Chapter 19
Fuzzy Based Modeling, Control, and Fault Diagnosis of Permanent Magnet Synchronous Generator

N. Selvaganesan
Indian Institute of Space Science and Technology (IIST), Govt. of India, India

ABSTRACT

This chapter presents the design methodology of fuzzy based modeling, control, and fault diagnosis of Permanent Magnet Synchronous Generator (PMSG) system. The fuzzy based modeling scheme for PMSG is developed using the general Takagi-Sugeno fuzzy model. Subsequently, fuzzy controller is designed and simulated to maintain three phase output voltage as constant by controlling the speed of generator. The feasibility of the fuzzy model and control scheme is demonstrated using various operating conditions by MATLAB simulation. Also, fuzzy based fault detection scheme for PMSG is developed and presented. The positive and negative sequence currents are used as fault indicators and given as inputs to fuzzy fault detector. The fuzzy inference system is created, and rule base is evaluated, relating the sequence current component to the type of faults. The feasibility of this scheme is demonstrated for different types of fault under various operating conditions using MATLAB/Simulink.

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INTRODUCTION

Permanent Magnet Synchronous Generator is receiving significant attention from industries for the last two decades. PMSG is widely used in industrial electric drives, wind energy generation systems, flywheel energy storage system, automobiles, aerospace technology, shipboard and submarine power systems. Present research in the design of the PMSG indicates that it has high torque to current ratio, large power to weight ratio, high efficiency, high power factor and robustness (Sergey Edward Lyshevski, 2001). Currently, there is much interest in using brushless electronically commutated servo machines in high performance electromechanical systems and the application of neodymium-iron-boron ($Nd_2Fe_{14}B$) and samarium cobalt (Sm_1Co_5 and Sm_2Co_{17}) rare-earth magnets results in high torque and power density, efficiency and controllability, versatility and flexibility, simplicity and ruggedness, reliability and cost, weight-to-torque and weight-to-power ratios, better starting capabilities (Aleksandr Nagorny, 2005; Kai Zhang, 2005; Dehkordi B, 2005).

Building models of reality is a central topic in many disciplines of engineering and science. Models can be used for simulations, analysis of the system's behavior and for a better understanding of the underlying physical mechanisms in the system. In control engineering, a model of the plant can be used to design a feedback controller or to predict the future plant behavior in order to calculate optimal control actions. The analytical model of PMSG and its simulations were discussed by researchers in various literatures (Sergey Edward Lyshevski, 2001; Kai Zhang, 2005; Aleksandr Nagorny, 2005; Dehkordi, 2005; Kazuo Tanaka, 2001).

Recent advances in the theory of fuzzy modeling and a number of successful real-world applications show that fuzzy models can be efficiently applied to complex nonlinear systems intractable with standard linear methods. The idea of fuzzy modeling was first proposed by Zadeh (1973) and has subsequently been pursued by many others for more than two decades (Sen, 1990; Krishnan, 1987; Slemon, 1992). The fuzzy modeling for complex processes is regarded as one of the key problems in fuzzy systems research.

In the field of fuzzy modeling, the Takagi - Sugeno (T-S) fuzzy model (Sugeno, 1993; Zhu Wenbiao, 2000; Takagi, 1985; Kuang-Yow Lian, 2001; Natarajan, 2006) has been used to approximate accurately the dynamics of complex systems. Besides the capability of modeling nonlinear systems, there are other properties that make fuzzy models interesting not only theoretically but also for the industrial practice. Few researches (Zhang Bo, 2001; Jacek Kabzifski, 2005) have attempted in making a fuzzy model for permanent magnet synchronous motor drive. But the fuzzy modeling of PMSG is largely unexplored.

The first part of this chapter presents the design methodology for Takagi-Sugeno (T-S) based fuzzy modeling (Selvaganesan, 2007; Selvaganesan, 2009) and Mamdani based fuzzy controller for Permanent Magnet Synchronous Generator. Fuzzy model is simulated using Matlab m-file and responses like q-axis current and voltage, d-axis current and voltage are compared with analytical model simulation. Subsequently, fuzzy controller is designed and simulated for PMSG to maintain the output voltage as constant. The feasibility of the fuzzy controller scheme is tested using different operating conditions. The performance of the proposed controller is evaluated based on the performance index in compare with conventional PI controller performance.

Fault detection and diagnosis is important in engineering systems to avoid serious consequences. In complex systems, any fault possesses the potential to impact the entire system's behavior. In a manufacturing process, a simple fault may result in off specification products, higher operation costs, shutdown of production lines and environmental damage, etc. In a continuously operated system, ignoring a small fault can lead to disastrous consequences.