Design and Implementation Sliding Mode Controller Based on Radial Basis Function Neural Network for Synchronous Reluctance Motor

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Abstract—This paper presents a sliding mode control (SMC) design based on radial basis function neural network (RBFNN) to robust stabilization and disturbance rejection of the synchronous reluctance motor (SynRM) drive system. This method utilizes Lyapunov function and the steep descent rule to guarantee the convergence of the SynRM system asymptotically. Finally, we employ the experiments to validate the proposed method.

Index Terms—Sliding Mode Control, Radial Basis Function Neural Network, synchronous reluctance motor, Lyapunov function, steep descent rule.

I. INTRODUCTION

In recent decade years, a mechanically simple structure and suitable in high speed and high temperature environments of the SynRM \([1,2]\) has been a renewed interesting research subject. The rotor circuit of the SynRM is opened such that the flux linkage of SynRM is directly proportional to the stator currents. Hence, we can control the torque of SynRM by adjusting the stator currents.

The fast and no error dynamic response is a primary topic in control systems. In real worlds, the real servo systems always include parameter variations and external load disturbances. In order to overcome the uncertainties, one of the famous methods about robust control of the variable structure control \([3,4]\) is adopted. It has been proven as an effective and robust control technology in the synchronous motor and SynRM \([5-7]\). The uncertainties, parameter variations and/or external disturbances can be rejected for the variable structure control when the upper boundary of the systems lump uncertainty is known. However, specific and reliable system uncertainty boundaries are difficult obtained for practical applications. In real applications, uncertainty boundaries can easily exceed the assumed magnitude range, under which the sliding mode can not be used. Using high gain control to improve disturbance rejection has been proposed \([8]\). A control system using a large constant gain is simple to implement. However, it produces unnecessary deviations from the switching manifold and causes chattering in the control system. Serious chattering can reduce by using the boundary layer which the signum function is replaced by the saturation function. Hence, it produces the steady state errors. Hence, in recent years, some researchers \([9-11]\) proposed the methods to find the uncertainty upper boundaries and reduce the steady state error which the signum function is replaced by the saturation function. Their major concept is to estimate the bounded uncertainties in real-time for the controlled system. Hence, the control signal of the controller is smaller than the conventional sliding mode controller and the chattering phenomenon is also reduced.

In recent years, the neural network of intelligent control has been applied in some motor speed control systems \([12-14]\). The neural network control does not require mathematical model to approximate nonlinear systems. The radial basis function neural network (RBFNN) theory \([15]\) employs local receptive fields to perform function mapping based on biological receptive fields. The RBFNN is a multilayer perceptron (MLP) feedforward neural network structure. The RBFNN is simpler than the MLP which only adjusts the connective weights between the hidden layer and output layer of the network. Hence, the RBFNN always has a fast convergence property and learning speed faster than the MLP. It has been successfully employed in the area of motor control field \([16-19]\). The RBFNN controller is an effective method when the systems mathematical model is unknown, or known with uncertainties.

The RBFNN \([20]\) is a three-layer feedforward neural network structure. It has the nonlinear transformation of Gaussian basis function of the hidden layer and output layer is the linear combination in hidden layer responses. This structure is similar to multilayered feedforward neural network and using nonlinear transfer function. Hence, it can approximate any unknown mapping function.

According to the RBFNN advantages, we proposed the SMC design based on RBFNN concept of SynRM system. The spirit of proposed control is different from the conventional sliding mode controller that the conventional sliding mode controller assumes the boundary of the upper lump uncertainty system is known. The SMC is replaced by RBFNN which the sliding surface function \(S\) and system control \(u\) is the mapping input and output function, respectively. The RBFNN doesn’t use the signum function control element hence this system reduces chattering phenomenon and has the response more smooth.

The organization of this paper is as follows. SynRM modeling in the synchronously rotating rotor reference frame for maximum torque control (MTC) strategy is discussed in