LUND UNIVERSITY
DEPARTMENT OF INDUSTRIAL ELECTRIC ENGINEERING AND AUTOMATION

MAGNETIZING SYSTEM

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Presentation of the development of a ring magnetizer at Lund University

Background

Electrical PM engines needs permanent magnets to produce the rotating torque. The magnetic field at the permanent magnets oppose with the magnetic field that is generated from the current in the engine. These different magnetic fields is generating the force that rotate the engine.

Normally, the whole magnetization is performed at the same time. In this way the magnetization is affecting each other and the result is a slightly disturbance at the magnetizing strength. The presented solution at this report is, to develop a magnetizing system that magnetize the ring with similarity to a tape at a tape recorder. This report treats the development of such a system.

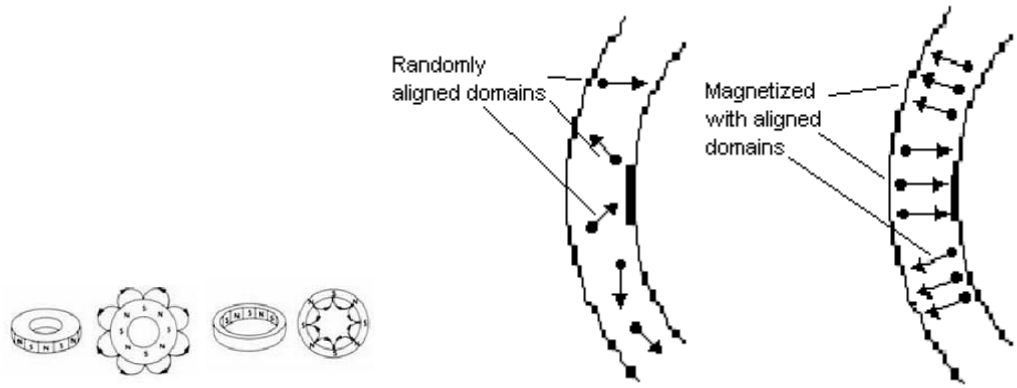
About the ring

These rings are often used in electrical motors. The purpose is to construct a pattern of magnetization that could be seen as a bar code along the ring. With north and south poles that could exist in a great number which results in a multipole ring.

The properties for magnetization is that electrons spinning around an atom create a magnetic field. An amount of those atoms are divided into domains, cause to they will affect each others magnetization.

Scientific solution to the ring magnetization

The magnetization will be performed at a specific place at different times with a system that could adapt to the ring properties, while the magnetization is done. The development started with the construction of a suitable magnetizing device that could deliver the right amount of field strength to align the domains in the ring. There were also some specifications about the area size of the ring that should be magnetized, as well as the thickness of the ring.



Magnetic field density of the rings.

MAGNETIC PROPERTIES

Magnetic flux that passes a wire loop in emotion will give raise to a current flow at the wire. This current will try to oppose the flow by producing the same amount of magnetic flux, but in the opposite direction.

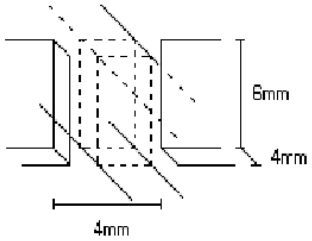
If instead the flux is changing and the ring is hold still, the same phenomenon will occur.

Iron and magnetic flux

Placing an iron core inside a wire loop with current flow will increase the amount of magnetic flux. This occurs due to the current rises a flux that align the domains at the iron which leads to a flux in the iron. Those two different magnetic fluxes rises to the sum of the both. Iron increases the magnetic flux to approximately 200-1000, compared to an air core wire loop.

PARAMETERS

The field strength demanded for magnetization was set to 4 Tesla, and the area to 4x6mm. The air gap is 4mm where the ring is placed.



The ring placed between the magnetic field conductors.

The system was also meant to be flexible so the ring could have other measurements.

MAGNETIZING DEVICE

High amount of Tesla

The amount of magnetic flux is 4 T, this led to the problem that iron and most of the magnetic flux conducting materials is saturated at approximately 2.2 T. After this amount the material behaves like air, the flux will go in all the directions and leave the material.

The solution to this problem was to force the flux into a sort of tunnel where the flux couldn't leak out.

Core material

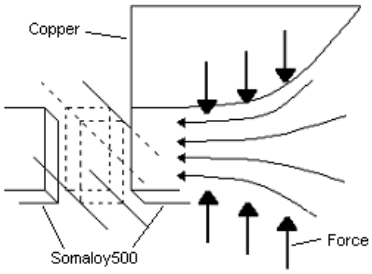
The core consists of laminated iron at the parts where there is no saturation.

At the tunnel part there is a material named Somaloy500. This material have properties to conduct magnetic flux at high frequencies with low power losses. It is developed at Hoganas AB. The tunnel part is also obliged to conduct flux in 3 dimensions, therefore this part is not laminated.

Magnetic flux compressors

As mentioned, current will oppose a magnetic flux field. The compressor part is made of copper plates, since copper is a good current conductor.

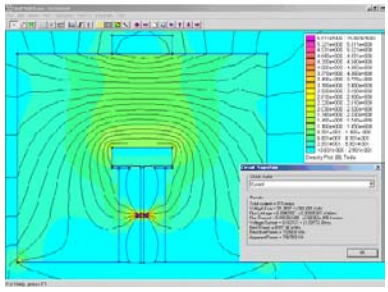
When the incoming flux reaches the copper plates it will meet a flux in opposite direction, the incoming flux will then be forced to change it's direction.



