三相交流感應馬達之建模與線上轉矩速度特性模擬分析

Modeling of Three-Phase AC Induction Motor and On-Line Simulation Analysis of the Torque-Speed Characteristics

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摘要(Abstract)

交流感應馬達因比永磁馬達有更強健、低成本的特性，因此廣泛地應用在馬達驅動系統中，尤其在較大功率電動車與牽引車的應用上，感應馬達的重要性將逐年增加。在這些應用中，需要分析馬達的轉矩速度特性，使得在適當的速度範圍內產生足夠的轉矩以驅動馬達帶動車體，因此精確的感應馬達模型與建構，在研究感應馬達轉矩速度特性暨其模擬與分析，是非常有用與重要的。

我們建立了一個三相交流感應馬達之相變數模型，以電磁、機電與機械三部份來推導感應馬達的數學方程式，並利用 PSIM 模擬軟體工具建立該感應馬達的相變數模型方塊，給予輸入信號的頻率與負載轉矩分析，驗證了該模型轉速穩態響應的正確性。所建模型並和 PSIM 內建與 MATLAB/Simulink 內建之感應馬達模型相比較，所得到三者的轉速與電流響應一樣，驗證了所建模型其暫態響應的正確性。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，可以數學函數的形式加入負載轉矩。

我們並提出一個以線上計算方式得出一個待測感應馬達的轉矩速度曲線。利用所建模型，以傳統的直流測試、無載測試與堵轉測試方法進行該待測馬達的參數量測，用所得參數及感應馬達在穩態的轉矩方程式，以線上計算方式即可得出該待測感應馬達的轉矩速度曲線。並用所建模型，仿照動力計的方法，在馬達模型的轉矩輸入端加一斜坡負載轉矩，得出施加負載後的轉矩速度曲線圖。比較仿照動力計的方法和線上計算方法，兩者所得到的轉矩速度曲線相差不大，說明所提線上計算量測感應馬達轉矩速度曲線方法的可行性。

AC induction motors have been widely used in modern motor drive systems due to features such as more rugged structure and lower price compared to PM motors. The importance of induction motors will increase in high-power electric vehicles and traction applications. In these applications, the torque-speed characteristic analysis is needed, so that enough torque can be generated to drive the vehicle and load during the proper speed range. Therefore, an accurate model and construction of the model for understanding the induction motor torque-speed characteristics and performing simulation and analysis would be very useful and important.

In this paper, the phase-variable model of a three-phase ac induction motor has been constructed in the PSIM simulation tool. It can be divided into an electro-magnetic part, an electro-mechanical part, and a mechanical part in deriving the mathematical model of the induction motor. Given a three-phase input voltage and a constant load torque, the stead-state speed response can be shown to be correct. The constructed model block is also compared with the built-in model block in PSIM and MATLAB/Simulink, respectively. The speed and current responses of the three model blocks are the same. This can prove a correct model in transient responses. There are two features of the constructed model block. One feature is that the three-phase inputs are circuit-based, so it can be directly connected to the inverter for integrated system simulation. The other feature is that the load torque input is equation-based, so the load torque can be given by a mathematical function.

This paper also proposes an online computational method to obtain the torque-speed curve of an under-test induction motor. With the constructed model block, the parameters can be measured by using the conventional dc test, no-load test, and locked-rotor test methods. Then, with the tested parameters, the motor torque equation in steady state can be computed on line to obtain the motor torque-speed curve. The simulation as a dynamometer to obtain the motor torque-speed curve has also been done by using a ramp-function load torque input to the model block. From the simulation results, it can be seen that the two methods have little difference and shows the viability of the proposed online computation method for getting the motor torque-speed curve.