

40 YEARS OF PROGRESS

In the autumn of 2008 it will be 40 years since the world's first volume produced frequency converter was sold; a VLT® frequency converter, produced by Danfoss.

Since then, a rapid technological evolution has taken place. In line with the global spread of automation, the growth of drive applications the number of motors applied in each application and in line with the share of motors controlled with frequency converters, the production of frequency converters is virtually exploding. The fact that Danfoss Drives has managed to not only grow with the market, but also consistently win market share has for 40 years meant continued growth in the number of VLT® frequency converters sold.

This incredible story had its genesis much earlier than 40 years ago. From the birth of the 3-phase AC motor in 1889, developers struggled to solve the problem that the speed of the 3-phase AC motor is determined by the frequency of the electrical power supply. Except for this weak point, the AC motor was a relatively simple and reliable device for creating mechanical energy. Through the first half of the 20th century, many solutions, both mechanical and electrical, were proposed and used to overcome this inherent weakness in the AC motor. Mechanical gears, switchable pole configurations and slip-ring motors were applied, among others.

In Danfoss, the evolution towards the frequency converter was made possible with the acquisition of a small, local manufacturer of rectifiers in 1959, and Danfoss Electronics was established in 1962. This unit produced high power rectifiers (often for currents up to 10,000 A), but the unit was not sufficiently profitable and was closed in 1965. The electronic know-how was maintained however, in a unit called Teknisk Forskning (Technical Research) and in this unit the VLT® drive was eventually born.

Two development engineers from the unit, Arne Riisager and Arne Jensen, attended the IFAC congress (International Federation of Automatic Control) in London in 1966. Among the subjects that caught their interest were power transistors and the possibilities for controlling AC motors. "In IFAC they talked about variable speed and claimed that a standard mass produced motor control was not possible for AC motors", Arne Riisager reported. The two Danfoss engineers saw the enormous possibilities in this untouched area of controlling the performance of standard AC motors via the power supply.

Ready in two years

From the start, the strategy was to develop a standard, volume produced AC motor control. The expertise was at hand, and missing equipment was developed on-site, driven by the spirit of pioneers who have given birth to many new projects and supported by plenty of creativity. Ideas were tested on ingenious arrangements with whatever means were available.

The inventiveness of this creative team resulted in 14 applications for patents within a year and in 1967 the first VLT® drive performance prototype was presented to the board of directors. It looked like a birds nest, but the performance was convicting, and the board gave its approval to proceed. The same year, the production prototype was ready and in mid 1968 the first 10 drives were submitted to selected customers for field-test. These drives were returned with the same speed as they were submitted, and therefore achieved the nickname "homing pigeons".

The first VLT® 5 drives sold benefited from data from the test drives and were sold in the autumn of 1968 – only 2 years after the triggering IFAC congress

Gave taste to Carlsberg in 40 years

The Carlsberg Breweries, one of the first customers, still uses VLT® drives. Initially the drives controlled the speed of their conveyers, but today VLT® drives also control processes such as flow, temperature and

speed in the delicate precision brewing process leading to tasty Carlsberg beers.

Stepwise marketing

At first the VLT® drive was marketed only in Denmark, followed by Scandinavia and in 1970 the rest of Europe. In 1973, the Borg-Warner Corporation in the USA bought the right to produce and sell VLT® drives and the American drives were produced by Morse Chain, which originally produced mechanical devices and had no experience in electronics. The construction was not successful.

Ongoing innovation

The first VLT® drives were produced in the main Danfoss factory in Nordborg, Denmark in facilities covering only 180 m² although in 1971 it was expanded to 240 m². The work space was still narrow and work tables had to be small, and shelves sloping to prevent coffee cups and other irrelevant items taking up precious space.

Moved out in 1977

'Benjamin', the smallest unit within Danfoss, continuously grew and in 1977 it was time to 'leave home'. The unit took over a building from a former provider of ready-made clothing in Graasten, on the Danish mainland, Jutland. The transfer of production was organised so that personnel not interested in continuing in the electronics factory were replaced and the new personnel trained before the migration. The production area in one step grew five-fold from 1200 m² to 6000 m². Marketing, administration and product development followed in 1989, and 1600 visitors (consuming 4000 sausages) attended the celebration of this reunion.

Leading Danish provider of electronics

In 1972 at the 25th anniversary, Danfoss Drives was the leading provider of electronic equipment in Denmark, and the evolution continued. The mean product life-time for electronic equipment continuously diminishes. The VLT® 5 was marketed for a dozen years while the newer generations last typically 3-4 years. This calls for ongoing and accelerated innovation. Danfoss Drives benefited from being the first on the market but in the beginning of the '70s, first General Electric and later Strömberg, entered the scene with competitive products.

Danfoss Drives also benefited from their unique cooling concept as well as the unique and at the time very impressive, 100% earth fault and shortcircuit protection that was built into the VLT® products. Oil cooling of the electronics was used until 1983 and the last oil cooled version was the VLT® 20. Another advantage was the perception of reliability emerging from the physical design of the products; they looked like robust electrical transformers.

