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An adaptive set-point modulation technique to enhance the performance of load frequency controllers in a multi-area power system

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Abstract

Parameters and configuration of power systems are continuously prone to change. This might negatively affect the performance of load frequency controllers. PI controllers are widely used for load frequency control (LFC) in power systems. Hence, enhancing the performance of these controllers is of great importance. In this paper, an adaptive set-point modulation (ASPM) method is proposed to enhance the performance of PI controllers. Simulation studies carried out on a two-area power system with different types of generating units and HVDC link prove the superiority of the proposed adaptive set-point modulation assisted proportional integral (ASPM-PI) over the conventional proportional integral (PI) and proportional integral derivative (PID) controllers. It has also been shown that the ASPM-PI controller is robust in case of power system parameters variations and change in the configuration.

Keywords: Adaptive set-point adjustment; Load frequency control; Parameters variation; PI controller

1. Introduction

In power systems, load changes continuously during the day and results in power imbalance. Generated power should be controlled to retain the power balance such that the frequency would not deviate beyond the specified limits and also tie-lines power remains within the permissible constraints. These objectives can be achieved by fine tuning the load frequency controllers. Over the last decades, a large number of methods have been proposed for tuning load frequency controllers.

Internal model control was implemented in (Ibraheem et al., 2005) for tuning a unified PID load frequency controller. To design robust load frequency controllers in multi-machine power systems, a systematic method based on maximum

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peak resonance specification was proposed in (Khodabakhshian and Edrisi, 2008). In (Dong et al., 2012), an active disturbance rejection control method was used in a decentralized LFC scheme. An adaptive fuzzy gain scheduling scheme has been used in (Talaq and Al-Basri, 1999) for the PI load frequency controllers. A control scheme based on artificial neuro-fuzzy inference was presented in (Abdennour, 2002) to optimize and update the automatic generation controllers' gains according to the load variations. In (Kocaarslan and Cam, 2005), the gains of a PI load frequency controller are adaptively determined implementing a fuzzy system. Takagi-Sugeno fuzzy system has been proposed in (Lee et al., 2006) for LFC in a two area power system. In (Bevrani and Daneshmand, 2012), fuzzy logic based load frequency controllers have been implemented in a system with high penetration of wind turbines.

Evolutionary algorithms have been widely used for tuning load frequency controllers. In (Abdel-Magid and Dawoud, 1996), genetic algorithm (GA) was used for tuning the load frequency controllers of a two area non-reheat thermal power system. Actually, in (Abdel-Magid and Dawoud, 1996), several performance indices were used for tuning the PI controllers using GA. In (Pingkang et al., 2002), GA was used for LFC in a multi-area power system. A robust method for tuning the PI load frequency controllers using GA was proposed in (Huddar and Kulkarni, 2008). In (ADITYA, 2003), the load frequency controllers of a three-area deregulated power system with thyristor controlled phase shifter were tuned using particle swarm optimization (PSO). An adaptive weighted PSO is used in (Sharifi et al., 2008) for tuning multi-objective load frequency controllers. In (Bhatt et al., 2010), a hybrid PSO was implemented for tuning the gains of PID load frequency controllers of a deregulated multi-area power system. In (Stron and Price, 1997), differential evolution (DE) was used for tuning the PI load frequency controllers in a two area power system. For load frequency control in a multi-source power system including HVDC links, DE was implemented in (Mohanty et al., 2014). In (Sahu et al., 2013), a parallel 2 degree of freedom PID controller (2-DOF PID) was used for LFC in a two area power system. Imperialist competitive algorithm (ICA) was implemented in (Rakhshani et al., 2012) to find the weighting matrices for an LQR output feedback in LFC problem. In (Soheilirad et al., 2013), the performance of ICA in tuning the load frequency controllers in a multi-area power system was compared with GA. For optimizing the gains of the PID load frequency controllers in a three area power system, ICA has been used in (Shabani et al., 2013). In (Taher et al., 2014) ICA was implemented for tuning the non-integer load frequency controllers in a three area power system with reheat, non-reheat and hydraulic generating units. In (Debbarma et al., 2013) bacterial foraging algorithm was used for tuning the non-integer load frequency controllers.

Literature review shows that, due to the importance of LFC, a lot of effort has been made to introduce new load frequency controllers which are robust in case of uncertainties or parameters variation. The controllers tuned by fuzzy logic and the evolutionary algorithms have received a considerable attention in this field. However, for tuning the fuzzy logic controllers, knowledge of fuzzy logic is necessary. Also, tuning the controllers using evolutionary algorithms might be time consuming. Therefore, an alternative robust controller which does not have the aforementioned tuning difficulties seems to be necessary.

Online set-point modulation method has been newly introduced. Using this method, the performance of PI voltage and current controllers in terms of overshoot/undershoot and settling time has been improved (Mehrizi-Sani and Iravani, 2012a,b). In this paper, an adaptive form of set-point modulation method is proposed to enhance the performance of the PI load frequency controllers. It should be mentioned that, however; a PID controller might ideally have a better performance, but PI controllers are widely used for LFC in real power systems because the derivative term of PID controllers could be problematic in presence of noise. Although noise can be filtered, this might degrade the performance of PID controllers (Romero Segovia et al., 2014). Hence, upgrading the PI controllers, which are not susceptible to noise, would be a better solution in practice. The purpose of the proposed ASPM method is to enhance the performance of PI controllers widely used for LFC. Through simulation studies carried out in Matlab/Simulink, the performance of the proposed ASPM-PI controllers has been compared with the optimal PID controllers which have been tuned using DE algorithm (Mohanty et al., 2014).

2. Test system

The studied power system consists of two areas with identical generating units which are connected together via parallel AC-DC tie-lines. As shown in Fig. 1, in each area, electrical power is generated by thermal, hydro and gas turbine power plants. Although power systems are nonlinear and dynamic, the model linearized around the operating point can be used in solving the LFC problem because only small changes in load are expected during the normal operation (Mi et al., 2013). In power systems, any change in electrical loads reflects in the electrical power of the