Principle of compressor mechanism.

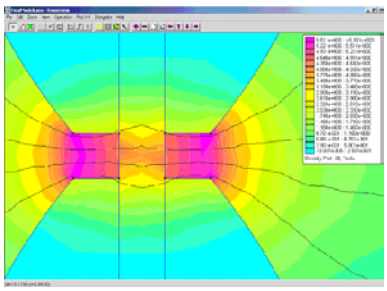
Simulation results of the device

In order to conclude towards a suitable magnetizing device, the use of a simulation program has been used. The program is FEMM, a useful and powerful tool in magnetic simulations.



Simulation result for the magnet.

The view of the air gap is enlarged in the next picture. It is seen that a satisfied amount of flux is reached at the air gap (4T).



CIRCUIT PROPERTIES

At the calculations of the different power parameters, which also is given by FEMM, shows that the demands is a system that has a possibility to deliver a very high power.

Power parameters

The current is set to 315 A, with a voltage of 518V. This is sent in to the system with the frequency 1kHz.

Due to the high frequency the power is also very high. The power is 52kW at one magnetizing pulse.

Wire

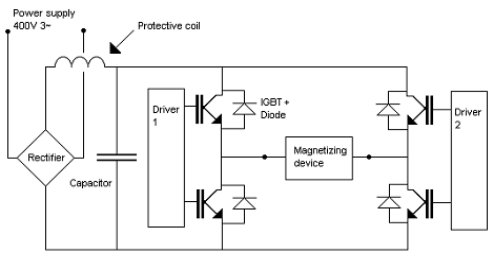
The wire is made of copper and has an area of 9mm^2. The number of turns at the coil is 115.

POWER ELECTRONICS

The magnetization is supposed to be obtained in both radial oriented directions. This obligate the current to be able to pass thru the magnetizing device in both directions.

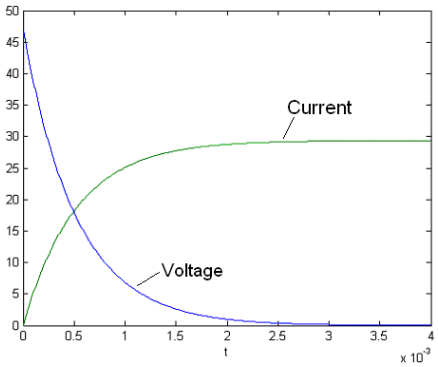
4 quadrant converter

The building of a 4 quadrant converter has been necessary, which is able to conduct current in two directions thru the magnetizing device. Opening the IGBT:s that is diagonally placed relatively each other, allows the current to flow along the same diagonal line. It is build with IGBT:s that is able to conduct a current of 400A, which has been increased to this level due to safety margins.



4 quadrant converter

The capacitor stores the energy that is demanded in front of each pulse. A protective coil is assembled between the rectifier and the capacitor to ensure that the energy will be taken from the capacitor and not from the net voltage. This would otherwise destroy the rectifier immediately. The coil raises the current slowly after each pulse.

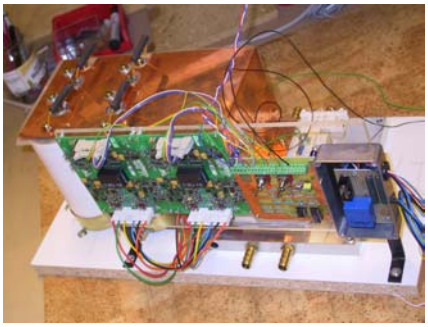


Current and voltage across the protective coil right after a magnetizing pulse.

Signal measurement

The measured signals, voltage, current and magnetic flux reminisce at the ring are sent to a control system.

The signal measurements is passing thru a PCB buffer board that separates the signals galvanic between the control system and the outside environment.

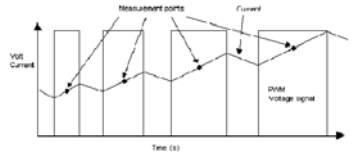


4 quadrant converter with driver boards and buffer board.

IGBT:s and the capacitors

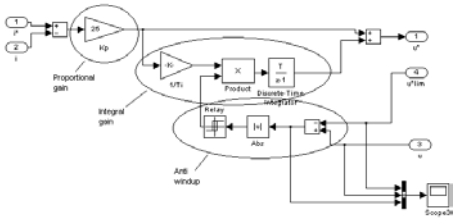
CONTROL SYSTEM

The programming is done in Simulink and is able to control the right amount of current thru the magnetizing device. The output to the IGBT:s is PWM (Pulse Width Modulation) signals, which is high at open and low for closing the IGBT:s. To measure the current at the right time, when it has increased by half for each PWM signal, it is trigged on that event.



Triggered measurement points

The current loop for controlling has also an anti windup part, to ensure that a large built up integral part wont occur. At this event the integral part will be disconnected.



Current control loop

CONCLUSION

The control system is tested and it is switching the IGBT:s with full satisfaction.

The magnetizing device is not yet built, this is performed at a sheet metal workshop. When this part arrives the final tests will be performed.