Switched reluctance motor drive for 42 V electric power steering

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Abstract

In modern cars, the use of electrical and electronic features to enhance comfort, convenience and safety has contributed to a sharp increase in power demands and in wiring harnesses. Consequently, the limitations of the 12 V power electric system have become apparent. The new 42 V Power-Net has emerged as a solution to these drawbacks and provides the opportunity to replace mechanically actuated systems with systems that are based on electronically controlled electric motors [1]. Electric power assisted steering (EPAS) is becoming an alternative to conventional hydraulic power steering. EPAS improves fuel economy, gives the capability to vary the assist according to the speed of the vehicle, provides assistance even when the internal combustion engine is switched off and enables an awkward fluid to be eliminated. The main function of an EPAS is to provide steering assistance to the driver by means of an electronically controlled electric motor.

The key components of an EPAS system are a combined torque and position sensor, an electric motor with a gear reduction mechanism, an electronic control unit, and control and diagnostic algorithms that are implemented in the software components of an EPAS system are a combined torque and position sensor, an electric motor with a gear reduction mechanism, an electronic control unit, and control and diagnostic algorithms that are implemented in the software. There are different types of EPAS. The name of the system depends on the location of the electric motor and each system is designed for a specific vehicle weight and size. The three main types are column assist for small cars, pinion assist for medium-sized cars, and rack assist for bigger cars [2-3]. Different types of motors have been proposed for EPAS applications [4-5]. Although the brushless DC motor and permanent-magnet synchronous motors are the best-placed candidates, the switched reluctance motor (SRM) can be an attractive alternative due to its simple and rugged construction, its fault tolerant capability, and its high efficiency [6].

In this paper, an SRM drive is designed for rack-type EPAS systems that should provide a maximum rack force of 10 kN and the torque-speed curve given in Fig. 1.

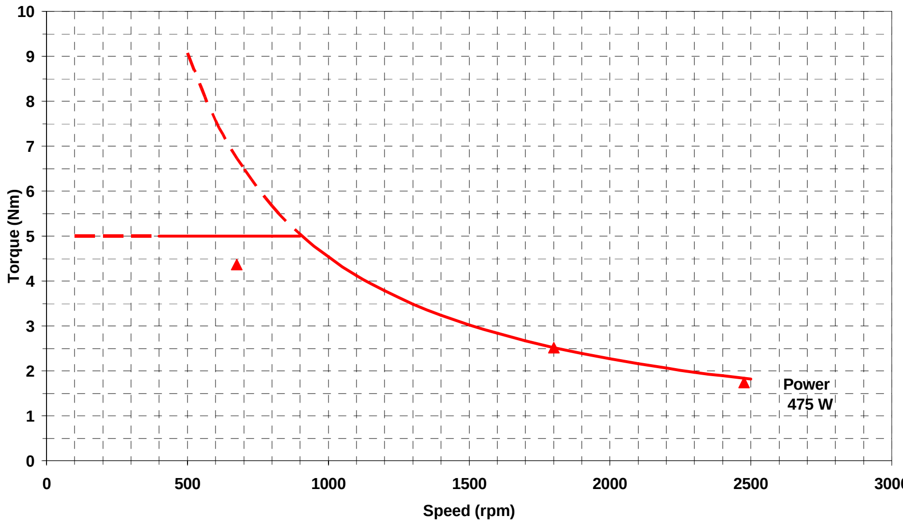

Fig. 1. Torque-speed curve required for the SRM to provide a rack force of 10 kN

This requires electric motors with a mechanical output power of about 475 W and a torque of 2.52 Nm at 1800 rpm. The static peak force (10 kN) in stall conditions is forecast during the parking operation. It is required for a duty cycle of 5 s over 1 min. (S3 8.5%). The DC voltage is 42 V and the environmental temperature is between -40 ºC and 125 ºC.
A four-phase SRM with 8 stator poles and 6 rotor poles has been chosen to reduce torque dips and to ensure better behavior in fault conditions. The control of the SRM drive must take into account the fact that torque ripple minimization is a strong requirement [11]. The drive must also have specific controls to mitigate the effects of the faults. In the 8/6 SRM, the external diameter, including the stator frame required for the application, is 94 mm and the air gap is fixed to 0.35 mm. Fig. 2 and Fig. 3 show photographs of the stator and the rotor of the 8/6 SRM. The power converter is an asymmetric bridge or classic converter with two switches and two diodes per phase. A resolver is chosen as a position and speed transducer.

