A worthwhile investment

The drive to reduce emissions and energy consumption

Jukka Tolvanen, Timo Miettinen

Variable-speed drives (VSDs) control the speed of machinery, pumps, mixers, fans and compressors to match the needs of the process. In many applications VSDs save so much energy that their economic payback time is only a matter of months. A new approach to the assessment of environmental impacts shows that the environmental payback time of VSDs can be even shorter, in many cases as little as one to two days.

Sustainable processes

AC variable-speed drives (VSDs) operate by converting the fixed supply from the network to a variable voltage and frequency in response to an electrical control signal. The change in frequency results in a corresponding change in the speed (and torque) of the motor coupled to the drive. This means that the motor speed, and therefore the speed of the equipment being driven, can be set on the basis of external parameters, such as flow rate or temperature.

Speed control can significantly boost the efficiency of the entire motor driven system. In the case of conventional systems such as pump and fan applications, for example, the electric motor drives the pump or fan at full speed and then the desired flow rate of liquid or gas is achieved by restricting the output by means of valves, vanes or similar "throttling" devices.

Running the system at full speed and then restricting the output is obviously very inefficient. Some applications have proven that even a modest decrease in motor speed will considerably reduce energy consumption. According to the affinity laws, which govern the performance of pumps and fans, a pump running at 80 percent speed, for example, uses only 64 percent of the energy and slightly more than 50 percent of the power than one running at full speed.

There is a huge scope for energy and emissions savings through speed control by VSDs. Pumps, fans, compressors, extruders and other motor-driven applications account for two-thirds of industrial electricity consumption, which in turn represents 40 percent of the overall electricity use in the world. However, less than 10 percent of motors are operated by drives and, of motor-driven applications under 2.2 kW, as many as 97 percent have no form of speed control at all! In Europe it has been estimated that if VSDs were used in motor-driven systems throughout the continent, annual savings in electricity consumption totaling 50 million MWh could be achieved. This is equivalent to 25 million tons of carbon dioxide[1], or roughly a quarter of the total annual emissions of Finland.

Variable-speed drives offer the most effective method of controlling a motor's speed, thereby contributing significantly to energy saving.

Payback time

The economic benefits of VSDs are relatively easy to calculate, as the investment cost, reduction in energy consumption and cost of power are known. This in turn enables the payback time to be readily computed. Quantifying the environmental effects of VSDs, however, is somewhat more complicated.

The methodology generally used to study the environmental impacts of manufacturing, use and disposal of products is life-cycle assessment (LCA). ABB conducts LCA work in accordance with the requirements of the ISO 14000 series of environmental management standards. LCAs are designed to cover all the phases of a product's life cycle: from the production of raw materials and components to its disposal. Data is collected on all the relevant inputs and outputs, and this is then related to environmental impact categories such as global warming and ozone depletion. The selection of impact categories depends on the purpose of the LCA, and the ones most commonly considered for VSDs are shown in 1. The areas of highest impact are identified, and then addressed in order to reduce the overall environmental burden.
In this way, LCA studies highlight the importance of Design for the Environ-

1 Common categories of environmental impacts evaluated during life-cycle assessment (LCA) studies

Category of impact		Description
Global warming potential	GWP	Translates the quantity of gases emitted into a common measure to compare their contributions (relative to carbon dioxide) to the absorption of infrared radiation from the Earth over a 100 year perspective
Acidification potential	AP	Translates the quantity of sulfur dioxide and nitrogen oxides emitted into a common measure to compare their contributions to the capacity to release hydrogen ions
Eutrophication potential	EP	Translates the quantity of nutrients (mainly nitrogen and phosphorus) emitted into a common measure expressed as the oxygen required for the degradation of dead biomass
Ozone depletion potential	ODP	Translates the quantity of CFCs and halons emitted into a common measure to compare their contributions (relative to the freon CFC-11) to the breakdown of the ozone layer
Photochemical ozone creation potential	POCP	Translates the quantity of VOCs and nitrogen oxides emitted into a common measure to compare their contributions (relative to ethylene) to the formation of photochemical oxidants

Footnote

[1] This value is calculated based on the average CO_2 produced per kWh of electricity generated. The average depends on the mix of fossil fuel plants and renewable energy sources in electricity production.

ment (DfE) and other pro-environmental design and product development practices.

