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NEURAL NETWORK BASED CONTROL DESIGN TO EXTENUATE SUBSYNCHRONOUS RESONANCE

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Abstract

Subsynchronous resonance (SSR) is a menace in the electrical power system in which disturbances are exchanged between electrical and mechanical systems. This paper aims to examine the neural network (NN) controller incorporated in a modified unit template algorithm to alleviate SSR using a static synchronous compensator (STATCOM). To understand the problem of SSR, time domain analysis and frequency scan are presented. A single machine infinite bus system is studied and simulated in MATLAB/Simulink to substantiate the efficacy and robustness of the proposed control strategy. The deviation in generator rotor speed is as high as 10.8% due to SSR oscillations, which increases mechanical stress, causing heavy damage to the mechanical shaft system. The STATCOM equipped with the proportional and integral (PI) controller in the proposed strategy reduces the deviation to 0.19% and further to 0.006% with the annexation of the NN controller.

Key Words

Subsynchronous resonance, STATCOM, neural network, torsional oscillations, frequency scan

1. Introduction

The increasing popularity of wind power energy has substantially elevated the risk of subsynchronous resonance (SSR) due to interaction between series compensated transmission lines and doubly fed induction generator [1]. This increase in SSR interactions has been observed throughout the world, especially in the wind farms, such as in Hebei (China), Guynan (China), and ERCOT (USA) [2], [3]. Nowadays, wind generation is the futuristic energy source and wind power plants are prone to SSR. Effective countermeasures are required to alleviate SSR oscillations as it has a ruinous effect on wind power, transmission system, and other generating plants. The cost of replacing the existing series transmission lines is highly expensive. Thus, alternative mitigation measures of SSR are necessary as the future of electrical power energy depends on wind generation [4].

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Drastic effects of SSR were found out right from its first known incident in Mohave, where the damages to the mechanical shaft system were disastrous [5]. From definition [6], SSR is a condition where the exchange of energy takes place between electrical network and mechanical system at a frequency less than the nominal frequency of the system. In a series compensated network, if a disturbance occurs, then the currents flow in the stator having a resonant frequency (f_r). This induces negative slip and hence negative resistance. If the total effective resistance is negative, then self-excitation of generator takes place causing amplification of oscillations.

Flexible AC transmission system (FACTS) devices have been designed in the past to mitigate SSR [7]. To reduce the risk of SSR, the thyristor controlled series capacitor (TCSC) has been designed in [8]. Series compensation being the main reason for SSR has been conferred in [9]. The modal frequency aspect of SSR is provided in [10]. The controller design for the alleviation of SSR is given in [11] as well as in [12]. However, the results and study carried out in the literature can be improved.

A novel modified unit template control algorithm has been proposed for the static synchronous compensator (STATCOM). It is further equipped with the neural network (NN) controller to increase the potency of STATCOM. The results found in this study by far exceed the level of alleviation achieved in [13] and [14]. The main contributions of this manuscript are as follows:

- A modified unit template algorithm is proposed, which proves to be highly effective as compared to the conventional controllers.
- Controller response is faster as the use of phase locked loop is eliminated.
- The NN controller is implemented in the modified unit template algorithm to enhance capability.
- Frequency scan at various compensation levels is presented to obtain resonant frequencies.
- Previously, the level of mitigation of SSR oscillations achieved was up to 92% [15]. With the modified unit template algorithm, the level of mitigation is increased up to 98.1% and further enhanced to 99.7% by incorporating the NN control.