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GENERATION OF SINUSOIDAL ALTERNATING CURRENT OF VARIABLE FREQUENCY AND INTENSITY FOR MEASURING THE ELECTROMAGNETIC CHARACTERISTICS OF ELECTRIC MOTORS

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Abstract

The electric vehicle drive is nowadays considerably widespread in everyday road transport. These vehicles have an important component: the electric motor. The motors are tested using a simulation program for which knowledge of its electromagnetic and dynamic parameters are needed. These data are usually not provided by the manufacturers; therefore, it must be determined experimentally by measurements. For this purpose, at the Faculty of Engineering of the University of Debrecen there is the structure of a complex measuring system in progress. With this system, we can determine the motor parameters required for the simulation for all electric motors used in the automotive industry. In this publication, we will present a method designed to produce one of the characteristic electromagnetic parameters of electric motors; the variable frequency and strength sinusoidal alternating current required to determine the inductance of windings.

Keywords*: electric motor, measuring system, motor test bench, simulation.*

1. Introduction

Nowadays, more and more attention is being paid to alternative propulsion vehicles, and electric / hybrid propulsion. [1] This is due not only to the development of technology, but also to our more environmentally conscious lifestyle, as we all want a cleaner world free of harmful substances.

There are several designs of alternative vehicle drives, but most of them are powered by some kind of electric motor.

The Faculty of Engineering of the University of Debrecen also conducts a lot of research on alternative drives, and the Faculty team has started and achieved success in several races with electric-powered, self-designed racing cars. For the conscious development of vehicles, a vehicle dynamics simulation program is essential [2, 3], with which we can calculate the performance and driving dynamics of the electric motor as well as the car, and thereby optimize the technical characteristics of the vehicle for a given competition goal. This requires knowledge of vehicle parameters, including the characteristics of the electric motor that drives the vehicle.

The performance and other characteristics of an electric motor depend on a number of electromagnetic and dynamic parameters that are not normally provided by the manufacturer. Consequently, they must be determined experimentally. [4–8]

It is very important for successful measurements to have a complex, validated measuring system. For this purpose, the Faculty of Engineering of the University of Debrecen is in the process of building a measuring system [9], with which we can determine the motor parameters required for the simulation in the case of all electric motors used in the automotive industry.

In this publication we deal with the determination of one of the electromagnetic parameters of electric motors, the inductance of windings, which depends on the intensity of the current flowing through the windings. Described in detail are plans for a power source for generating a variable frequency and intensity sinusoidal current to excite the motor windings while measuring the voltage induced therein. This equipment complements our previously built measuring system.

2. Determination of inductance of windings

The simulation of different types of electric motors (SWDC, BLDC, PMSM, IM) requires knowledge of the inductances of the motor windings as an input parameter. [10] This is not usually provided by the manufacturers, so should be determined experimentally. The measuring arrangement assembled for this purpose is illustrated in figure 1.

For the measurements, a sinusoidal AC voltage would be applied to the stator or rotor winding in the motor, and then the voltage across the winding (*U(t)*) and the current flowing through it (*I(t)*) would be measured with the NI 9239 measurement data acquisition card. The measurement would be performed at different current intensities. Based on this, the magnetic flux of the winding (*Ψ(t)*) can be calculated by the following procedure [4, 5]:

$$\psi(t) = \int_0^t (U(\tau) - I(\tau) \cdot R)d\tau + \psi(0) \quad (1)$$

The calculation would be performed with the Simulink module of the MATLAB program. Knowing the functions *Ψ(t)* and *I(t)*, the magnetic flux can be given as a function of the current intensity. The current derivative of the magnetic flux gives the inductance *L(I)* as a function of the current, which can be given to the simulation program with “Lookuptable”.

In the following, the plans of the previously mentioned AC power source required to perform the measurements are described.

3. The planned power source

To perform accurate measurements, we need to produce sinusoidal alternating current with variable frequency (5-50 Hz) and intensity (0-200 A). One way to do this would be to use a frequency converter. For this, we have a Morgensen MSI200A-004G/5R5P-4 device, the output voltage signal of which was examined using an HAMEG HM303-6 analog oscilloscope. The measured voltage signal is illustrated in figure 2.

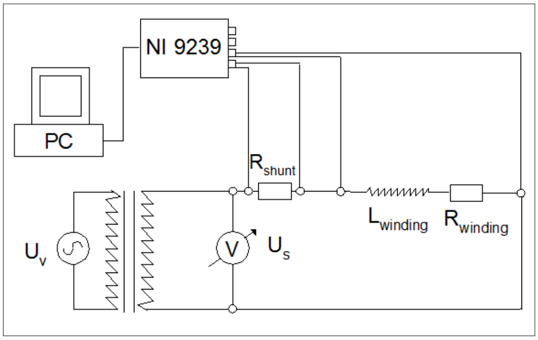

Figure 1. *Measurement layout for determining inductances.*

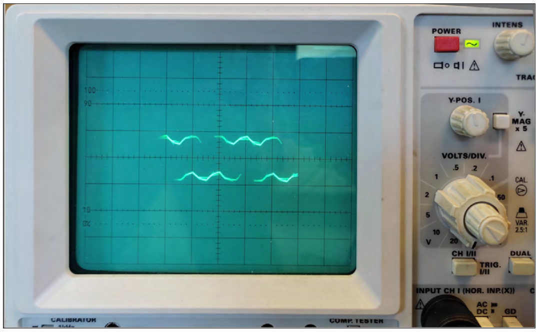

Figure 2. *Frequency converter output voltage signal.*

The voltage signal generated by the frequency converter, as shown in the figure, is not sinusoidal, so it cannot be used directly for measurements. It has also been observed that the frequency converter can only reach the set frequency a certain time after switching on, so this is not suitable for measurements, as it is not advisable to load the winding for a longer period of time at high current intensities. Furthermore, it only supplies voltage to its output when it is connected to a three-phase motor. Thus, to solve the above problems, we plan to build a system that is suitable for producing purely sinusoidal alternating current.

