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The Influence of Wind Power on the Small Signal Stability of a Power System

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Abstract. This paper analyses the influence of wind power on the small signal stability of a power system. Factors like power dispatch, generator technology, wind farm location and wind power integration level are considered. The oscillatory modes that arise as a result of changes in system operating conditions are computed using modal analysis. Participation factors are also calculated to determine the relative contribution of each system state variables to a certain mode. Time domain simulations are carried out to validate the conclusion inferred from the modal analysis.

Key words

Wind power, small signal stability, modal analysis, damping ratio, Power system.

1. Introduction

Grid integration of wind power today has achieved a considerable development. This fact is leading to a growing concern about its influence on the operation of a power system [1]. Much of these concerns are centred on the impact of wind power integration on the transient and voltage stability with less attention given to the small signal stability.

Small signal stability is considered when there are small changes in operating parameters of a power system [2]. These changes can result in electromechanical oscillation but mostly decay with time and thus the system comes back to stable operating point. However, if the system is not adequately damped, the oscillation can lead to loss of synchronism.

Small signal stability studies are based on linearised system around the operating point. The differential equations that describe the dynamic system are linearised and the system eigenvalues are computed from the characteristic equation. Majorly, there are two kinds of oscillation usually considered in small signal stability studies, the local area oscillations and the inter-area oscillations. Participation of each generator's state variables to a particular mode of interest is computed from the participation matrix. The information obtained here is used to identify the critical generators that can cause instability and hence appropriate measures can be taken.

The different methods that have been used in the literatures for analysing small signal stability of a large power system include prony analysis, Fourier-method [3], modal analysis method, time domain analysis and Probabilistic method [4, 5]. The issue of constant speed wind turbine generator on power system oscillation was studied in [3], impact of large scale wind power was analysed in [1] using three area network and modal analysis of doubly-fed induction generator was presented in [6] where the main focus is on the control mode.

The objective of this paper is to identify the influence of wind power on the power system small signal stability considering factors like direction of power flow in the tie-line, Transmission line length of the location of wind resources to the main grid, integration level and generator technology.

The paper is organised as follows: section two presents the model of wind generators, the methodology of the study is described in section three, the test system and simulation results in different scenario are given in section four while the conclusion is presented in section five.

2. Characteristic and Modelling of Wind Generators

The per unit d-q stator, rotor voltage equation and the flux linkage equation of an induction machine in a synchronously rotating reference frame are given in equations(1)-(4) [7]. The generator convention is adopted i.e the stator and rotor currents are positive when flowing towards the network and both active and reactive power are also positive when flowing towards the grid.

$$V_{qs} = -r_s i_{qs} - \psi_{ds} - \frac{1}{\omega_s} p\psi_{qs} \tag{1}$$

$$V_{ds} = -r_s i_{ds} + \psi_{qs} - \frac{1}{\omega_s} p\psi_{ds} \tag{2}$$

$$V_{qr} = -r_r i_{qr} - s\psi_{dr} - \frac{1}{\omega_s} p\psi_{qr} \tag{3}$$

$$V_{dr} = -r_r i_{dr} + s\psi_{qr} - \frac{1}{\omega_s} p\psi_{dr} \tag{4}$$