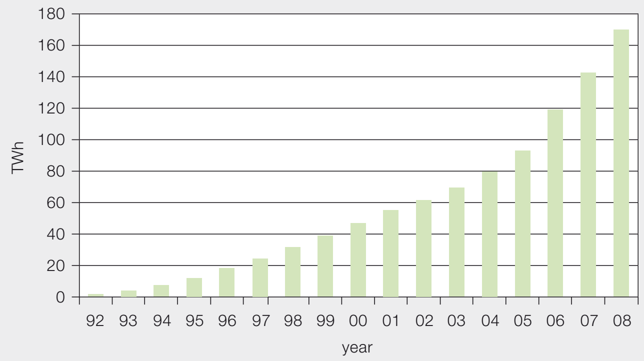
Driving down carbon emissions

Environmental payback analyses with ABB drives

JUKKA TOLVANEN, TIMO MIETTINEN – Environmental product declarations (EDPs) attempt to describe the environmental consequences of manufacturing a specific piece of equipment. The problem with this approach is that it takes no account of the benefits afforded by the future use of the equipment. ABB is therefore developing a new way of assessing the environmental impact of a piece of equipment over its operational life-span and beyond, taking account of the costs of production, its usage and its recycling potential, providing a value for the return on natural capital (RNC). By calculating RNC, a customer can assess the payback time for the equipment. The assessment of variable speed drives (VSD), for example, would provide an indicator as to how long the equipment would have to operate before it offsets the carbon footprint generated during its manufacture. Current EDPs take no account of the energy savings made throughout the operational life span of the equipment. The use of VSDs in industries using pumps and fans would make significant savings.

1 The installed base of ABB low voltage drives saved about 170 TWh in 2008



Energy saving in 2008 equivalent to the consumption of more than 42 million households in the EU-27 per year.

Electric motors account for an estimated 65 percent of industrial energy use; however some 20 percent of this energy is lost through the wasteful methods used to control their speeds. Most often the speed of motors is controlled by some kind of throttling mechanism. The motor itself runs at full speed, but valves in a pump system or vanes in a fan application are adjusted to vary their effective operational speed. Similarly gears and belts can be used to regulate the speed of rotating machinery, but since the motor driving the operation continues to work at full speed, such mechanisms are inherently inefficient and wasteful.

Improvements in the operational efficiency of industrial drives have the potential to make major savings and help reduce CO_2 emissions. There are two main ways in which energy consumption for electric motors could be reduced:
– implementing efficient control over the speed at which they run
– increasing the efficiency of the motors themselves

In pump and fan applications the use of variable speed drives can cut energy bills by as much as 60 percent. A pump or fan running at half speed consumes only one quarter as much energy as a unit running at full speed. The speed of a motor can be adjusted by altering the voltage and frequency of its power supply. AC electricity is supplied at a fixed voltage and frequency, which means an AC-motor will continuously run at a fixed speed. By altering the voltage and frequency the speed of an AC motor can be adjusted. A change in frequency results in a corresponding change in motor speed (and torque). This means that the motor speed, and therefore the speed of the equipment being driven, can be set according to external production parameters, ie, flow rate or temperature by altering the voltage and frequency of the power supply. Variable speed drives (VSD) provide a system by which the voltage and frequency of the power supplied to the motor can be varied and controlled.

Environmental payback

Many motors operate at less than full capacity, yet they operate at full-speed. VSD are designed to vary the speed of the motor so that the least amount of energy is consumed during the motors operation. This reduction in energy consumption can be quantified in environmental payback days. This is the time taken for the VSD to compensate for the CO_2 (carbon dioxide) emissions made during its production. With larger drives the reduced energy consumption of the motor can compensate for the energy required to manufacture the VSD in less than a day's operation. This means that subsequent days of operation will effectively reduce the CO_2 emissions that would otherwise have occurred if conventional methods were used to regulate the motor's speed.

An assessment of the RNC of a VSD would provide an indicator as to how long the equipment would have to operate before it offsets the carbon footprint generated during its manufacture.

2 Environmental product declaration (EPD) data for ABB's industrial drive, ACS800, 250 kW – emissions

Environmental effect	Equivalent unit	Manufacturing phase	Usage phase
Global warming potential (GWP)	kg Co_2 / kW	3.65	1,570
Acidification potential (AP)	kmol H^+ / kW	0.00	0.27
Eutrophication	kg O_2 / kW	0.05	18.20
Ozone deleption potential (ODP)	kg CFC-11 / kW	0.00	0.00
Photochemical oxidants (POCP)	kg ethylene / kW	0.00	0.27

Regulating small motors

Although the efficiency of motors has improved on average by 3 percent over the last decade, further significant savings could be made since small reductions in speed can make major impacts on energy consumption.

It has been estimated that AC drives supplied by ABB over the last ten years for the speed control of pumps and fans have reduced electricity consumption by around 170 TWh per year ➔ 1. This is equivalent to the average annual consumption of electricity of more than 42 million European households. This corresponds to an average reduction of CO_2 emissions of over 140 million tons every year.

