Project Title: Evaluating the design of the permanent magnet-assisted synchronous motors and 3 kW Sample prototyping.

Department:	Knowledge and Technology Transfer and Development of Synchronous Reluctance and Superconductor Electric Motors plan	***Employer:***	Niroo research institute (NRI)
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Project Necessity:

The need to energy saving to reduce the intensity of electricity consumption, has led to the use of high-efficiency motors in various applications, such as electric-hybrid vehicles, pumps and fans, production lines, etc., has received serious attention. In recent years, due to the many advantages of reluctance synchronous motors compared to other types of electric motors, many activities have been done to replace these motors with conventional motors in various applications. If a magnet is added to the rotor structure of SynRM motors (PMA-SynRM), the motor energy efficiency class will be upgraded from IE4 to IE5, making it a viable option for both fixed speed and variable speed applications. It becomes.

Due to the increase in the price of rare earth permanent magnets in the last decade and its effect on the cost of all types of electric motors that use magnets in their structure, many research activities have been done to replace rare earth magnets in these motors. Meanwhile, the use of ferrite magnets has received more attention due to its low price and easy accessibility, and large companies such as ABB, reluctance synchronous motors with ferrite auxiliary magnets in the range of 0.55 to 18.5 They produce kilowatts and speed ranges of 1000 to 5400 rpm.

Considering the mentioned advantages for PMA-SynRM, this project aims to gain technical knowledge of designing auxiliary synchronous motors with auxiliary magnet in common industrial applications (as an alternative to induction motors) and to build a 3 kW sample.

Project Goals:

- Design of two sample PMA-SynRM and its drive (taking into account the thermal problems of electric motors)
- Prototyping a 3kW sample of a three-phase PMA-SynRM with ferrite permanent magnet and its drive system with the following technical specifications:
  - Output power 3 kW
  - Four poles, with a nominal speed of 1500 rpm and the ability to control the speed up to the nominal speed
  - Line voltage 400 volts (drive system input)
  - Energy efficiency class equivalent to IE5
  - Temperature performance range: between -20 to 40 degrees Celsius
  - Overload tolerance of 10% for one minute
  - Torque ripple equal to three-phase induction motors with similar power
  - Use of standard body (Frame) of standard three-phase induction motors
  - Closed-loop control system
  - Power factor more than 95%
- Multifunction optimization of the motor and its drive system with objective functions:
  - Price reduction (in proportion to the country's resources)
  - Increase the efficiency of the motor and the drive
  - Reduction of engine torque ripple

Abstract:

First, the technical specifications and the minimum efficiency of the electric motor with IE5 energy efficiency standard were determined. Different structures of PMA-SynRMs and their design procedure were extracted by studying related articles. Then, two samples PMA-SynRMs were designed using two different types of permanent magnets and simulated by finite element method. Motor operating parameters, including torque, torque ripple, and efficiency, as well as the equivalent circuit parameters of the PMA-SynRM were calculated using this method.

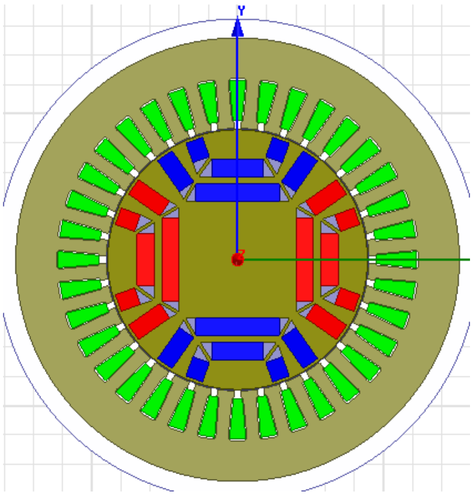

Figure 1: The structure of PMA-SynRM used in the design

Finally, by comparing the performance characteristics of these designs, a sample of a three-phase PMA-SynRM with ferrite permanent magnets was designed and optimized. Electromagnetic simulations have been performed in the Maxwell software environment. With the help of the features of this software, the designed motor was thermally analyzed.

Table 1: Optimal structures of machines with ferrite magnets

Design No.	PM No.	PM depth (mm)	Each phase turn No.	Stack length	PF (%)	Ripple (%)	Efficiency (%)	Current (A)
1	3	3	210	300	94.5	4.1	93.60%	9.6
2	3	4	210	300	97	6	92%	10.1
3	2	3	180	200	92	4.1	95%	9.6
4	2	3	180	250	95	4.35	94.70%	8.8

