The Integral Motor – a new variable-speed motor drive

ABB Motors has developed a new, energy-saving variable-speed motor drive for the 0.75 to 7.5 kW power range. A combination of standard induction motor and integrated frequency inverter, the so-called Integral Motor is especially well suited for industrial applications such as driving pumps or fans. The new motor is as easy to install and commission as a standard induction motor.

The Integral Motor 1, which was introduced on the occasion of PCIM 95[1] in Nuremberg, Germany, in mid-1995, is designed for use with machines such as fans and centrifugal pumps, which have a square-law load characteristic and are operated over their full speed range. Other possible applications are as motor drives for machines featuring a constant counter-torque (eg, screw-type compressors, rotary pumps or conveyor belts) providing their minimum speed is limited.

Since the integrated frequency inverter allows the Integral Motor to be operated at supersynchronous speed, it has been designed for speeds of up to 6,000 rev/min. Power losses due to harmonics are low, and the bearing lifetime is not adversely affected by the high speed.

The Integral Motor consists of a four-pole standard induction motor from the new M 2000 series and a miniature frequency inverter mounted on the non-drive side of the motor 2. This has resulted in the Integral Motor being approximately 40 percent longer and weighing about 15 percent more than a standard induction motor. The height of the motor remains the same.

[1] PCIM = Power Conversion and Intelligent Motion

Development of the Integral Motor

Electric motor drives are found in practically every branch of industry. Often referred to as industry's workhorse, it is cheap to manufacture, performs reliably and requires only minimal maintenance.

Nevertheless, when the induction motor is powered from the 50-Hz or 60-Hz mains, some troublesome limitations arise: its speed cannot be controlled and there is a ceiling of 3,000 and 3,600 rev/min, respectively. When lower or higher rotating speeds are needed, the problem is usually solved by means of gears or belt drives, while the capacity of the driven machine is usually controlled by throttling valves in the case of pumps, or vane control in the case of fans 3. However, such arrangements waste energy and generate noise.

Alternative drive systems are based on a frequency inverter that allows the frequency of the stator current, and therefore the speed of the induction motor, to be varied. This feature allows drive systems to be built for a wide speed range. Inverter-based motor drives for pumps or fans can be adapted to any load without any unnecessary loss of energy. However, to install drive systems of this kind special knowledge of both the motor and inverter performance is required.

Today, the inverter can be fitted direct to the motor and matched to it already in the factory.

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Mechanical design of the Integral Motor

The design of the inverter casing matches that of the motor casing and, like the latter, is fully enclosed (protection class IP 55 to DIN 40050). It was decided to fit the inverter to the non-driven side of the motor as its performance would be impaired if it were mounted on top of the motor, where it would be most affected by the heat losses, especially with the motor at standstill after being run at high speed.

The inverter housing also features a mains filter, as required by new EU guidelines that went into effect at the beginning of 1996.

Numerous benefits for machine manufacturers

An Integral Motor is just as easy to install and commission as a standard induction motor. All the parameters which are important for ensuring the best interaction between the inverter and motor are set already in the factory, with the result that the variable-speed drive is optimized on delivery. All the necessary protection is also incorporated during manufacture of the motor drive.

The asynchronous motors used in pump, fan and compressor drives can be easily replaced by Integral Motors. No problems are encountered with the connection to the mains. Existing control cables (eg, the cable used to operate the valve that regulates the liquid flow in a pump), can be used to control the motor speed, and with it the pump capacity.

ABB Integral Motor with a power output of 0–4–4 kW at 0–1,500–3,000 rev/min, for field tests **1**

Fewer parameter settings mean easier commissioning

Prior to commissioning, only a few application-specific values have to be set, either in the factory or during the installation. They include:

- The speed range (0–3,000 rev/min, or as an option 0–6,000 rev/min, at 50-Hz) and the speed limits
- The acceleration and retardation values
- The direction of rotation of the shaft

If these values need to be changed at any time later, this can be done with the help of a small, hand-held control panel **4**. Just one of these panels is required to set the values for all the Integral Motors in a plant. No more than a few minutes are needed to adjust the machines for new tasks, since this requires only the input of new values, which are then transmitted direct to the motors.

