New topology of Single-Phase Field Excitation Flux Switching Machine for High Density Air-Condition with segmental rotor

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Abstract

This paper presents a new topology of 12S-6P field excitation flux switching machine (FEFSM). Three-phase 24S-10P FEFSM has been developed with the overlap windings between armature and FEC, create problem of the high end coil which increase the size of the motor and also losses. Therefore, a single-phase 12S-6P FEFSM with adjacent armature and the FEC is introduced to reduce the coil end problem. In this study, the operating principle of single-phase 12S-6P FEFSM with segmental is also investigated. Then finite element analysis is used to validate the torque, speed and power characteristics. Finally, the designed is suitable for High Density Air-Conditioner because 1kW power generated at 1.8Nm and the corresponding speed of 4977r/min.

Introduction

Air-conditioner usually works under the hot environment, in order to improve the hot environment, to enhance the comfortable feeling of human body [1]. In common use, an air conditioner is a device that lowers the air temperature. Nowadays most of the air conditioner system used AC electric motor. AC motor have three kinds namely induction motor (IM), synchronous motor (SM) and switched reluctance motor (SRM) [2]. This induction motor is commonly used on the blower and fan of air conditioner. An induction motor's rotor can be either wound type or squirrel-cage type. It has winding at rotor and stator. Induction motors (IM) use shorted wire loops on a rotating armature and obtain their torque from currents induced in these loops by the changing magnetic field produced in the stator (stationary) coils. These motors use carbon brush and it indirectly involves the maintenance process. In addition, the iron loss will increase as the use of the rotor winding. The switched reluctance motor (SRM) is a type of reluctance motor, an electric motor that runs by reluctance torque [3]. The synchronous motor (SM) is an electric motor that is driven by AC power consisting of two basic components a stator and rotor. Flux switching machines (FSM) is a new category of synchronous machines.

The flux switching machine (FSM) is a form of salient-rotor reluctance machine with a novel topology, combining the principles of the inductor generator [4-5] and the switched reluctance machine (SRM) [6]. The rotor and stator are the main part of FSM. Rotor is the iron core at the center stator and has a simple shape and has high strength. While both field and armature winding are placed on the stator. The term “flux switching” is to describe machines in which the stator tooth flux switches polarity following the motion of a salient pole rotor and this is basic principle of operation [7].

Based on the literature, the three-phase 24S-10P non-segmental rotor has been developed it only suitable for applications that required high speed, due to its robust and single rotor structure [8]. Fig. 1 shows the three-phase FEFSMs topologies. The overlap windings between armature and FEC create problem of the high end coil which increase the size of the motor and also have a complex structures. Therefore a 12S-6P FEFSM with non-overlap winding is introduced to reduce the coil end problem. A single-phase AC can be realized in the armature winding with the field winding position with DC excitation on the stator and armature winding is connected to the AC supply to allow the rotor to rotate. Torque is developed from the changing mutual inductance of the windings [9-10].

There are some advantages when both field winding and the armature winding are placed on stator such as elimination of carbon brush and field flux can be easily controlled. Another advantages of this machine are easy cooling of all active parts in the stator and robust rotor structure that makes it better suitability for low-speed or high-speed application. This type of machine is classified into flux switching synchronous machines (FSSM) which is also getting more popular and popular in recent years [11]. This paper shows the analysis of single-phase FEFSM 12S-6P with segmental rotor and effected with non-overlap armature and field winding.

Design Specifications and Procedures

The design restrictions, the target specifications and parameters of the proposed FEFSM 12S-6P with segmental rotor are listed in Table 1. The limit of the current density is set to the maximum $30A_{rms}/mm^2$ for armature winding and $30A/mm^2$ for FEC, respectively. The machine configuration and windings for 12S-6P FEFSM with segmental rotor are illustrated in Fig. 2.

