source converter (VSC) and cross-linked polyethylene (XLPE) DC cables.

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The VSC used in HVDC Light allows independent control of both active and reactive power[2], providing the best combination of each to stabilize the grid 4. Such regulation is critical for voltage and frequency control in the power grid and is essential to stabilize power fluctuations inherent to wind farms.

XLPE DC cables avoid the reactive charging power of AC cables and allow efficient power transmission over long distances 5. Two major obstacles had to be overcome in order to develop XLPE DC cables:

1. The space charges in the insulation that can lead to local uncontrolled high electric fields that cause dielectric breakdowns had to be prevented.
2. Uneven stress distribution in the outer part of the insulation caused by temperature-dependent resistance had to be avoided.

The German utility E.ON has awarded a contract to ABB to supply the power equipment that will integrate the world's largest offshore wind farm with the existing German power grid. The wind farm consists of 80 wind turbine generators of 5 MW located about 130 km from the coast in the North Sea. The generators will feed power into a 36 kV AC cable system, which will be transformed to 154 kV for the HVDC Light offshore station. The receiving station will be located on land, 75 km from the coast at Diele, where the power will be introduced into the German 380 kV grid Factbox.

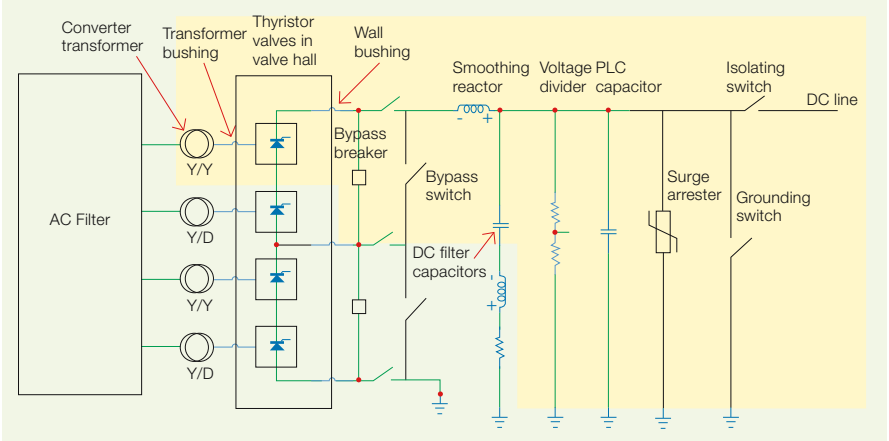
Distribution transformers

Distribution transformers are responsible, after transmission lines, for the next-largest electricity losses in networks. Now, modern technology exists to reduce these losses by up to 80 percent. The worldwide electricity savings potential of switching to high-efficiency transformers is estimated to be at least 200 TWh. The losses made by distribution transformers consist of no-load losses[3] and on-load losses[4]. No-load losses can be reduced by selecting high-performance steel for the core. Over the years, better steel for transformer cores have been developed. Various processing and coating techniques and reduced silicon content have led to the creation of high-permeability grain-oriented steels (HiB). They remain the current standard material for manufacturing distribution transformers in Europe. During the 1980s, techniques were introduced to refine the domain of the iron crystals by laser etching, and more recently, the development of amorphous iron introduced a significant new evolution for reducing iron losses.

ABB's award-winning S11 rolling-iron core distribution transformer produced in China is helping clients decrease power losses during transmission and distribution.

In addition to the choice of the steel, the way in which distribution transformer cores are designed, cut, fabricated and assembled plays an impor-

3 AC to DC converter



Factbox Specifications for German utility E.ON offshore wind farm

Main data	
Commissioning year	2009
Power rating	400 MW
AC voltage	170 kV (offshore), 380 kV (Diele)
DC voltage	±150 kV
Length of DC underground cable	2 x 75 km
Length of DC submarine cable	2 x 128 km

Footnotes

[3] No-load losses: The power loss of a device that is operated at rated voltage and frequency, but is not supplying power to a load.

[4] On-load losses: The sum of the copper loss of a transformer, due to resistance in the windings, plus the eddy current loss in the winding, together with stray loss.

tant role in energy efficiency. Increasing the size of the core reduces the density of the magnetic field, and in this way improves energy efficiency. ABB's award-winning S11 rolling-iron-core distribution transformer produced in China is helping clients decrease power losses during transmission and distribution.

