A Literature Review on Advanced Control Strategy of a Wind Driven DFIG under Various Fault Conditions

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***Abstract*—This paper focuses on improving the dynamic performance of a DFIG based Wind turbine system connected to the supply side using a PWM converter from both the rotor and the stator side. In order to keep the dc link voltage constant, stator-flux-oriented vector control is applied to the scherbius drive. This control decouples the active and reactive component of the power generated by the DFIG and enables their individual control independently. The various parameters of the controller employed are optimized using Artificial Neural Network (ANN). The machine which is being studied is considered to be operating under various fault conditions. A simulated module has been designed using MATLAB to obtain dynamic control of the power components when the DFIG is operating under variable-speed conditions. The system performance under various faults is studied for both the conventional PI control as well as the intelligent ANN control. The performance is found to be better when intelligent control module is being used instead of the conventional control.**

Keywords*— Renewable energy generation, wind turbine, wind farms, power system modelling, dynamic stability, DFIG, vector control, PWM converter, PI control, ANN logic.

I. INTRODUCTION

Wind power has emerged as the fastest growing power sector and has continuously been proving to be more economic in the past decade. This has been mainly due to the growing demand for energy over the past two decades. In order to meet the increased energy requirements fossil fuels have been exploited extensively. The result of this exploitation has rendered the fossil fuel sources at the verge of their extinction. Thus, they do not seem promising enough to fulfill future energy requirements which would only grow with the population, as well as technological, growth. Besides that, the conventional sources of energy are not 'clean' sources of energy and their use has contributed majorly in polluting the environment. Wind energy conversion systems have cut down the emissions of greenhouse gases in the atmosphere to a great extent. Wind farms, therefore, have been trending as a major source of electricity generation in the global scenario of power sector. It has seen a rise up to 20% in the past decade and the cost of generation has reduced up to half the earliest known values. Apart from the comparative benefits, wind energy has its own advantages as a renewable and dependable source of energy.

The efficiency of a wind conversion system is high and it has a wide range of operating conditions. The high installation and maintenance costs are made up by the lower operating costs and wind being available as a free source of energy.

The use of doubly fed (wound rotor) induction generator as the machine for conversion of flowing wind into electrical energy is trending due to their ability of working under variable speed operating conditions. When compared to fixed speed generators the DFIG offers higher efficiency owing to less power loss in the system. The flexible control over DFIG operation creates maximum power generation opportunities. A converter needs to be placed intermediate to the machine and the grid. Recent advancements in the power electronic converters have enabled lower costs and increased efficiency.

The increase in energy contribution to the power systems from the wind farms has invited an extensive research in this field. The studies aim at eliminating the disturbances caused in the power system by the variable-speed wind power being generated by the WTs.

II. LITERATURE REVIEW

Sathan S. and Jitendra Rohilla in their work have implemented an intelligent speed control scheme using ANN for a DFIG based variable speed wind turbine system. They have explicitly explained the modelling of the wind turbine and the ANN based rotor side converter design. They have derived simulation results after implementing the ANN logic for the rotor side controller. A comparison is made between the dynamic performances of the DFIG using conventional control method as opposed to intelligent control scheme. It was thus established by the results that the ANN based control provided better results for the dynamic response of the DFIG based wind turbine under various wind speed conditions as compared to the vector control method. The ANN control used was fairly accurate and simple in its design. It was also established that ANN contributes positively towards enhancing system stability. [1]

S K Salman and Babak Badrzadeh have explored a grid interactive DFIG driven by a wind turbine. They have made an effort to present a detailed switch by switch model of PWM converters for both rotor and stator side converters of a DFIG. An effort was made to control the active and reactive components of power individually and hence maintain the dc-link voltage between the grid side and the rotor side converter to be constant. The performance of PWM converters have been presented in great detail while employing the decoupling scheme for establishing the independent control of direct and quadrature axis voltage and current components. The application of Internal Model Control (IMC) approach helps to achieve a controller design that is more precise in its response. The results showed a fault responsive control system that helped ensure the transient stability of the DFIG driven by a wind turbine. [2]

Dayanidhi N and Muralidharan D presented in their work an analysis of the dynamic response of DFIG based wind farms after and during the application of fault conditions using both conventional PI control and ANN control. A fifth order model of a DFIG is developed using MATLAB. Then PI control was introduced to minimize the fluctuations during transient operating conditions and hence observe the system performance after implementing fault conditions, such as line to ground and three phase faults. A proposed ANN using Multi-level inverter (MLI) control technique was later trained to replace the PI control in the system. Then again the system performance was observed under influence of fault conditions implied to the system. Comparisons were made between the simulation results obtained for the conventional and the proposed system performance. The results approved that the proposed ANN control helped dampen the fluctuations in power components during the recovery time after the clearance of fault to a great extent. [3]