The speed can be controlled by two types of signal:

- Analog signals from a potentiometer, computer or other setpoint generator
- Digital signals for start-up and shut-down of the motor as well as for input of the direction of rotational speed and rev/min

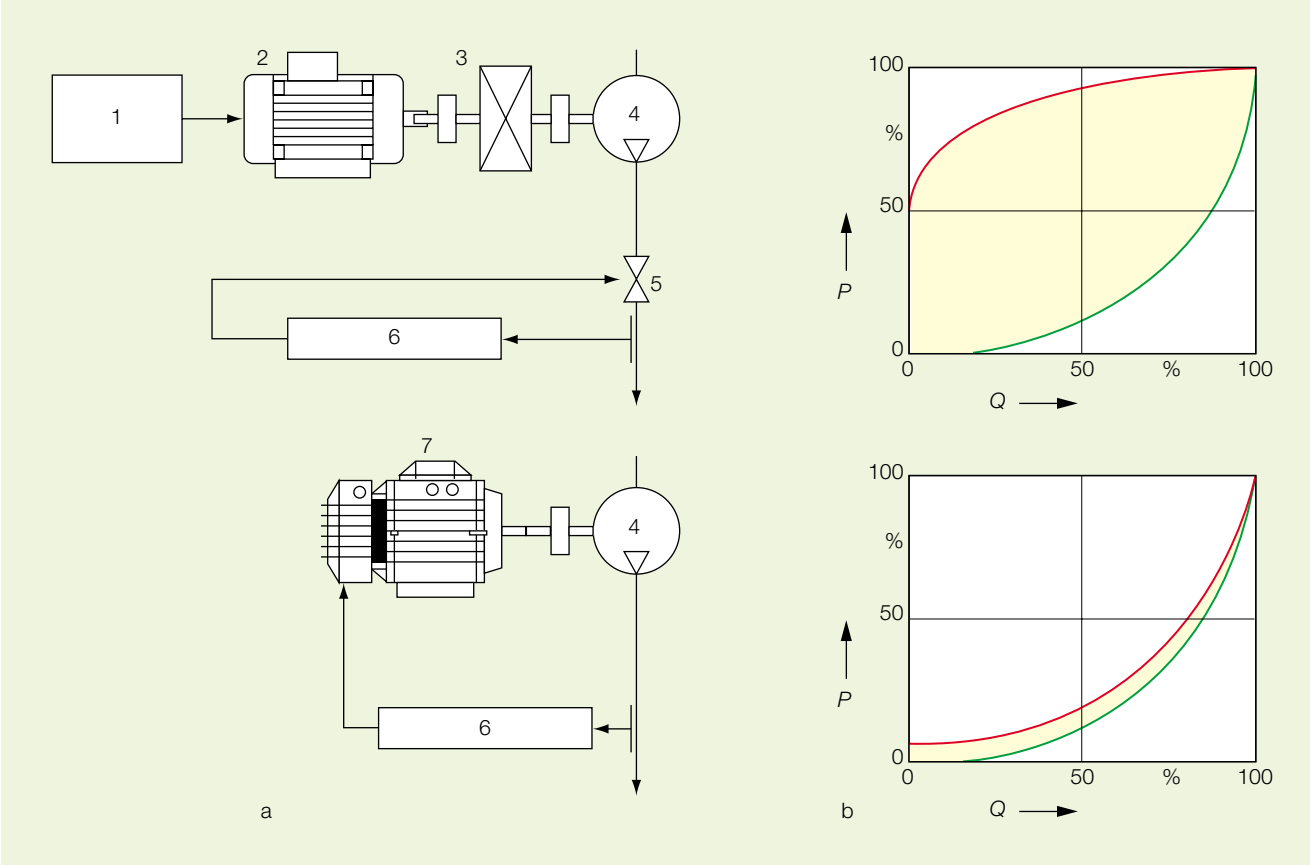
New possibilities for pump and fan manufacturers

Previously, it has always been necessary to design the load (the driven machine) to match the constant-speed AC motor. With the new Integral Motor, designers of pumps, fans and compressors have access to a much wider speed range, allowing them to optimize their equipment. Manufacturers of the driven machines will be able to reduce the number of different types of drive needed, since the Integral Motor allows optimum matching to operating conditions.

Smaller machine inventories

Large numbers of industrial companies have to keep many different types of AC motor in stock for production and service purposes. They may be motors with the same frame size, but with different numbers of poles for operation at speeds of 750, 1,000, 1,500 and 3,000 rev/min. All of these different types of motor can

Miniature frequency inverter (0.37–3.0 kW) for series-produced ABB Integral Motors **2**



Comparison of a drive with conventional valve control (top) and a variable-speed Integral Motor (bottom) 3

a *Drive configuration*

1 *Starter*
2 *Constant-speed AC motor (3,000/3,600 rev/min)*
3 *Gear unit*
4 *Pump*
5 *Throttle*
6 *Controller*
7 *Variable-speed Integral Motor (0-6,000 rev/min)*

b *Relative motor output P as a function of relative flow rate Q*

Red *Power taken from drive motor*
Green *Power required by pump*
Yellow *Losses*

be replaced by just one size of Integral Motor, since it can be adjusted to the required application range. In addition, since speeds of up to 6,000 rev/min are possible, step-up gears are no longer needed. This can translate into a considerable reduction in the size of future stock inventories.