Focusing on environmental impacts

The information (or results) obtained from LCAs forms the basis of Environmental Product Declarations (EPDs). EPDs describe a product's most important environmental impacts during the manufacturing, usage and disposal phases. They can be certified by an impartial third-party organization, which gives the data additional credibility. ABB produces EPDs for all its core products, including VSDs, and information concerning resource utilization, energy consumption and losses, and emissions from the EPD for ABB's 250 kW ACS800 industrial drive is given in 2 to 4.

EPDs enable users to directly compare the environmental performance of different products, because the data is shown in terms of a functional unit (1 kW of rated output power in the case of the data presented in 2 to 4). EPDs also support manufacturers' efforts to enhance their products because they establish an environmental performance benchmark.

Even though EPDs focus on environmental impacts, they ignore the environmental benefits of using products like drives instead of a less efficient solution. According to the EPD information shown in 2 to 4, for example, an ABB industrial drive creates the greatest environmental impact during its usage phase. In fact a VSD can easily halve energy consumption in many applications, compared with the alternative of running the motor at full speed and then restricting output. Unfortunately the energy saved and emissions avoided by using a drive are not taken into consideration in the EPD in any way. Given the scale of the benefits – it is estimated that in 2008 alone the worldwide installed base of ABB drives saved around 170 TWh or about 142 million tons of carbon dioxide[2)] – this is a significant drawback to EPDs. One proposal to address this shortcoming is to determine the ecological payback of products.

In Europe it has been calculated that if VSDs were used in motor-driven systems, annual savings in electricity consumption totaling 50 million MWh could be achieved.

Ecological payback

Determining ecological payback is a new approach to the assessment of the lifetime environmental effects of products, which takes into account both their positive and negative environmental impacts. Natural capital – ie, natural resources – is consumed both in the manufacturing and disposal phases. However, by using eco-efficient products and processes such as drives in place of older, inefficient

2 Environmental Product Declaration (EPD) data for ABB's industrial drive, ACS800, 250 kW: resource utilization. Negative figures for the disposal phase reflect reuse or recycling.

	Manufacturing phase unit / kW	Usage phase unit / kW	Disposal phase unit / kW
Use of non-renewable resources			
Coal kg	0.66	560.8	–0.46
Aluminum (Al) kg	0.06	0.00	–0.00
Copper (Cu) kg	0.12	0.00	–0.11
Iron (Fe) kg	0.61	0.00	–0.49
Manganese (Mn) kg	0.00	0.00	0.00
Natural gas kg	0.18	65.35	–0.02
Uranium (U) kg	0.00	0.02	0.00
Oil kg	2.26	58.51	–0.06
Use of renewable resources			
Hydropower MJ	0.04	109	0.00
Wood kg	0.02	28.83	0.00

3 EPD data for ABB's industrial drive, ACS800, 250kW: energy consumption and losses

	kWh / product			kWh / kW		
Energy form	Manufacturing phase	Usage phase	Disposal phase	Manufacturing phase	Usage phase	Desposal phase
Electrical energy	57.0	625,331	–	0.23	2,501	–
Heat energy	31.1	–	–	0.12	–	–

4 EPD data for ABB's industrial drive, ACS800, 250kW: 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

Footnote

2) This value is specific to the energy generated by fossil-fuel power plants, and is determined on the basis that the amount of CO_2 emitted by a fossil fuel powered electricity plant is approximately 0.84 tons/MWh. Wind turbines, nuclear power or hydropower plants produce little or no CO_2.

solutions, it is possible to considerably reduce the overall load on the environment. The ecological payback value shows how long a product has to be used in order to compensate for the one-time environmental burden of its manufacture and disposal. Basically it can be considered as the environmental payback of a product.