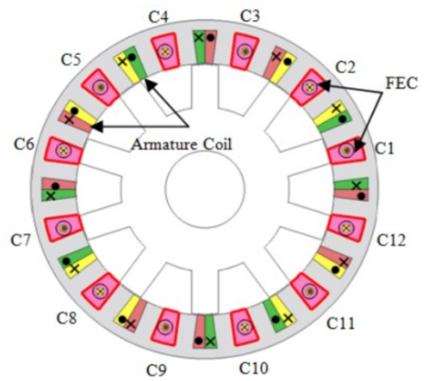

Fig. 1. Examples of 3-phase FEFSMs 12S-10P non-segmental rotor

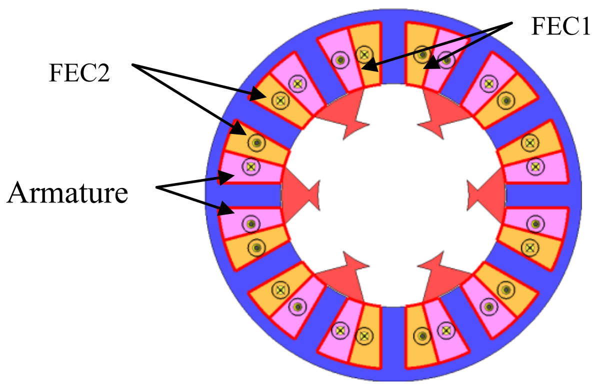

Fig. 2. Single-phase 12S-6P FEFSM with segmental rotor

From the Fig. 2, both FEC and armature coil is non-overlap windings. The directions of the FEC are in counter clockwise polarity and anti-clockwise polarity, while the armature coils are placed in between of FEC. Commercial FEA package, JMAG-Designer ver. 13.0, released by the Japan Research Institute (JRI) is used as a 2D-FEA solvent for this design. Initially, the rotor, stator, armature coil and FEC of the proposed 12S-6P FEFSM is drawn by using Geometry Editor followed by the set up of materials, conditions, circuits and properties of the machine are set in JMAG Designer. The electrical steel 35H210 is used for rotor and stator body. Furthermore, coil arrangement tests are examined to certify the operating principle of the machine and to situate the position of each armature coil phase.

Table 1: Design Restrictions, Specifications and Parameters for 12S-6P FEFSM

Items	**12S-6P FEFSM with Segmental**
Number of phases	1
No. of slots	12
No. of poles	6
Stator outer radius (mm)	75
Stator inner radius (mm)	70
Stator back inner width (mm)	5
Stator tooth width (mm)	10
Armature coil slot area (mm^2)	251
FEC slot area (mm^2)	251
Rotor outer radius (mm)	44.5
Rotor inner radius (mm)	30
Rotor pole radius (mm)	33.5
Rotor tooth width (mm)	23
Rotor shaft	30
Air gap length (mm)	0.5
Number of turns per field tooth coil (FEC)	75
Number of turns per armature coil slot (AC)	11

Performances of 12S-6P FEFSM with segmental rotor

Fig.3 shows the graph torque versus excitation current density, J_E at various armature current densities, J_A. Torque produced at segmental rotor is higher which is it can be seen when J_E and J_A on 30A/mm2, the torque produced is 16.6Nm. The torque and power versus speed curves of the designed motor is plotted in Fig. 4. From figure, the initial speed 4977r/min, the resulting torque is 16.6Nm and this is the highest torque value. The corresponding power reaches 8.66kW and the average power is 8.17kW.

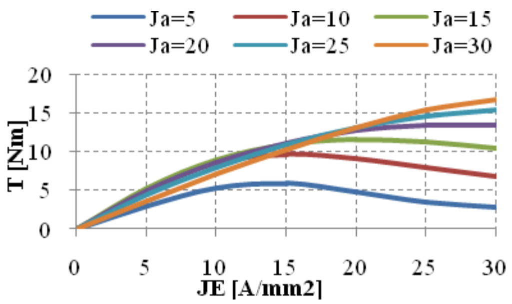

Fig. 3. Torque versus J_E at various J_A for 12S-6P FEFSM with segmental rotor

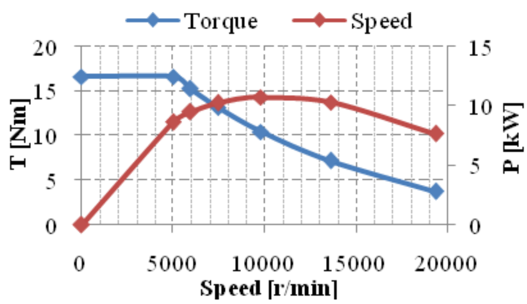

Fig. 4. Torque and power versus speed characteristics 12S-6P FEFSM with segmental rotor

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Conclusions

In this paper, design study of 12S-6P FEFSM with segmental has been investigated. The procedure to design the FEFSMs has been clearly explained. The performances of the FEFSMs such as torque, speed and power characteristics have been investigated. The machines have very simple configuration yet no permanent magnet and thus, it can be expected as very low cost machine. Problem of high end coil which increase the size of the motor is solved with adjacent armature and FEC to reduce the coil end problem. Finally, 12S-6P FEFSM with segmental rotor is considered be applied suitable for High Density Air-Conditioner. It is because 1kW power generated at 1.8Nm and the corresponding speed of 4977r/min. To produced torque equal to 1.8Nm, FEC current density, J_E and armature current density, J_A should be set to less then 5A/mm^2.

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