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Sensor-free magnetic bearings

Increased safety at low cost – new bearing technology, also for high rotational speeds

The bearings used in rotating shafts can sometimes present a challenge in a wide range of applications. Achieving increases in efficiency by minimising of frictional and wear losses is gaining in importance all the time. In this context roller and ball bearings are increasingly unable to cope with the rising requirements. For such requirements, magnetic bearings are usually the best choice.

With active magnetic bearings (AMB), forces are created with the help of electrical magnets with which, in contrast to classic bearings, mechanical attributes such as rigidity and damping can be influenced on a targeted basis. Active magnetic bearings are unstable systems which require a stabilising form of control, however. The rapid advances in the semiconductor industry are enabling increasingly sophisticated and therefore more efficient controllers for unstable systems of this kind. The controller requires a notification of position which is provided according to the state of the art by special sensors.

On this basis, it has not been possible to realise a wide range of useful applications for magnetic bearings, because until now, the use of a position sensor has always been viewed as being necessary for the stabilisation of magnetic bearing systems.

To increase the failure safety of magnetic bearings in safety-critical areas of use, engineers would now prefer to omit the use of sensors and/or, to make redundant position information available in addition to the sensors which are at risk of failure.

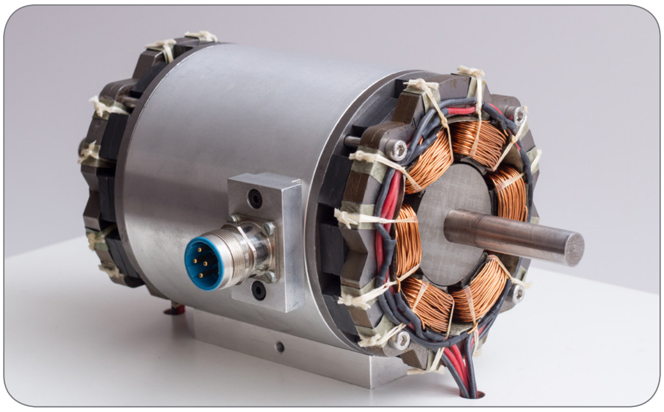
Objective

The aim of Prof. Manfred Schrödl and his research group at TU Wien was to develop a new type of control system which does not require an extra position or motion sensor and nevertheless ensures the stability of the control loop at each operating point, and/or offers a second independent position information to check the sensors for a sensor-based system.

Approach

A 3-phase structure is used in order to minimise the cost of the hardware. This structure can be operated with standard frequency inverters from the drives sector. In contrast to most active magnetic bearings which require a frequency inverter for every degree of freedom (usually 3), a 3-phase structure only needs 2 frequency inverters, which leads to significant reduction in the hardware costs.

To stabilise the system, these days the controller is always implemented in a digital signal processor (DSP) which normally also completes other tasks. This digital control loop has to provide a sufficient stability reserve and level of robustness. The position sensors that are standard today have unavoidable analogue paths which cause additional noise with the measuring signal and therefore bring vibrations to the rotor, that should be positioned smoothly. If the installation of position sensors is not required or not possible, the position information has to be calculated from the physical attributes of the system. One procedure for the sensor-free determination of the rotor position is the INFORM method, as developed by Prof. Schrödl.



Sensor-free magnetic bearings – e.g. for the rotor of an electric motor

Institute of Energy Systems and Electrical Drives
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The INFORM procedure has been used successfully for the identification of the rotor angle of electrical machines for many years. It has also been further developed for the area of active magnetic bearings. The procedure is based on the change of the magnetic characteristics depending on the position of the rotor. Via analysis of test impulses which only last a few millionths of a second, it is possible to determine the rotor position.

The INFORM method stands out due to its short computation times and therefore enables a high control dynamic. Active magnetic bearings with a sampling frequency of 50 kHz have already been realised which make rotor speeds of over 100,000 revolutions safely controllable.

INFORM stands for „INdirect Flow measurement through Online Reactance Measurement“, and means Analysis of the current slope due to voltage pulses from the inverter; with the rotor running, the space phasor of the current change (trajectory) moves along a circular path with offset; the path speed being equal to double the rotor speed.

Results

Different designs of bearing were constructed at TU Wien and the INFORM method was compared with sensor-based control systems. It was demonstrated that the position information of the INFORM method is of approximately the same quality as that of the sensors. The INFORM method can be used during the controlled operations without any problems and stabilise the rotor with its magnetic bearings.

After the implementation of the INFORM analysis, the same control strategy can be applied as for the sensor-based system. This fact enables a rapid conversion of existing magnetic bearing systems to sensor-free operation.

The benefits for you

Use of all the advantages of magnetic bearings, such as changeable bearing characteristics; no friction and low loss; no leakages of oil or lubricant possible; suitable for wide range of revolutions – up to more than 100,000.

- Reduction of your costs by omitting of the sensors and reduction of costly electronics (generally from 3 to 2 inverters)
- Increase in process safety due to the omitting of sensors and cabling liable to failure
- Reduction of the construction space of your magnetic bearing
- Omission of production and maintenance errors in the connection between the sensor and controller
- Elimination of signal noise and the resulting vibration of the rotor (due to the elimination of analogue paths of the sensor)
- Simplified commissioning of the rotors and systems

The functionality and failure safety of the sensor-free INFORM method has now proven its value in many applications for the speed control of synchronous motors. Many thousands of units are in daily use. This practically tested technology is now being applied to magnetic bearings.

TU Wien can help you to implement this technology for the sensor-free operation of magnetic bearings for low to very high speeds and/or in the range of a few watts up to many kilowatts.

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