5 shows ecological payback in days for three different ABB drives. The payback times are short, decreasing with increasing power ratings. For a 250 kW drive (ACS800), for example, the payback time is calculated as one day.

Determining ecological payback is a new approach to the assessment of the lifetime environmental effects of products. It takes into account both their positive and negative environmental impacts.

Negative carbon footprints

Emissions data from the EPD of an ACS800 250 kW drive shows that its manufacturing carbon footprint is 3.65 kg CO_2/kW or 912.5 kg CO_2 in total 4. The information given in 5 for the same drive indicates that ecological payback 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 avoid enough emissions to fully compensate for the carbon impact of manufacturing. The footprint then "turns negative" as the drive will continue to benefit the environment by saving emissions throughout its lifetime. In fact, an ACS800 industrial drive will typically provide a total lifetime savings of around 7,500 MWh or 3,800 tons of carbon dioxide emissions.

In a world where AC induction motors are still the undisputed "workhorses of industry," VSDs can play a very important role in reducing energy costs and carbon emissions.

5 Ecological payback (in days) for three types of ABB drives by environmental impact categories. Assumptions: drive provides 50 percent energy savings in typical pump or fan application using an average EU-25 electricity mix.

Product	Power kW	GWP	AP	EP	POCP
ACS140	0.75	6	6	8	15
ACS350	7.5	1.1	0.9	1.2	1.3
ACS800	250	0.5	0.4	0.9	1.0

Source: Tampere University of Technology

A power generating water pumping station

A German utility company in Stuttgart uses ABB industrial drives to control pumps that can also operate in turbine mode to generate power. Water is abstracted from Lake Constance in southern Germany and, after treatment, is piped around 120 km to a storage tank in Rohr on the outskirts of Stuttgart. From Rohr the water is piped to the pumping station at Gallenklinge, where it passes through the pumps/turbines and is then stored in a tank before being fed into the Stuttgart network. The height difference (head) between Rohr and Gallenklinge is 120 meters.

As part of a recent upgrade project, three ABB industrial drives (ACS800, 400 kW) were installed at the pumping station. The drives used are regenerative drives, which have an active supply unit to allow full power flow in both motor and generator modes. The drives are also fitted with EMC filters for the first environment, and the power generated is supplied to the regular grid.

Emissions data from the EPD of an ACS800 250 kW drive indicates that ecological payback in terms of global warming potential is half a day.

The drives operate 315 kW, 400 V motors, and the pumps are arranged in a parallel configuration for redundancy. ABB's intelligent pump control (IPC) software in the drives provides additional functionality, including energy optimization, master change, PID control, and pump priority control. The pumps are normally used in turbine mode, with pumping mode only used in emergency. Output power is typically 200 kW. The pumping station previously used turbines with pitch-controlled blades, but VSDs have been found to offer a more economic solution with greater flexibility.

Cement producer cuts energy and maintenance costs

Castle Cement's Padeswood Works in North Wales, United Kingdom, home to one of Europe's most modern cement kilns, uses ABB industrial drives to operate fans. These include a 2 MW induced draft (ID) fan, a 750 kW exhaust fan, and a 560 kW cooler fan. The fans have to be controlled to accommodate differing flow requirements due to changing atmospheric and process conditions, and changing ventilation needs. A further four fans – rated at 110, 160, 200 and 250 kW – push air into the grate cooler to reduce the temperature of the hot clinker to a set point.

Fan control was previously implemented by means of slip rings and DC motors, which require regular maintenance. With the installation of ABB industrial drives and the replacement of the slip rings and DC motors with maintenance-free AC motors, the plant has realized savings of up to 30 percent on the total energy costs of the fans, together with major savings in maintenance costs on the old type motors.

Jukka Tolvanen
Timo Miettinen
ABB LV Drives
Helsinki, Finland
jukka.tolvanen@fi.abb.com
timo.j.miettinen@fi.abb.com

Footnote

[3] This calculation has been made assuming a typical service life of 10 years, 6,000 running hours per annum and average energy savings of around 50 percent.