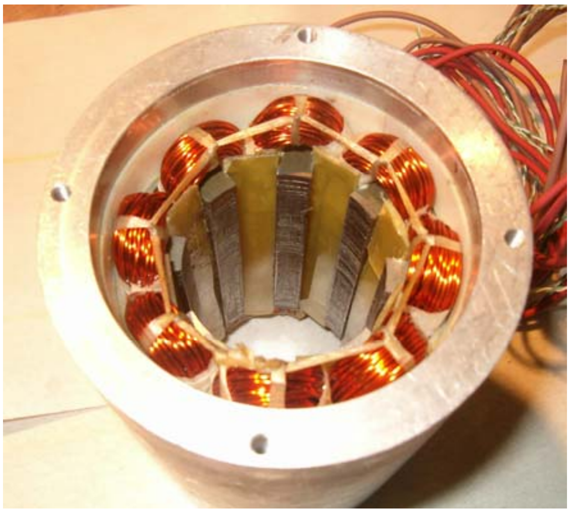

Fig. 2. Stator of the 8/6 SRM

Fig. 3. Rotor of the 8/6 SRM

As the length of the rotor is almost twice its diameter, two-dimension finite element analysis (2D FEA) is used to validate the design. No correction factor is required to take end effects into account. Flux plots in the aligned and unaligned position are obtained using the FLUX 2D FEM package [7]. Static torque plots of torque versus position for various current levels, which were obtained by the method of virtual work, are shown in Fig. 4.

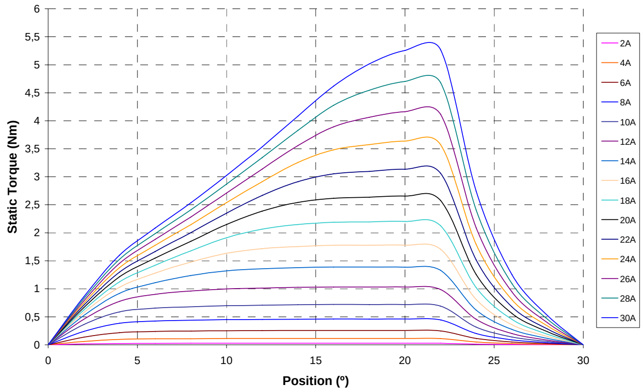

Fig. 4. Plots of torque versus rotor position for various current levels for the SRM

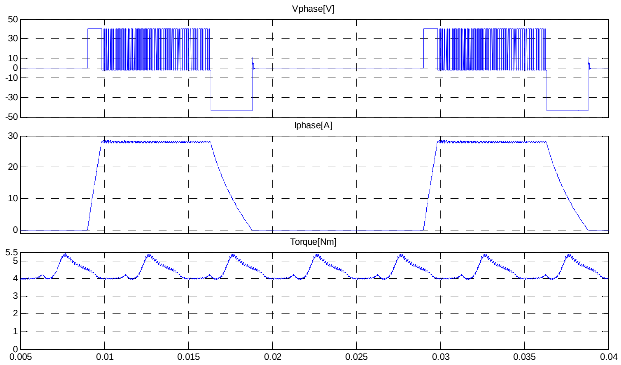

Fig.5. Voltage, current and torque waveforms at 500 rpm and a current reference of 28 A.

The simulation of the drive (including the SRM, power converter and control) was implemented in Matlab-Simulink using the 2D-FEA results. Fig.5 shows the voltage, phase current and torque waveforms at 500 rpm and a current reference of 28 A.

Acknowledgments

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