Chapter 11

Power Quality Improvement using Improved Approximated Fuzzy Logic Controller for Shunt Active Power Filter

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ABSTRACT

This chapter presents the design approach of an Improved Approximated Simplest Fuzzy Logic Controller (IASFLC). A cascade combination of simplest 4-rule Fuzzy Logic Controller (FLC) and an $n^{th}$ degree polynomial is proposed as an IASFLC to approximate the control characteristics of a 49-rule FLC. The approximation scheme is based on minimizing the sum of square errors between the control outputs of a 49-rule FLC and a simplest 4-rule FLC in the entire range of Universe Of Discourse (UOD). The coefficients of compensating polynomial are evaluated by solving instantaneous square error equations at various test points in the entire UOD. This IASFLC maps the output of a 49-rule FLC with absolute deviation of less than 5%. The proposed IASFLC is used to control the dc link voltage of a three-phase shunt Active Power Filter (APF). A detailed analysis is performed during transient and steady state conditions to check Power Quality (PQ) and dynamic performance indices under randomly varying balanced and unbalanced loading conditions. The performance of proposed IASFLC is compared with a 49-rule FLC and Approximated Simplest Fuzzy Logic Controller (ASFLC) based on minimization of the deviation at central values of Membership Functions (MFs). It is found comparatively better for harmonic and reactive compensation with a comparable dynamic response. The memory requirement and computational time of proposed IASFLC are even lesser than the ASFLC.

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INTRODUCTION

Fuzzy logic controllers (FLCs) have been successfully used for the control of shunt active power filter (APF) due to their ability to handle complex control tasks at randomly varying operating conditions. With remarkable increase in the applications of semiconductor devices, the issues of harmonic contamination, poor voltage regulation, poor power factor, low system efficiency, and interference in nearby communication system etc are need to be addressed. All these issues in some form or other affect the power quality. Shunt APF has emerged as an undisputed solution for current harmonics mitigation and reactive power compensation.

Bose (1994) in his invited paper has explored the possibilities of expert system, fuzzy logic and neural network applications in power electronics and motion control. This work has opened a new space of opportunities for control engineers. It is now an established fact that an FLC based shunt APF shows better dynamic response and higher control precision as compared with the PI controller as concluded by Dixon et al. (1999), Jain et al. (2002), Singh et al. (2007), An et al. (2009), Karuppanan & Mahapatra (2011), Panda & Mikkili (2013), Benassia et al. (2013), and Agarwal & Bhuria (2013). In all these papers a 49-rule FLC is used with uniform or non uniform distribution of membership functions (MFs) in the entire universe of discourse (UOD). Due to large number of rules a 49-rule FLC is structurally more complex, required more memory and large computation time to execute a desired control action.

Some studies regarding approximation and reduction of rule base size have been reported in literature. Zeng & Singh (1994, 1995) proposed a mathematical description of approximation theory of fuzzy systems for single input single output (SISO) and multi input multi output (MIMO) cases. These papers were mainly focusing on the approximation capabilities of the fuzzy systems for approximating a mathematical polynomial rather than on the rule reduction. Hampel & Chaker (1998) provided analyses for minimization of number of variable parameters for optimization of fuzzy controller and concluded that reduction of variable parameter does not necessarily result in a restriction in the quality of an FLC. Moser & Navara (2002) proposed a fuzzy controller with conditionally firing rules. In this work numbers of rules were not minimized but the degree of overlapping of MFs was replaced by the truth value of a conditional statement. So the conditions of firing a particular rule were reduced rather than rule base size. Bezine et al. (2002) explained some issues on design and rule base size reduction for the fuzzy control of robot manipulators. Ciliz (2005) explained some concepts regarding resizing of rule base by removing inconsistent and redundant rules for the application of vacuum cleaner. These two studies were application specific.

Arya (2006) has proposed a process independent simplest FLC using approximation for unit step response analysis of two different processes of second and third order. A robust and application independent ASFLC was given by Singh et al. (2011) for a multi-objective and highly complex control application of shunt active power filter. The methodology was based on comparing the output of 49-rule FLC with 4-rule FLC at central values of MFs and then designing the compensating factors to minimize the deviation between the responses of two controllers. The ASFLC exhibited better dynamic performance than conventional PI controller and harmonic compensation was comparable with 49-rule FLC during transient state and even better during steady state operation of shunt APF. The response of ASFLC was compared with a 49-rule FLC at six points in the entire UOD and based on that six compensating factors were designed. The approach is analogues to a piecewise linearization of a nonlinear function. To achieve exact behavioral mapping of a 49-rule FLC by a 4-rule FLC the entire UOD need to be analyzed at more locations than at merely six distinct points. This is what exactly motivated...