永磁輔助同步磁阻馬達之相變數模型建構

Phase-Variable Modeling of a PM-Assisted Synchronous-Reluctance Motor

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關鍵詞(Keywords)

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- 相變數模型建構
  Phase-Variable Modeling
- 能效模型
  Energy Efficiency Modeling

摘要(Abstract)

交流馬達可分同步馬達與交流感應馬達，兩者相比較，同步馬達有能源效率較高的優點。同步馬達可分為永磁同步馬達、繞線同步馬達與同步磁阻馬達，其中同步磁阻馬達其轉子不像繞線同步馬達需要在轉子繞線以激磁；也不必像永磁同步馬達那樣需在轉子裝置永久磁鐵，同步磁阻馬達的轉子材料是如矽鋼片的高導磁材料，藉由轉子凸極現像產生磁阻的不均勻，反應在定子電感的不同來產生力矩稱之為磁阻轉矩(reluctance torque)而轉動，其優點為不會像永磁同步馬達那樣轉子磁鐵經年累月運轉後會產生磁性減弱的問題，且構造簡單，具有堅固的特性，近年來吸引著工業界的注目。但其缺點為其轉矩成份只靠 d 與 q 軸定子電感的不等所形成的，在某些應用場合，此轉矩會有不夠大的現像。為此，而有所謂的永磁輔助同步磁阻馬達(PMa-SynRM)的出現，它的構造是在一般同步磁阻馬達的轉子上加裝一點輔助的永久磁鐵，一則以增加激磁轉矩(excitation torque)成份，二則讓 d 軸定子電感變小，使得馬達產生的整體轉矩增大。故精確的馬達模型，以便

分析其特性，使其性能優化是非常重要的。

本文描述一個 PMa-SynRM 馬達之相變數模型之建構，以電磁、機電與機械三部份來推導其數學方程式，並利用 PSIM 模擬軟體工具建立該馬達的相變數模型，在其三相輸入端以電阻、電感與相依電壓源電路元件來建構其模型，使其在模擬分析時可仿如一實際的馬達操作。所建模型的特色有二：一是三相定子輸入端是採用電路元件建立的，可以和馬達變頻驅動電路連接，以便做馬達驅動控制的整合模擬；二是負載轉矩輸入端是以數學函數元件建立的，可用數學函數的形式加入負載轉矩。給予三相輸入電壓的頻率並加入負載轉矩來模擬分析，驗證了該模型建構的正確性。

The AC motors can be classified as synchronous motors and induction motors, and the synchronous motors have more energy efficiency than the induction motors. The synchronous motors can be classified into permanent magnet synchronous motors (PMSM), wound synchronous motors, and synchronous reluctance motors (SynRM). The SynRM motor is unlike the other synchronous machines, in which the rotor is wound with wire for magnetic excitation or is equipped with a permanent magnet. The rotor material of SynRM motor is a material with high-permeability such as silicon steel. The torque generation for rotation of the SynRM is by means of the reluctance unbalance due to the salient pole effect. In addition, the SynRM motor is unlike the PMSM motor, in which the rotor magnetism will decrease after long-time rotation. Recently, with the features of simple and rugged construction, the SynRM motor has received a lot of attention in the industry. The weakness of the SynRM motor, however, is that the motor development torque is generated by means of the un-equivalence of the d- an q-axis stator inductance. In some applications, the development torque is not large enough. Therefore, the so-called permanent-magnet assisted reluctance motors (PMa-SynRM), in which some permanent magnets are added on the rotor, have appeared recently. This design not only assist the addition of the excitation torque component, but also increase the reluctance torque component by decreasing the d-axis stator inductance so as to increase the motor total torque. Thus, an accurate model of the PMa-SynRM motor is important as to analyze and optimize the motor performance.

This paper presents the phase-variable modeling of a PMa-SynRM motor in PSIM simulation tool. The model was divided into an electro-magnetic part, an electro-mechanic part, and a mechanical part to derive the mathematical model of the synchronous reluctance motor. Just like a real motor, the three-phase inputs were modeled by means of the resistor, inductor, and the dependent voltage source circuit elements. There are two features of the constructed model block. One is that the three-phase inputs are circuit-based, so it can be directly connected to the inverter for integrated system simulation. The other one is that the load torque input is equation-based, so the load torque can be given by a mathematical function. Given a three-phase input voltage and a