From static to dynamic unit

With the VLT® 200 series, the oil cooled concept (fan assisted in the VLT® 20,) was finally replaced by forced air cooling. Discontinuing oil cooling considerably simplified production, as ingenious systems with magnetic valves, pumps, level controls and oil containers on the roof were no longer necessary.

The last 15 years

1982: Danfoss Drives acquire Hampton Products in Rockford, USA. Today, 350 people are employed in the USA.

1995: Danfoss Drives take over the Graham Company in Milwaukee, USA. Graham is a renowned

provider of HVAC equipment in the USA.

1996: The environmentally certified plant in Graasten has been recently enlarged and now covers 22,500 M².

1999: Danfoss Bauer GmbH join the Danfoss Group and again, the US plants become environmentally certified.

2001: Danfoss Drives achieved their target for recycling and sorting of waste products set for 2003

2003: Currently, 65% of all waste products are being reused and only 25% incinerated. (90%?)

New technology platform

In 2004 Danfoss Drives launched the first models built on the new modular technology platform. The developers realised that the vast possibilities offered by information technology would create customer demand for more and more features – while at the same time covering greatly more customised and application specific solutions.

In order to meet these conflicting demands, Danfoss developers identified the separate elements in standard drives' architecture and the internal communication between these elements. Having achieved this, different elements can be used in varying drives series, reducing the cost of development and time to market.

The same concept supports Danfoss Drives' unique supply chain set-up. Each element in the frequency converter can be produced in high volumes and used for numerous variants of drives. An advanced IT system controls the assembly from the moment a customer has defined the features for his specific drive. Customers' specifications determine which printed circuit boards, frames, enclosures, user interface, software, fieldbus and which options to include in the drive. Everything is built-in and tested in the factory before shipping.

This way, customised drives can be built and shipped within hours. From limited amounts of choices for each element, thousands of different drives can be configured to meet customers' specific requirements. Even the manuals are printed on-demand in the required language to go with the drive. This means no stock of finished drives and no stock of possibly outdated manuals. In 2006 this set-up was awarded the Frost & Sullivan Award for Product Innovation. On the same technology platform, reusing the hardware, the Strategic Business Area (SBA) specific VLT[®] HVAC Drive and VLT[®] AQUA Drive were launched in 2006 and 2007 respectively.

Product range completed

In 2007 the panel optimised enclosures for the new generation were also launched and with the launch of high power drives up to 1.2 MW and up to 690 V, Danfoss today provides a complete product range to cover the entire low voltage market. The high power drives – over 90 kW – are developed and manufactured by Danfoss Drives' facility in Loves Park in Rockford, Illinois, USA. Production also takes place in China, where Danfoss Drives in 2006 acquired the Chinese drives manufacturer Holip, and established production facilities for the smaller drives.

International recognitions

The designs of VLT® drives have always played an important role, both to optimise production and operation of the drive, but also for the aesthetic look of the units.

- 1973 Danish ID prize (Industrial Design)
- 1974 “Honourable Mention” at the Electrex exhibition in London
- 1975 Gold medal at the Leipzig Fair
- 1977 “Die Gute Industrieform” at the Hannover Fair
- 1979 Danish ID prize (Industrial Design)
- 1979 “Die Gute Industrieform” at the Hannover Fair
- 2004 IF Design Award

Innovative manufacturing

Danfoss’ ongoing innovation in manufacturing techniques was also noticed in the global industrial world. In Milan in 1974 Danfoss Drives received the International Aluminium Prize for an original and functional design based on form-stable aluminium and a brand new gluing technique. Arne Riisager had the idea to use glue to assemble the cabinets from his knowledge of gliders. He knew these planes were assembled with glue but several attempts to assemble the drives failed because internal pressure caused leaks in the cabinet. At an intensive course at SAAB in Sweden, where both cars and aeroplanes were assembled with glue, Danfoss Drives engineers learned to master the technique. Abandoning oil cooling, other innovations emerged. Examples are designs allowing for automatic assembly, real side-by-side mounting, front access to all connections, electronics separated from cooling air flow, etc.

Most significant though, is the “mass customisation” set-up, which allows customers to order highly customised drives and have them ready for shipping within 24 hours. IT systems control the gathering of modules, assembly and test of the customised drive and the printing of the actual manual in the required language to accompany it. This means no stock of finished drives and no stock of possibly outdated manuals. In 2006 this set-up was awarded the Frost & Sullivan Award for Product Innovation

Trends in the past

More compact drives. The 5 kW VLT® 5 from 1968 weighed 54 kg. The new VLT® Micro Drive, which handles 50% more power, weighs less than 3 kg.

Electronics became digital. The VLT® 5 was an entirely analogue device. The present drives are completely digital, allowing for better control and enhanced performance of the drives.

Easier to use. While the IT evolution made it possible to build advanced facilities into the drives, the digital user interface has kept the operation of the drives intuitive and easy to set-up.

Communication. With the IT evolution, drives became highly communicative. Information from sensors, other drives and from central control units are freely passed to the drive and make it capable of reacting to any change, event or parameter.