ABSTRACT

This thesis presents the methodological aspects and algorithmic approach for controller design of a doubly fed induction generator for performance enhancement and reliability improvement of a wind energy conversion system. Recently, the doubly fed induction generator is one of the most frequently used generators in the wind energy conversion systems. The optimal control of large scale wind farm becomes a critical issue for the development of the renewable energy systems and their integration into the power grid to provide reliable, secure and efficient electrical energy. A critical review of the DFIG based WT, its control aspects for wind energy conversion system and emerging issues from last one decade have been described and demonstrated in detail. The study starts with describing widespread perception on wind energy and commonly used generator in wind energy conversion.Then it presents additional particulars on DFIGs active modes and utilization. It is followed by DFIG control methods in addition to overviews of different engaged electrical and mechanical controlling methods. The DFIG overview along with its merits and demerits, the principle of operation in synchronous / super synchronous speeds, the mathematical modeling and controller design for the DFIG driven by variable speed wind turbine, and its converter aspects have described and illustrated appropriately.

The DFIG control parameters are very much essential to be optimized to enhance the performance characteristics of the WECs. In previous research in this field, the conventional techniques have improved the control parameters however; this thesis proposes to design a DFIG controller for wind turbine system to improve its transient performance with, rise time, settling time and peak overshoot by using optimization and soft computational evolutionary techniques. The techniques namely: Static output feedback (SOF), Particle swarm optimization (PSO), Bacterial forging optimization (BFO), Firefly algorithm (FFA), Differential evolution algorithm

(DE) and Genetic Algorithm (GA) in conjunction with their fitness functions have been described for DFIG controller design for WECs in detail. These evolutionary techniques have several advantages over the conventional methods like use of objective function, no other auxiliary functions, irrespective to the type of parameters, avoid local optimization solutions, probabilistic nature and provide solution for any number of dimensions. During design process, a sixth order transfer function of DFIG model as a plant transfer function is used for performance improvement of the DFIG based wind energy conversion system.

On the other hand, an on-off Control method is used for MPPT and anticipated to control the rotor side converter of DFIG based wind turbine connected to the grid. This approach is trying to keep the torque within the optimal value at which the maximum power is obtained. A concept of MPPT has been proposed to achieve the goal of tracking maximum power at a given wind velocity. To perform the MPPT from the wind system, the MPPT block in coordination with the rotor control block acts to maintain the torque to the value that is optimum for extracting the maximum power output from it. The energy conversion device which is used in wind turbine systems is DFIG therefore; a doubly fed induction generator is modelled as an energy conversion device. The Grid Side Converter is controlled in such a way to assure a smooth DC voltage as well as ensure the sinusoidal current on the network. Finally the Reliability of DFIG based wind turbine with performance analysis is described in details, for calculating the reliability of the DFIG based wind turbine unit which builds on the reliability of its components by using the Markov process. This thesis is organized in following seven chapters to describe the reliable controller design of DFIG for performance enhancement of the WECs.

In chapter 1, the proposal of the current research work and historical development of the wind power generation technology are presented in a chronological behaviour. The fundamental concepts of the DFIG based WECS with its possible present and future applications along with its major salient features have described in details. The study starts with describing widespread perception on wind energy and commonly used generator in wind conversion. Finally, it presents additional particulars on DFIGs active modes and utilization. It is followed by DFIG control methods in addition to overviews of different engaged electrical and mechanical controlling methods. This chapter concludes with motivation, research objectives, and organization of thesis.

In chapter 2, the modeling methodologies along with controller design for the DFIG using SOF method is described in details. The mathematical model of the DFIG, its converters, and their controllers have discussed appropriately. The controller design for DFIG based wind energy generation system using SOF technique with LMI approach is described. The received results are compared with the supervisory controller techniques for performance improvement of the DFIG-based wind turbine to wind energy conversion system. The supervisory PID controller even though improves the system response in compare to the open loop system; however, the number of oscillations is not removed entirely. The PI controller designed using SOF technique not only improves the system response but in addition to reducing the percentage overshoot to zero. The PI controller using SOF technique shows that the system settles down in smaller time as in the case when supervisory PID controller used. Finally, it is concluded that the Static Output Feedback control technique provides another option for the design of controller to be implemented in DFIG based WECs.