3.1. Schematic diagram of the arrangement

Figure 3 shows a schematic drawing of the designed power source.

The sinusoidal alternating current required for the measurements would be generated by a separately excited generator. A variable DC voltage would be applied to the excitation windings (stator) of this, thereby changing the voltage at the output of the generator, and thus the alternating current applied to the excitation of the windings.

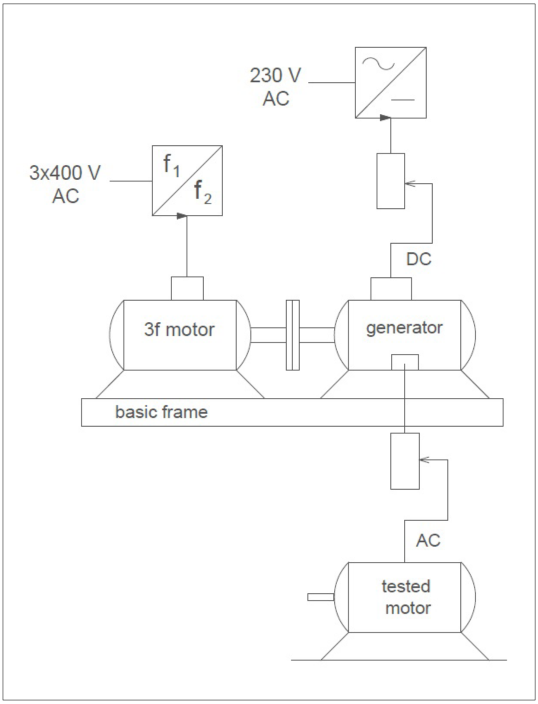

Figure 3. *Schematic diagram of the power source.*

Figure 4. *Morgensen MSI200A-004G/5R5P-4 frequency converter.*

Variable resistors can also be used in the measuring circuit to more accurately set the desired current intensities on the tested motor. In addition, a transformer can be used to achieve high current intensities if required.

The generator would be driven by a 3-phase asynchronous motor through a clutch. This motor would be connected to the previously mentioned frequency converter, thus ensuring the setting of different RPMs and thus different output frequencies.

The whole system would be fixed to a basic frame designed by us, which would be connected to our previously built measuring system, which is suitable for testing electric motors

3.2. The selected components

A Morgensen MSI200A-004G/5R5P-4 frequency converter with a power of 4/5.5 kW is planned to drive the motor (**figure 4**).

This would drive the Morgensen MSE3-90L-2 2.2 kW three-phase asynchronous motor shown in **figure 5.** The performance of the motor is designed to be adequate to perform the measurements.

The generator, according to our plans, would be an EVIG separately excited generator (**figure 6**).

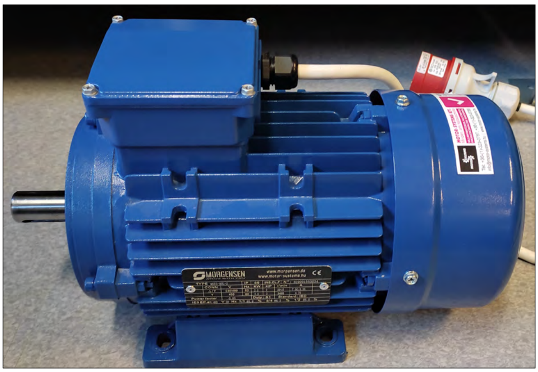

Figure 5. *Electric motor for driving the generator.*

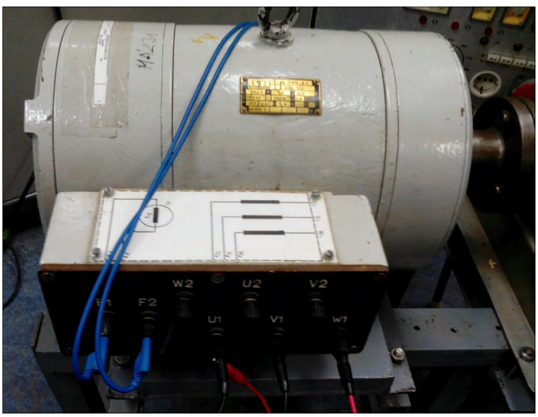

Figure 6. *The separately excited generator.*

External excitation is required to control the magnitude of the alternating current at the output of the generator at a given RPM (frequency). This can be done with a DC current of 0-230 V connected to the excitation windings. To do this, a rectifier and a toroidal transformer will be added to the system.

4. Conclusion

In this paper, we deal with the determination of one of the electromagnetic characteristics of electric motors used in the automotive industry, the inductance of windings. To determine this experimentally, a purely sinusoidal alternating current of variable frequency and intensity is required. To do this, we examined a frequency converter available to us, which, based on our measurements, revealed that the voltage generated by it was not directly suitable for performing the measurements.

Therefore, we have planned to create a system that can generate alternating current that meets our requirements. The main elements of this are a 3-phase asynchronous motor driven by a frequency converter and a separately excited generator connected to it. We presented the structure and operation of the planned measurement arrangement and the devices selected for it.

We plan to build this measuring arrangement in the Laboratory of Machine Elements of the Faculty of Engineering of the University of Debrecen, thus supplementing our previously established measuring system suitable for the experimental testing of electric motors. Once the system is set up, we will measure the inductance of the windings of the motors used in vehicle drives, and then use the measured data in simulation programs as input data.

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