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- Công nghệ thông tin và trí tuệ nhân tạo;
- và những tiến bộ kỹ thuật trong các lĩnh vực kể trên.

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Numerical simulation method application in the design of a line-start permanent magnet synchronous motor

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ABSTRACT

Saving energy is quickly becoming an unavoidable issue for countries all over the world. One of the most important requirements for sustainable development is the efficient and economical use of energy. The electromechanical conversion stage consumes the most power of any stage of electricity use, accounting for more than 70 percent of total power consumption. High-performance motors, such as synchronous motors with permanent-magnet squirrel-cage rotors (PMSM), are becoming increasingly popular and used to reduce power consumption for electromechanical conversion. Because of the complicated structure of the PMSM, designing by an analytical method with low accuracy reduces motor efficiency, so it is critical to research, design, and innovate technology to improve engine performance. The article's content discusses the use of numerical simulation methods in the design of PMSM, replacing the traditional analytical method and thus improving the efficiency of motor design.

1. Introduction

Nowadays, energy saving is becoming an important issue for countries all over the world. Economical and efficient energy use is one of the most important requirements for sustainable development in order to deal with the risk of depletion of fossil fuel sources and the harmful effects of pollution on the environment. The electric motor consumes the most electricity of any electrical appliance, accounting for roughly 70% of total grid power [1].

The IEC60034-30 standard divides motor efficiency into five categories: IE1-Standard Efficiency, IE2-High Efficiency, IE3-Premium Efficiency, IE4-Super Premium Efficiency, and IE5-Ultra Premium Efficiency. Induction motors (IM) are widely used in the market today, but increasing their efficiency to IE3 or IE4 according to IEC60034-30 is extremely difficult [3-2]. A line-start permanent-magnet synchronous motor (LSPMSM) is an energy-saving alternative to the IM motor [3-5].

The rotor losses of the IM account for about 20% of the total losses, the LSPMSM have no rotor losses [5-6]. Also the loss on the LSPMSM is greatly reduced due to the reduction of the motor's magnetizing current. Therefore, LSPMSM has high efficiency reaching IE3, which can go up

- Choose the membership function and approximate the solution on each element.
- Concatenate all elements in the analytical domain to obtain the system matrix.
- Solve the system matrix by iterative method.

To calculate according to FEM requires the support of digital computers and software programs written on the mathematical foundation of FEM.

3. Optimization of LSPMSM design using FEM numerical simulation method

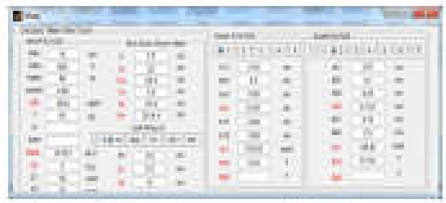
The LSPMSM is a hybrid motor with three-phase windings distributed in the stator tracks (similar to an IM), the rotor of the motor uses a squirrel cage and is fitted with a permanent magnet, shown in Figure 1 [10].

Figure 1. LSPMSM

LSPMSM can be started directly without using controller, after starting the motor will work at synchronous speed with high torque, low inertia. Depending on the arrangement of the permanent magnets on the rotor, there will be different rotor configurations.

The motor selected for design simulation is a 3-phase type and has typical specifications: Nominal power Pn = 15kW; nn = 3000 (rpm); Un = 660/1140 (V), type 2P. In order to perform the simulation of the optimal design of the LSPMSM, perform the calculation of the initial motor parameters with the calculation results given in Table 1.

Table 1. Calculation results of motor parameters Pn = 15kW



Result of circuit parameter design from stator steel foil and motor rotor Pn = 15kW; nn = 3000 (rpm), Un = 660/1140 (V) type 2P shown in Figure 2 and Figure 3.