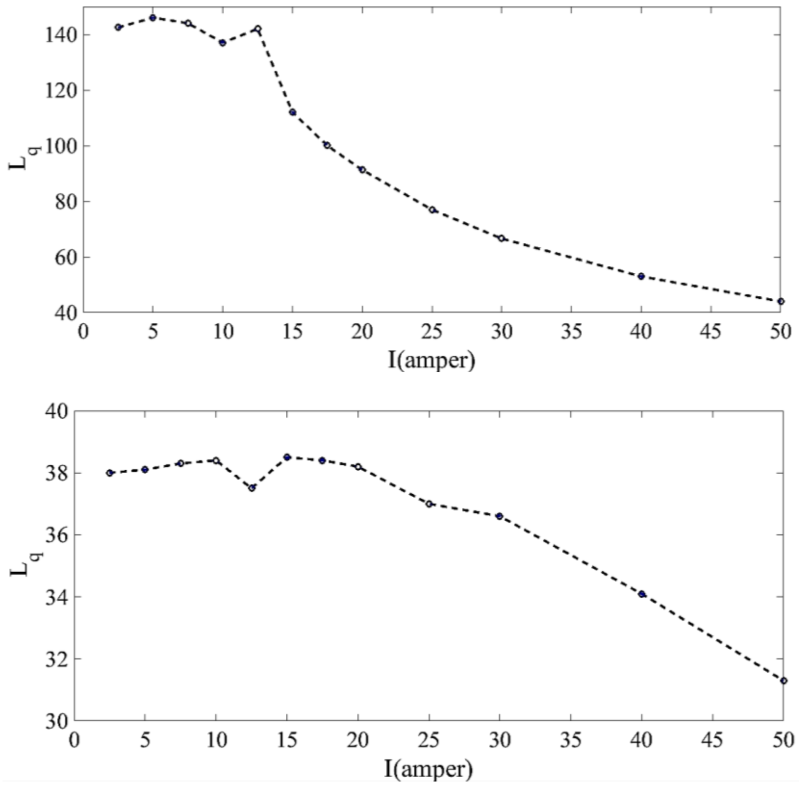

Figure 2: The dq stator winding inductances

Also, The drive of the optimally designed motor was designed and simulated using the expected technical specifications and equivalent circuit parameters of the motor. Based on this design, print boards were prepared and prototyped. Due to the lack of a sample of designed PMA-SynRM, the drive of this motor was tested using a permanent magnet synchronous motor sample. The motor control system is implemented based on the vector control method.

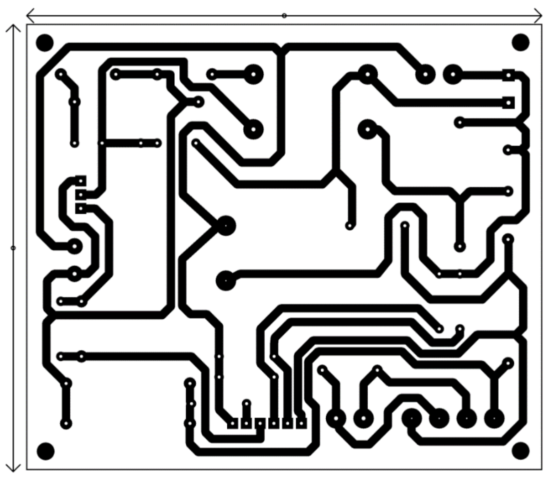

Figure 3: Printed board of the power circuit

95mm

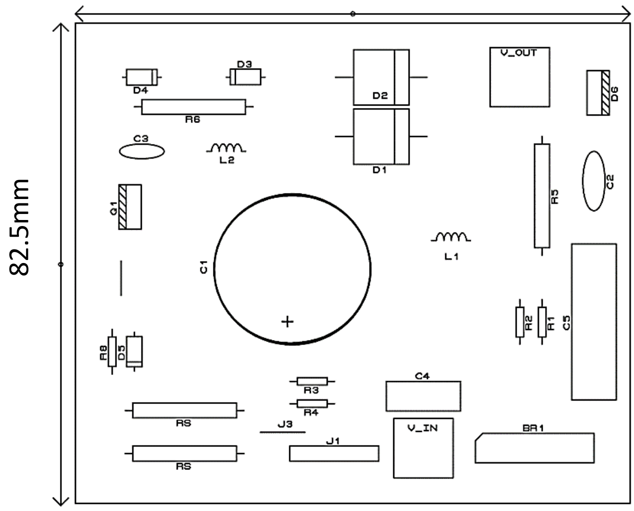

Figure 4: The location of the components is the power circuit printed board

Steps and Methodologies:

1. Study of the standards and articles related to the design of the PMA-SynRM, with IE5 energy efficiency standard.
2. Finite element simulation and dynamic modeling of the motor and its drive using Matlab software.
3. Prototyping and testing the designed drive of the motor.

Main Results (technical outputs, patents, papers, books, reports, etc.):

- Project steps (1 to 3) reports.
- A prototyped motor drive.