Amorphous iron deserves a special mention. Distribution transformers built with amorphous iron cores can have more than 70 percent lower no-load losses compared with the best conventional designs, and achieving up to 99.7 percent efficiency for 1,000 kvar units. These transformers have cores wound with amorphous ribbon made from a ferric metal alloy produced by very rapid quenching to avoid crystallization. Currently, amorphous technology has been proven for transformer sizes up to 10 MVA, and its application range is expanding.

Power consumption

Huge demand for steel – especially in China – has encouraged steel producers to increase melt capacity and improve power supply. Unfortunately the electric arc furnaces of steel plants cause fluctuations in voltage when operating, commonly causing flicker and other power-quality problems, especially in weak power grids. These flickers not only affect other electricity consumers, but also reduce the productivity and efficiency of the electric arc furnace itself. Static VAr compensation (SVC)[5] equipment provides a powerful solution to flicker and improves the power supply to the furnace by providing fast-acting reactive power compensation. ABB is the number-one supplier of SVC worldwide, with more than 400 installations either in service or under construction.

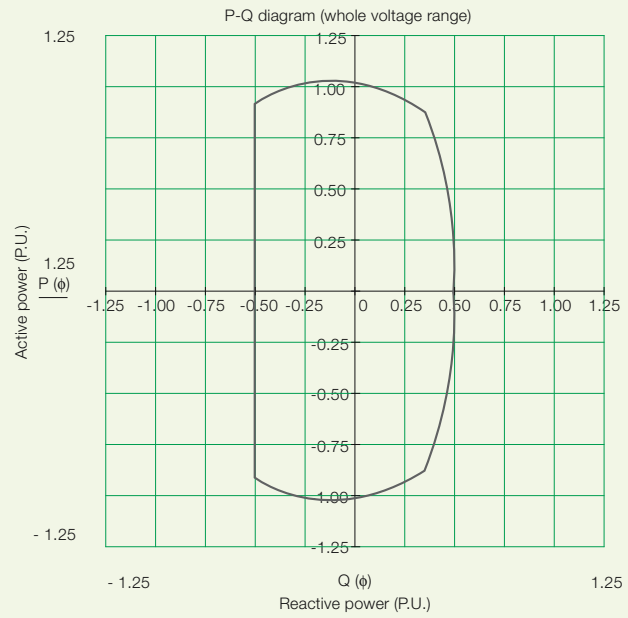
Power quality and energy efficiency

ABB's SVC Light® technology has been designed with special attention to the severe voltage variations created by electrical arc furnaces. With this new technology, response time is less than one millisecond. SVC Light, like HVDC Light, employs a voltage source converter (VSC) composed of high-voltage switching devices known as insulated-gate bipolar transistors (IGBTs). These devices can switch at very high frequency and allow connections in series. Pulse-width modulation (PWM) is utilized in the VSC with a switching frequency in the kilohertz range. This high frequency provides a very smooth voltage output from the VSC. The fast response of SVC Light means it can be used as an active filter. An ABB SVC Light device rated at 10.5 kV, 0 to 44 Mvar has been in operation since 1999 at the Uddeholm Tooling AB steel plant in Hagfors, Sweden 6.

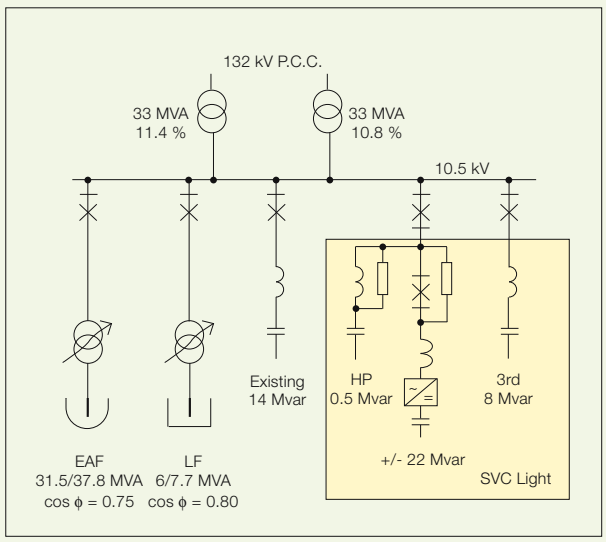
Measurements have been made of the active power consumption at the Uddeholm plant with and without SVC Light. Through dynamic compensation, the stabilized voltage increases