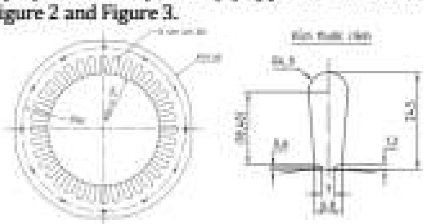


Figure 2. Dimensions of stator

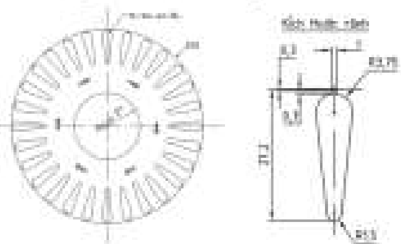


Figure 3. Dimensions of the rotor

In order to have the optimal design of the permanent magnets on the rotor circuit, different layout options are offered, then analysis and selection of the optimal design options are available. For LSPMSM Pn = 15kW type 2P permanent magnets placed on two symmetrical sides, offering two layout options as follows:

- Option 1: U-shaped permanent magnets is arranged from three segments forming;
- Option 2: permanent magnets in the shape of a horseshoe (C-shaped) are arranged

Simulation results of electromagnetic field distribution, conductor current and LSPMSM speed response of the two options are shown in Figures 4, 5 and 6.

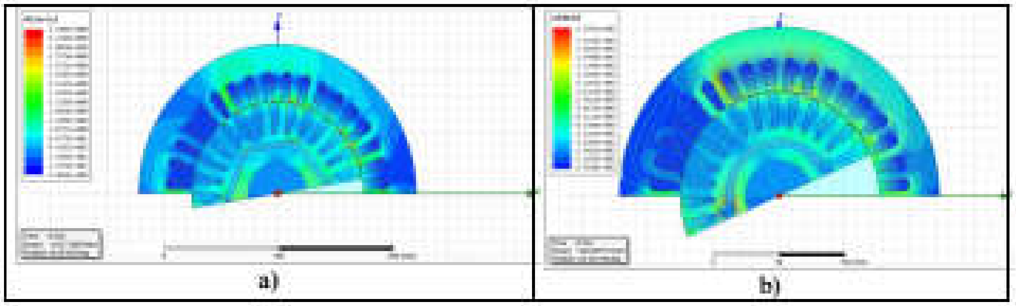


Figure 4. Electromagnetic field distribution in the magnetic circuit of the LSPMSM

a- Structure of U-shaped permanent magnets; b- Structure of C-shaped permanent magnets

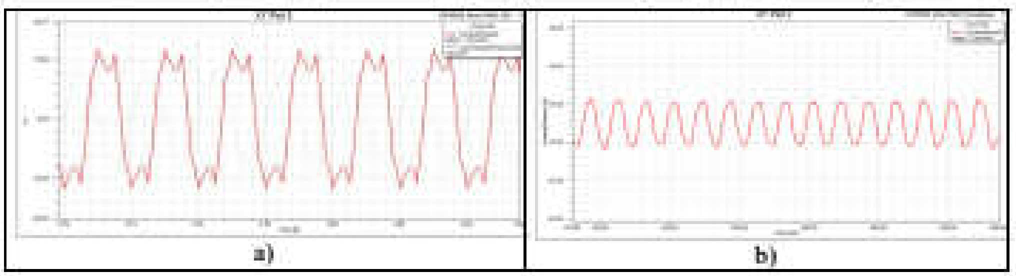


Figure 5. Current on the stator winding of the LSPMSM

a- Structure of U-shaped permanent magnets; b- Structure of C-shaped permanent magnets

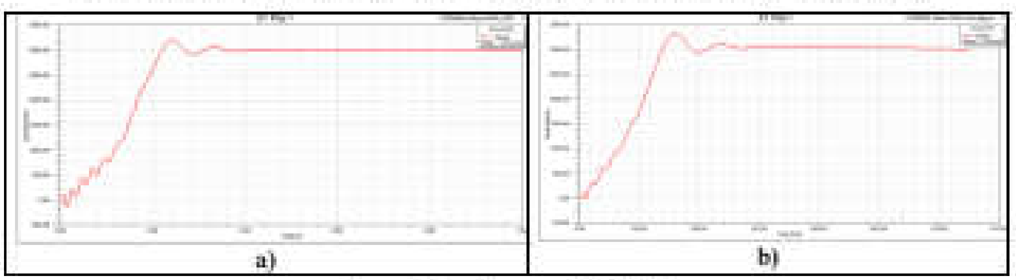


Figure 6. Speed response of LSPMSM

a- Structure of U-shaped permanent magnets; b- Structure of C-shaped permanent magnets

Numerical simulation results by FEM show that both layout options allow the motor to start automatically. However, the U-shaped layout plan has a strong distribution of electromagnetic fields in the motor, making the starting time long. At that time, the current on the winding is nonlinear, causing the starting torque to vibrate, speed response is slower the motor vibrates more