Some points to note

The Integral Motor does, of course, differ in some ways from the standard motors:

- It is longer. However, for the majority of applications this should not be a problem.
- The electronic circuitry, which is located within the motor casing for protection, has to be designed to withstand high temperatures and vibrations.
- Although the initial cost of an Integral Motor is higher, it offers greater functionality and pays for itself within a short time. And in the event of failure, the motor or inverter section can be quickly replaced and new values set for it.

Field tests

Beginning in March 1994, 43 pilot motors were field-tested by various equipment manufacturers and end-users for periods lasting from 9 to 12 months. The inverter used in each of these pilot units was of

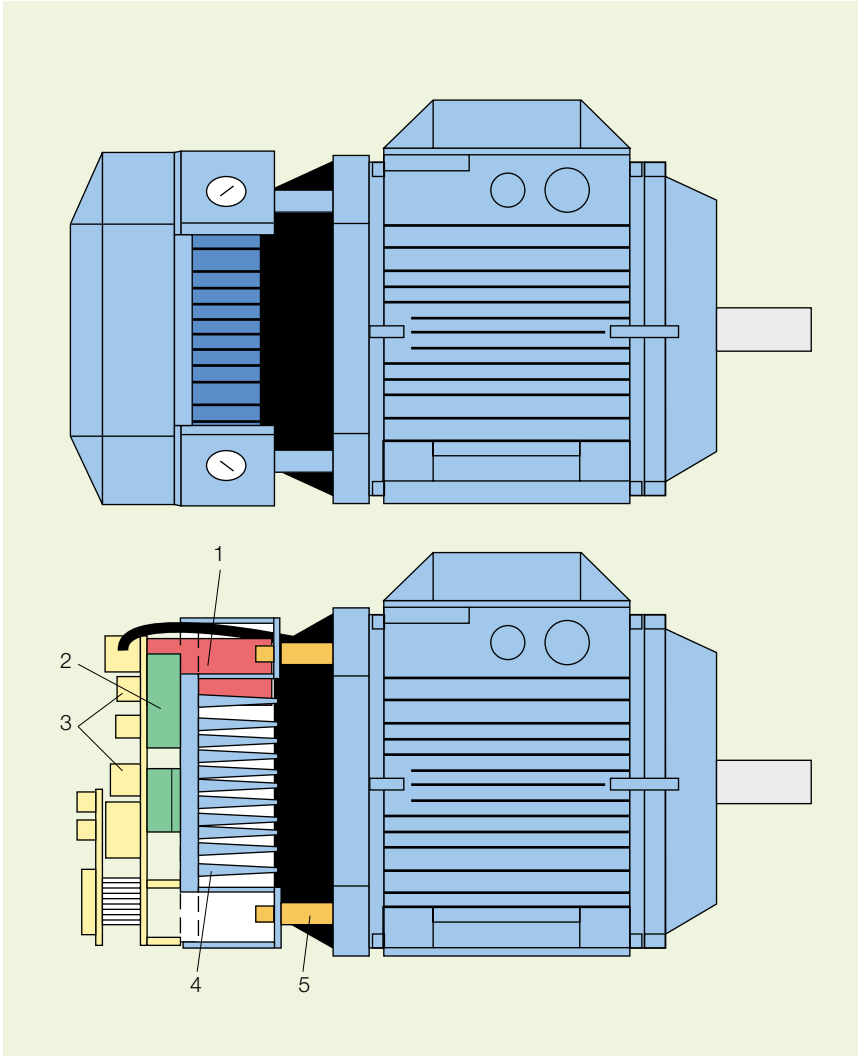
Table 1:
Customers and areas of application used for field-testing the ABB Integral Motor

Driven machine	End-user	Original equipment manufacturer	Total
Fans	9	8	17
Pumps	10	6	16
Conveyor belts	6	0	6
Others	4	0	4
Total	29	14	43