The controller design for DFIG using particle swarm optimization (PSO) procedure and its fitness functions are described in chapter 3. The responses of the DFIG system regarding terminal voltage, current, active-reactive power and DC-Link voltage along with generator speed have slightly improved with PSO based controller. Finally, the obtained output is equated with a standard technique for performance improvement of the DFIG based wind energy conversion system. On the other hand, obtained results show that the system using PSO based controller settles down in less time than the supervisory based PID controller. It is concluded that the settling time is reduced next to 12 percent approximately along with the percentage overshoot; rise time and peak time are reduced to zero using proposed method. Ultimately, it is concluded that the PSO control technique provides an alternative to design a reliable and adequate controller for implementation in the DFIG based WECs.

The bio-inspired procedure is illustrated to controller design for DFIG for WECs in chapter 4. This technique is based on exploiting the two efficient swarm intelligence based evolutionary soft computational method, i.e., Particle Swarm Optimization (PSO) and Bacterial Foraging Optimization (BFO) to design a controller for low damping plant of the DFIG. The controller design using PSO and BFO technique along with its fitness functions are described in detail. The responses of the DFIG system regarding terminal voltage, current, active-reactive power and DC-Link voltage along with generator speed have slightly improved with PSO based controller in comparison with BFO based controller. The comparison between PSO based controller and the BFO based PID controller are described precisely. It is accomplished that the settling time is reduced next to 62 percent approximately and the percentage overshoot, rise time and peak time are reduced to zero using proposed method. Finally, it is concluded that the PSO control technique make available an additional alternative to design a reliable and satisfactory controller for implementation in the DFIG based WECS.

The controller design of DFIG by using firefly algorithm method aims to design a PID controller to improve its transient performances: such as rise time, settling time, peak overshoot etc by using two evolutionary techniques such as Firefly algorithm (FFA) and Differential evolution algorithm (DE) along with Genetic Algorithm (GA). These evolutionary techniques have several advantages over conventional methods like use of objective function no other auxiliary functions, irrespective to the type of parameters, avoid local optimization solutions, probabilistic nature and provide solution for any number of dimensions. A sixth order transfer function of DFIG model as a plant transfer function is used in chapter 5. The controller design for DFIG based WECS using FFA, DEO and GAO technique along with their fitness functions are described in detail. The responses of the DFIG system concerning terminal voltage, current, active-reactive power and DC-Link voltage along with generator speed have slightly improved with FFA based controller in comparison with DEO & GAO based controller. The obtained results show that the system using FFA based controller settles down in less time as compared with the GA and DE based PID controller scheme. Finally, it is concluded that the FFA control technique provides another option to design a reliable and adequate controller for implementation in the DFIG based wind turbine scheme.

In chapter 6, an on-off control proposal is used for MPPT and predicted to control the rotor side converter of DFIG based wind turbine associated to the grid, which is trying to keep the torque within the optimal value at which the maximum power is obtained. The grid side converter is controlled in such a way to assure a smooth DC voltage as well as ensure sinusoidal current on the network. Finally the Reliability of DFIG based WT with performance analysis are described, which builds on the reliability of its components by using Markov process. A concept of MPPT has been proposed to achieve the goal of tracking maximum power at a given wind velocity. To perform the MPPT from the wind system, the MPPT block in coordination with the rotor control block acts to maintain the torque to the value that is optimum for extracting the maximum power output from it. The energy conversion device which is used in wind turbine systems is DFIG therefore; a doubly fed induction generator is modelled as an energy conversion device. The modeling included the verification of developed model with that of the generator present in the library of the MATLAB / Simulink. The results obtained showed that the system could perform well at average wind speeds while the results are inconsistent with that of expected values at lower and higher wind speeds. Hence at average wind speed, the rotor side controller changes such that to alter the torque to the optimal value generated by the MPPT controller. Finally, the reliability analysis of the DFIG based WECS is described in this chapter in detail. The stationary Markov process is used to compute the reliability of the whole DFIG based WT scheme with subsystems. In the last chapter, this thesis describes the overall conclusion on the DFIG controller design, summery of the research output and suggestions for future research work in this area.

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