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Comparative performance evaluation of SMES–SMES, TCPS–SMES and SSSC–SMES controllers in automatic generation control for a two-area hydro–hydro system

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ABSTRACT

This paper presents the automatic generation control (AGC) of an interconnected two-area multiple-unit hydro–hydro system. As an interconnected power system is subjected to load disturbances with changing frequency in the vicinity of the inter-area oscillation mode, system frequency may be severely disturbed and oscillating. To compensate for such load disturbances and stabilize the area frequency oscillations, the dynamic power flow control of static synchronous series compensator (SSSC) or Thyristor Controlled Phase Shifters (TCPS) in coordination with superconducting magnetic energy storage (SMES) are proposed. SMES–SMES coordination is also studied for the same. The effectiveness of proposed frequency controllers are guaranteed by analyzing the transient performance of the system with varying load patterns, different system parameters and in the event of temporary/permanent tie-line outage. Gains of the integral controllers and parameters of SSSC, TCPS and SMES are optimized with an improved version of particle swarm optimization, called as craziness-based particle swarm optimization (CRPSO) developed by the authors. The performance of CRPSO is compared to that of real coded genetic algorithm (RGA) to establish its optimization superiority.

1. Introduction

In power systems, changes in the load affect the frequency and bus voltages in the systems. For small changes in the load the frequency deviation problem can be separated or decoupled from the voltage deviation. The problem of controlling the real power output of generating units in response to changes in system frequency and tie-line power interchange within specified limits is known as load frequency control (LFC). It is generally regarded as a part of automatic generation control (AGC) and is very important in the operation of power systems [1]. With the increase in size and complexity of modern power systems, inadequate control may deteriorate the frequency and system oscillation might propagate into wide area resulting in a system blackout. However, most of the solutions proposed so far for AGC have not been implemented due to system operational constraints associated with thermal power plants. The main reason is the non-availability of required stored energy capacity other than the inertia of the generator rotors.

Fast-acting energy storage system provides storage capacity in addition to the kinetic energy of the generator rotors which can share sudden changes in power requirement and effectively damp electromechanical oscillations in a power system. An attempt to use battery energy storage system (BESS) to improve the LFC dynamics of West Berlin Electric Power Supply has appeared in [2]. The problems like low discharge rate, increased time required for power flow reversal and maintenance requirements have led to the evolution of superconducting magnetic energy storage (SMES) for their applications as load frequency stabilizers.

A superconducting magnetic energy storage (SMES) which is capable of controlling active and reactive powers simultaneously [3] is expected as one of the most effective and significant stabilizer of frequency oscillations. The viability of superconducting magnetic energy storage (SMES) for power system dynamic performance improvement has been reported in [4,5].

Moreover, in the future competitive electricity market, various kinds of apparatus with large capacity and fast power consumption may cause a serious problem of frequency oscillation. Especially, if the frequency of changing load is in the vicinity of the inter-area oscillation mode (0.2–0.8 Hz), the oscillation of system frequency may sustain and grow to cause a serious stability problem if no adequate damping is available [6]. Static synchronous series compensator (SSSC) is one of the important members of FACTS family [7] which can be installed in series with the transmission lines. With the capability to change its reactance characteristic from capacitive to inductive, the SSSC is very effective in controlling power flow [8]. Ngamroo et al. [9] proposed the application of SSSC

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