Control panel for the manual input of application-specific values **4**

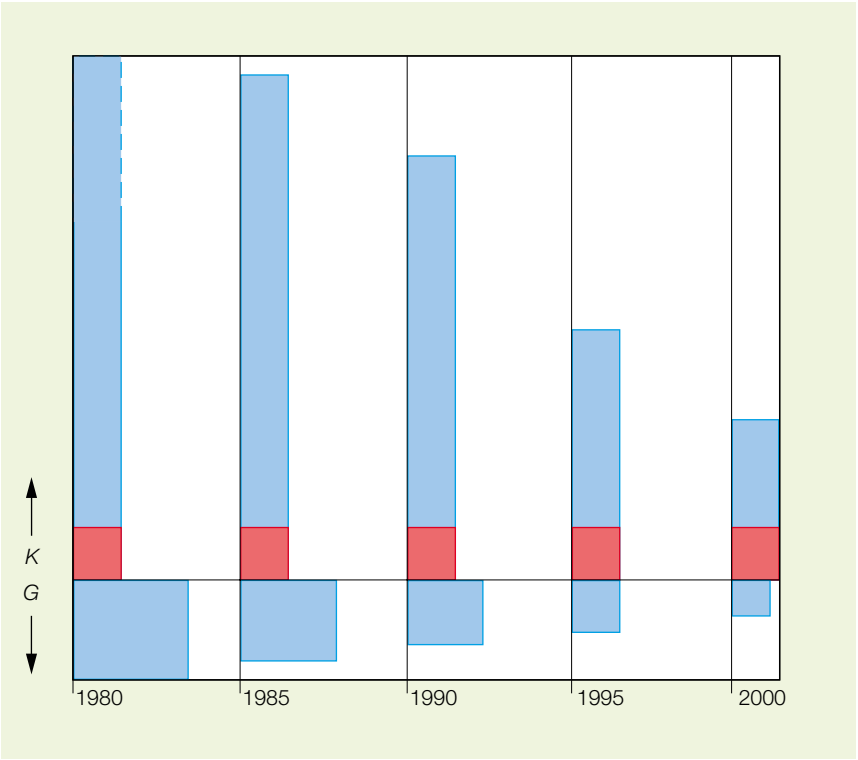
ABB Integral Motor for field tests with integrated conventional frequency inverter. The drive contains all the required control (yellow) and power (green) components. **5**

1 *Capacitors*
2 *Integrated power module*
3 *Printed circuit-boards*
4 *Heat sink*
5 *Mounting support*



Advantages of the Integral Motors over previous motor drives

- Compact variable-speed motor drive which is optimized in the factory.
- Easy, low-cost installation. Ready to run after connection to mains.
- Easily adapted to new tasks by modification of small number of application-specific settings.
- Low energy consumption thanks to high efficiency and absence of gearing. Short pay-back time.
- Suitable for wide range of applications. Can replace AC motors with different pole numbers as well as two-speed motors.
- Reliable. Based on ABB standard motor and custom-built inverter.
- The Integral Motor meets CE conformity requirements, and thus satisfies the guidelines for low-voltage equipment, machines and EMC applicable in heavy and light industries.



Development of total costs K and size G of frequency inverters over a period of two decades 6

Blue *Frequency inverter*

Red *Induction motor*

conventional design 5. The different customer categories and applications for the pilot units are shown in *Table 1*.

The test units were installed in different environments to test their operational reliability:

- 6 motors were installed indoors.
- 2 motors were installed outdoors.
- 8 motors were cleaned with water or steam under high pressure at least once a week.
- The remaining units were operated in dirty, dusty, humid or corrosive environments.

The modes of operation of the units were also different:

- A small number were operated with fixed speeds.
- Most were operated with closed-loop control to maintain a liquid or air flow, a liquid or air pressure, or some liquid level.
- A small number were operated with start/stop control, involving acceleration and deceleration times measured in tenths of a second.

The motors ran an average of 3,500 hours, one unit being subjected to 400,000 start/stop operations. The total running time for all the motors was 12 years.

The motors performed excellently under the described conditions. Breakdowns occurred in just a very few cases:

- In one case due to a wrong choice of application and the wrong application-specific setting.
- One motor broke down because of a defective capacitor terminal in the inverter's DC link.
- One breakdown was due to failure of the inverter power electronics.

All the customers taking part in the field tests were interviewed to determine where, if at all, weaknesses could be found in the design, user-friendliness or controllability of the motor drives. The information this yielded and the experience gained from the failed units provided a good basis for the final choice of frequency inverter 2. The final design chosen for the series-produced Integral Motor ensures perfect functioning under the full range of described environmental conditions.

Future trends

The Integral Motor is certain to add a new dimension to drive technology for machines traditionally powered by constant-speed drives. Drives for pumps and fans will profit in particular from this technology, as they will be less complex and easier to install. Energy consumption will also be reduced thanks to the high power factor and elimination of the gearing, so that the initial investment in an Integral Motor is soon paid back.

Since inverters were introduced at the beginning of the 1970s, their price has dropped constantly to a level where today it is approximately four times that of the associated AC motor. Due to the rapid progress being made in power electronics, it is likely that the price of the inverter will continue to decrease over the next five years to a level equivalent to twice the AC motor price 6.

The steady increase in the power density of the electronics is also bringing about a reduction in the size of the modules. This will allow Integral Motors with even higher power ratings to be built with sizes that more closely approach those of the standard induction motors.

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