5 XLPE DC cables.

4 P-Q diagram



6 Single line diagram with SVC Light



Footnotes

[5] SVC is a device that provides fast-acting reactive power to compensate for fluctuations in the voltage and current of an electric grid, thereby allowing more power to flow through the network, while maintaining safety margins and increasing network stability.

the available furnace power. With SVC Light in operation, the active power increase gives a furnace a production increase from 27.5 to 31.4 metric tons per hour. The active power increase allows a faster melt in the electric arc furnace, thereby saving energy consumption. This saving accrues over time, cutting around 25 kWh of electricity per metric ton of steel melted, thus providing about 4 percent savings to the plant operator.

Without ABB's SVC Light the Zhangjiagang Pohang Stainless Steel plant near Shanghai could not run at full capacity.

In China, SVC Light has been installed so that the Zhangjiagang Pohang Stainless Steel (ZPSS) producer near Shanghai can run at full capacity, avoiding voltage fluctuations and flicker. Without SVC Light, ZPSS would have to have significantly reduced production capacity in order to stay within the legal parameters that marshal the flicker effects produced by industry.

Intelligent building

Needless energy waste in China's buildings can be estimated in trillions of dollars. By reducing the energy wasted by consumers, less electric power generation would be required in the first place.

ABB i-bus® EIB (European Installation Bus) is an intelligent building installation system that was introduced in China at the turn of the century. ABB i-bus EIB provides increased security, efficiency, convenience and flexibility, whether in office buildings, industrial plants or residential properties. The system takes care of lighting, sunshade control, heating and cooling and can be tailored to the requirements of the user. Its flexibility is one of its major assets and can be adapted for use in a range of building types, from residential houses to commercial buildings such as exhibition centers, hotels, museums, schools, garages and meeting centers.

Since the introduction of ABB i-bus EIB in China, the ABB i-bus EIB system has been installed at the Xiamen Exhibition and Meeting Center, the Great Hall of Hangzhou, the Exhibition and Meeting Center of Changsha, the Exhibition and Meeting Center of Hefei, the New International Exhibition Center in Shanghai, the Modern Museum of Dalian, the National Library and Meeting Rooms of the Central Government Office Building. Generally, the energy saved by installing such a system covers the cost of installation within half a year of operation. The impact of installing such systems on a country's energy requirements is significant, particularly for a country the size of China.

Green shipping

Diesel engines are the main source of propulsion in most of the world's ships. These engines have an ideal operating efficiency range in which fuel consumption and exhaust emissions are optimal, but as soon as the ship slows, this optimal operating speed is lost. The solution is to keep engines running at their most favorable speeds at all times.

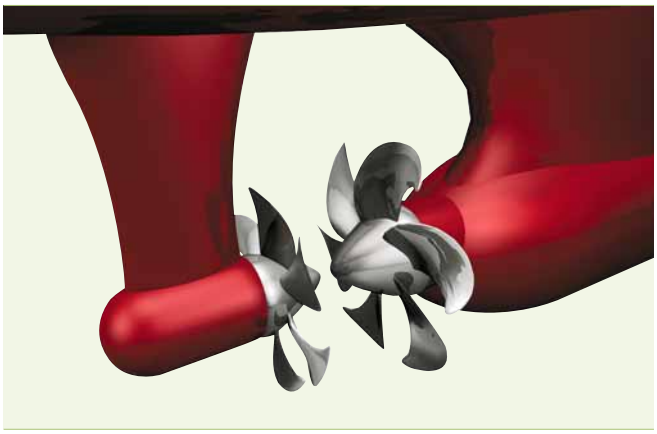
In the Azipod system, the electric motor is installed inside the pod and no gearbox is required, providing greater efficiency.