Despite the obvious energy saving advantages, 97 percent of all motors in applications less than 2.2 kW have no form of speed control at all. This corresponds to some 37 million industrial motors sold annually worldwide, and yet small VSDs have become less expensive year by year so that the financial payback time for a VSD is between six months and two years, depending on the application (two years for many pump and fan applications).

Improvements in the operational efficiency of industrial drives have the potential to make major savings and help reduce CO_2 emissions.

Production versus usage

The term environmental product declaration (EPD) is frequently used to describe the impact of production on the environment. The problem with this approach is that it focuses only on the manufacturing stage and takes no account of the environmental impact of the future use of the equipment ➔ 2.

Environmental payback, on the other hand, is calculated as the amount of time required through the use of a product for it to compensate for the one-time environmental burden caused by its production. This is sometimes referred to as the return on natural capital (RNC).

Emissions data from the EPD show that the manufacturing carbon footprint of an ACS800 250 kW drive is 3.65 kg CO_2 / kW or a total of 912.5 kg CO_2 / ACS800 250 kW drive. Studies made at Tampere University of Technology indicate that environmental payback information for the same drive, in terms of global warming potential (GWP), is 0.5 days. In other words, by operating the drive for just half a day it is possible to fully compensate for the carbon emissions made during its manufacturing. The footprint then "turns negative" since the drive will lower emissions for the motor it controls throughout its operational lifetime ➔ 3.

The manufacturing of light weight VSDs obviously produce lower CO_2 emissions than those produced when manufacturing industrial class VSDs. However, the environmental payback time for the larger drives is shorter. This is due to the fact that the larger drives save considerable amounts of energy and therefore have a greater impact on the reduction of CO_2 emissions. In a typical pump or fan application a VSD saves 50 percent of the motors energy consumption.

Energy consumption

The five major factors affecting the environmental payback period of a VSD are:
– the energy use of the drive
– manufacturing of circuit boards
– the final assembly
– the casing
– the capacitors

The most important factor influencing the environmental payback time of a VSD is the energy consumed by the drive during its operation. This can be improved not only by optimizing the control and efficiency of the VSD, but also by optimizing the efficiency of all equipment in the system, ie, the motor, pump, fan or extruder. Further savings can be made through design improvements and the optimization of drive use.

Low manufacturing emissions

During the manufacturing of VSD the most important factor influencing the environmental payback time is the production of the electronic components. Over 50 percent of the CO_2 emissions are generated during its production. Here the manufacturing of circuit boards creates the heaviest environmental burden. Their transportation is generally less significant, provided they are not moved by air freight.

The manufacturing process itself can be optimized to reduce emissions, ie, the use

3 Ecological payback (in days) for three types of ABB drives

Product	Power kW		GWP
ACS140	0.75		6
ACS350	7.5		1.1
ACS800	250		0.5
Product	**AP**	**EP**	**POCP**
ACS140	6.0	8.0	15.0
ACS350	0.9	1.2	1.3
ACS800	0.4	0.9	1.0

Assumptions: drive provides 50 percent energy savings in typical pump or fan application using an average EU-25 electricity mix.

4 A MET table can be used to evaluate the different components of a product's environmental load

Phase	Materials	Energy	Toxicity
– Manufacturing	– Weight (kg) – main material inputs – Recovered materials – Plastics (kg) – Valuable metals (kg) – Printed circuit boards and electronics) (kg, mm^2, layers) – Water use in processes (l) – Chemicals (kg) – Volume (m^3)	– Energy consumption of manufacturing processes (kWh) (R&D, production equipment and plant allocated for one product)	– Chemicals used in manufacturing (amounts, toxicity, …) – Emissions from manufacturing processes – Materials of concern (to be separated at the end of life)

of modular interchangeable parts that can be assembled easily, help optimize the assembly process increasing production efficiency and helping to reduce inventory, especially when the same part is used to manufacture different models. Such easy assembly can also help with the disassembly process, which means that parts can be sorted easily for possible reuse. Such considerations mean that the choice of raw materials for manufacturing becomes more significant.

In pump and fan applications the use of variable speed drives can cut energy bills by as much as 60 percent.

The use of eco-efficient products and systems contributes toward reducing the environmental load. Consideration of recycling efficiency of VSDs at the end of the product's life-phase helps reduce its impact on the environment, either through the reuse of materials or by extracting their energy content. For instance aluminum parts can be recast, which avoids the costly environmental impact that results when extracting aluminum from aluminum ore.

For evaluating the environmental load of a product, factors at different phases of production can be gathered in a so called MET table (MET; materials, energy, and toxicity). Here we present the row for manufacturing → 4. The table usually includes rows for raw materials and the production of raw materials and components; their use; and their usefulness at the end of the product's life.

Holistic approach

Manufacturers have tried to describe the environmental toll of a specific piece of equipment during its manufacturing process through an environmental product declaration (EPD). The problem with this approach is that no attention is paid to the future use of the equipment. Instead of EPDs, ABB has been developing a new way of predicting the life-time environmental costs. With these environmental payback calculations it can be shown that the environmental burden of manufacturing VSDs is paid back within days depending on the size and use of the VSD.

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