Baohua Dong, Sohrab Asgarpoor and Wei Qiao have worked to develop an innovative algorithm that uses both ANN and PI control technique to optimize the transient performance of a DFIG based wind turbine under variable wind speed conditions. Particle swarm optimization was used to optimize the PI controller parameters that were used at either rotor or grid side converters for various values of wind speed. The technique helped maximize the damping ratios of the system Eigen values that are generated during small signal stability analysis. The optimal values of controller parameters along with their corresponding value of wind speed are charted to create a data set that was used to train an ANN. The trained ANN module can easily predict the PI parameters for a specific value of wind speed and dynamically change the gain for the controller to suit the wind speed. Simulation results prove that ANN based adaptive PI control that was proposed brings about considerable improvement in the transient performance of the DFIG over a large range of wind speeds. [4]

Badrul H. Chowdhury and Srinivas Chellapilla have described the vector control for a DFIG based wind energy conversion system working under variable speed conditions. The system under study comprised of a wound rotor induction machine along with a three phase back-to-back converter as the connection between the rotor side and the grid side. Stator flux oriented control was employed for RSC bridge control and the stator voltage vector control was employed for GSC bridge control. The entire simulation model aimed at independently controlling the active and reactive power components of the DFIG for different wind speeds and the operating performance under such conditions. A laboratory setup was used for testing and studying the performance of the proposed system that was made of a wound rotor induction machine driven by a variable speed DC motor instead of the wind turbine. The purpose was to ensure the validity of the simulation performance of the proposed model. [5]

R Pena, J C Clare and G M Asher discuss the design of a DFIG including a back-to-back PWM converter connected at the rotor side. Both the components of the power drawn from the supply side is kept under control using vector control scheme for the supply side converter. The converters used made sure that a regular supply of sinusoidal currents to the machine was maintained. The control loops accommodate the vector scheme which provides for the tracking of optimal speed required to capture the maximum power or energy at a particular wind speed. The experimental setup presented was of 7.5KW capacity and the results exhibited brilliant performance of the system. [6]

Arantxa Tapia and Gerardo Tapia, J. Xabier Ostolaza, and Jose Ramon Saenz presents both the simulation and actual performance results for a grid interactive DFIG. The DFIG used was modeled such that the rotor side was connected with the grid via a double-sided PWM converter. The machine was operated at sub synchronous and super synchronous speeds to obtain the results. The stator flux oriented vector technique was used for the independent control of the active and reactive components of power. The wind turbine that drives the system has been designed following specific a specific mathematical model. It has been described how the parameters of this model can be controlled using the proposed strategy in order to limit the power factor of the energy produces by the system. The comparison between the simulated and the real results were fairly comparative and the simulated design of the wind generator was concluded to be successful and applicable for an overall wind farm system. [7]

J G Slootweg, H Polinder and W L Kling have considered the possible influence of wind farms on the performance of electrical power systems due its increasing use for the production of energy. This led them to design a wound rotor induction generator whose rotor was fed by a back to back voltage source converter. Their work contains the mathematical models for design and control of the wind turbine, the rotor side of the induction generator, and the controllers that are used for rotor speed, pitch angle and the terminal voltages. The design parameters of the model enabled them to study the machine performance via simulations as a response to the measured wind sequences that was fed as the input to the system. Their study revealed that it was viable to set up a mathematical model for a wind turbine that would define its behavior under operating conditions. [8]

III. PROPOSED SYSTEM

In the proposed system, the working of a wind energy conversion system has been depicted using a DFIG being driven by a wind turbine. The induction generator is connected to the grid via the stator while the turbine drives the rotor of the machine. The DFIG Wii be modeled using the fifth order equations. Mathematical model for all the system components have been described using parameters that allows the complete control of the system. A back-to-back PWM converter is used for decoupling the active and reactive components of power and their effective control. The PI control used for optimizing the system parameters is designed. Then the PI control is replaced by an intelligent ANN module for the control of system parameters and optimizing the power output.

All the system components will be modeled using MATLAB/Simulink. Certain parameters are pre-defined for the simulated model to enable the application of fault conditions to the system. The system performance was observed through the simulation results and compared for both the PI and ANN control.

IV. CONCLUSION

On careful observation of the simulation results of the reviewed paper it is seen that the addition of the ANN control block to the DFIG based wind provides a smoother response curve for the power generated by the DFIG as compared to the PI control technique. Therefore, the design and study establish that a doubly fed induction generator driven by a wind trurbine performs better under fault conditions when an intelligent ANN control is applied to it.

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