With traditional mechanical transmission, running the engines at their optimal speed is not possible, since engine speed is rigidly coupled to the propeller speed. Using electric transmission (generators and motors connected by cables), this is no longer the case. When diesel engines are operating at constant and optimum service speed, fuel consumption is lower than running the same engines at variable speed. In addtion, in a geared propulsion system, which involves the slowing down and changing from two-engine mode to single-engine mode, the propeller speed and pitch has to be controlled to avoid overloading the diesel engines.

7 The ABB i-bus EIB controlling technical building systems.

8 ABB's Azipod system for ship propulsion

9 Counter-rotating propellers (CRP)



In the Azipod® system, the electric motor is installed inside the pod. The propeller is connected directly to the motor shaft. No gearbox is required, providing greater efficiency 8. Electric power for the Azipod motor is conducted through slip rings that allow the Azipod unit to turn through 360 degrees. Because fixed-pitch propellers are used in Azipod systems, power for the Azipod unit is always fed through a variable-frequency drive that allows speed control of the propulsion motor.

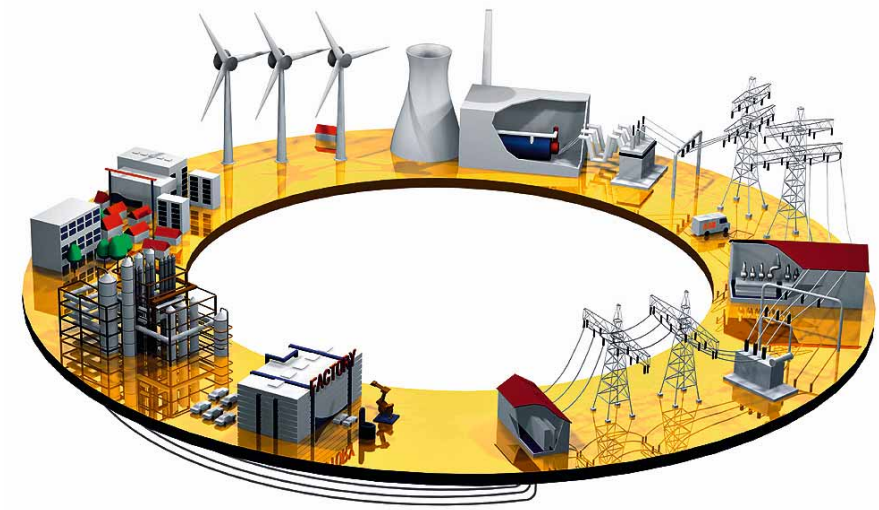
A further contribution to fuel efficiency is provided by counter-rotating propellers (CRP). These improve the hydrodynamic properties of the propulsion system, reducing fuel consumption. The CRP concept features a novel combination of conventional propulsion and Azipod propulsion. The propulsion systems are arranged coaxially, but without any physical connection 9. The pulling propeller of the Azipod unit will rotate in the opposite direction in relation to the main propeller driven through the shaft directly from the diesel engine. There is no need for a conventional rudder because the pulling Azipod unit rotates to maneuver the ship. Both propellers are fed by independent power supplies for greater redundancy. This arrangement allows the recovery of the main propeller's forward rotational velocity.

A study made by Samsung and ABB shows that the efficiency gain from this new propulsion system depends on factors such as ship type, ship speed, power level, loading and so on. In general, an efficiency improvement of 5 to 8 percent is achieved with a CRP system. Because 2 to 3 percent of fossil fuels in the world are consumed by shipping, the improvement in efficiency has a far-reaching effect on fuel consumption and emissions. In China, ABB's Compact Azipod propulsion system is already saving fuel consumption in ferries and a marine surveillance ship. This technology is expected to be adopted in the near future for use in ultra-large container ships, high-speed ferries and ocean work boats in China.

Counter-rotating propellers one from the ships conventional propulsion system the other from ABB's Azipod can improve efficiency by 5 to 8 percent.

Energy efficiency

Increasing energy efficiency is an effective way in which to reduce fuel consumption and carbon emissions. The installation of the most energy-efficient equipment, especially in countries with rapidly growing economies, will have far-reaching effects on the conservation of fossil fuels and contribute to the reduction of carbon emissions.



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