Small-signal stability analysis of DFIG based wind power system using teaching learning based optimization

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Abstract

The present paper formulates the state space modelling of doubly fed induction generator (DFIG) based wind turbine system for the purpose of small-signal stability analysis. The objective of this study is to discuss the various modes of operation of the DFIG system under different operating conditions such as three phase fault and voltage sags with reference to variable wind speed and grid connection. In the present work, teaching learning based optimization (TLBO) algorithm optimized proportional–integral (PI) controllers are utilized to control the dynamic performance of the modelled DFIG system. For the comparative analysis, TLBO based simulated results are compared to those yielded by particle swarm optimization (PSO) method for the same DFIG model. The simulation results show that the proposed TLBO based PI controller effectively works in minimizing the damping phenomena, oscillation in rotor currents and fluctuation in electromagnetic torque for the studied DFIG model. It is also observed that TLBO is offering better results than the PSO for the dynamic performance analysis of the studied model.

Introduction

In recent years, wind energy has witnessed a large surge in research and development. The drawback of wind energy is that electrical energy is obtained only when the wind blows. Even though modern wind turbines regulate power well and level off at their rated capacity, the amount of power produced by them varies throughout the day. Many installations have established that utility systems are able to accommodate the change in wind generation just as they modify their output to follow dynamic demand. Specialists predict that wind power can constitute up to 30% of present energy demands before reliability of the system would be an issue.

Generation of kinetic energy is done by utilizing the atmospheric air’s energy. Wind energy has been used from centuries to perform many different functions such as grain grinding, sailing and for irrigation purposes. The main function of wind power system is conversion of kinetic energy present in the wind into various sources of power. In ancient times, milling and irrigation were also done by wind power systems. During twentieth century, wind power started to generate electricity. Similarly, wind mills were used in several countries to pump water from the ground.

Wind turbines can be used as single unit as well as in groups (also known as wind farms). Wind turbines which are smaller in size are also called as aero generators. These can be used for charging large-sized batteries. Five countries in the world has greater than 80% of the installed global wind energy capacity, among them India is at the 5th position [1].

The output power can be improved by 2–6% for a variable speed turbine as compared to a fixed speed turbine [2] whereas it may go up to 39% according to [3]. It is revealed that the energy generation gain of the variable-speed turbine as compared to the fixed-speed turbine may fluctuate by 3–28% according to the condition of site and design consideration [4]. The energy capture is enhanced by 20% in case of doubly fed induction generator (DFIG) when compared to variable speed turbine using a cage bar induction machine and by nearly 60% from fixed speed system. As the assumptions used while performing the study of DFIG varies vastly from one person to another, therefore, the results may also vary accordingly. The controlling of DFIG is far more tedious than controlling any other machine. The rotor current in the DFIG is controlled by power converters. It is controlled by using vector control techniques. Till date, various vector control techniques has been suggested for the controlling of DFIG. The stator flux orientation can be used to control the rotor currents according to the system parameters [5,6]. According to [7,8], the eigenvalues of the DFIG are poorly damped having a corresponding natural frequency close to the line frequency. In addition to this, the DFIG system is not...
stable for various operating conditions. The poorly damped poles of the DFIG affect the dynamics of rotor current from the back electromotive force. The response of wind turbines to grid disturbances is a crucial issue, particularly, since the rated power of wind-turbine systems is a very important parameter. The response of wind turbines to grid disturbances must short circuit the rotor so as to shield the converter from the system. This means that the wind turbine needs to have extra protection to avoid these voltage dips. Today’s DFIG system encompasses a crowbar within the rotor circuit that at large grid disturbances must short circuit the rotor so as to shield the converter. This highlights that the turbine should be separated out from the grid, if large voltage sag occurs.

According to the works reported earlier, there are different ways to change the DFIG system so that it can withstand the voltage sags. In [12], thyristors are placed in anti-parallel topology around the generator to shield the converter. However, this technique is not very practical due to the large number of thyristors required and the additional cost. In [13], a third-order model has been planned that neglects the simple model that is able to model the dynamics of concern. In [12], thyristors are placed in anti-parallel topology around the generator to shield the converter. However, this technique is not very practical due to the large number of thyristors required and the additional cost. In [13], a third-order model has been planned that neglects the simple model that is able to model the dynamics of concern.

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As a simulation model is yet to be shown, so as to preserve the behaviour of the oscillatory response. It is clear that second-order simulation model is the easiest one to use. At present, the DFIG wind turbine is disconnected from the grid when huge voltage sag appears in the system. When wind turbine is disconnected from the system, it needs few seconds before it can be reconnected with the system. This means that the wind turbine needs to have extra protection to avoid these voltage dips. Today’s DFIG system encompasses a crowbar within the rotor circuit that at large grid disturbances must short circuit the rotor so as to shield the converter. This highlights that the turbine should be separated out from the grid, if large voltage sag occurs.

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