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On-Off control based particle swarm optimization for maximum power point tracking of wind turbine equipped by DFIG connected to the grid with energy storage

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ABSTRACT

In this paper, particle swarm optimization (PSO) is proposed to generate an On-Off Controller. On-Off Control scheme based maximum power point tracking is proposed to control the rotor side converter of wind turbine equipped with doubly fed induction generator connected to the grid with battery storage. The Grid Side Converter (GSC) is controlled in such a way to guarantee a smooth DC voltage and ensure sinusoidal current in the grid side. Simulation results show that the wind turbine can operate at its optimum power point for variable speed and power quality can be improved.

Introduction

Electrical energy is increasing in recent years and the constraints related to its production, such as the effects of pollution, the research lead to the development of renewable energy sources. In this context, Wind energy conversion systems (WECS) offer a very competitive solution. To overcome the problem of efficiency for maximum performance, it is necessary to optimize the design of all parts of the WECS [1,2].

Variable-speed wind turbines are currently the most used wind energy conversion system. The doubly-fed-induction-generator (DFIG)-based wind energy conversion system, also known as improved variable-speed, is presently the most popular generator for wind energy application [3].

The DFIG is a Wound rotor induction generator with the stator windings connected directly to the three phases, constant-frequency grid and the rotor windings connected to a back-to-back (AC-DC–AC) voltage source converter [4].

The power electronics converter consists of IGBT converters, namely the rotor side and the grid side converter, connected with a direct current (DC) link. The main idea is that the rotor side converter controls the generator in terms of

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active and reactive power, while the grid side converter controls the DC-link voltage. The battery storage is directly connected to the common DC bus with DC–DC power converter.

Battery storage system plays an important role in an autonomous, wind power generation system and has received considerable attention in recent years [5].

Several research works have been presented with diverse power/voltage control of DFIG based wind energy conversion system connected to the grid with battery storage. These control diagrams are usually based on vector control notion with conventional PI controllers due to their simplicity and easy implementation [6–8]. Fuzzy logic and adaptive fuzzy controllers have been also used in the power/voltage control loop [9].

Classical controllers for wind energy conversion systems (WECS) can be developed for more efficient strategies based on intelligent control techniques.

On-Off control is a robust control method aiming at captured power maximization of DFIG-based WECS connected to the grid with battery storage. This method superposes the tracking of the optimal torque value [10].

The control objective can be formulated as an optimization problem, in which an objective function is maximized or minimized, in order to extract the maximum power from the wind energy.

Particle swarm optimization is one of the most widely used methods for solving optimization problems. PSO is an evolutionary computation technique developed by Eberhart and Kennedy inspired by social behaviour of bird flocking [11].

The PSO algorithm is an optimization tool based on population, and the system is initialized with a population of random solution. It can search for optima by the updating of generations [12].

There is a certain difficulty about the On-Off control, concerning the definition of a switched component (following the sign of the tip speed ratio error) with guaranteed properties of attractiveness and stability.

In this paper, we propose an On-Off control based on particle swarm optimization (PSO) algorithm. Firstly, On-Off Control scheme based maximum power point tracking is proposed to control the rotor side converter of wind turbine equipped with doubly fed induction generator connected to the grid with battery storage, then by the PSO algorithm, the parameters of a switched component function of On-Off controller are optimized for maximum power point tracking of wind energy conversion system.

Wind energy conversion system model

Fig. 1 shows the complete block diagram of the studied system. This system consist a variable speed wind turbine equipped by DFIG connected to the grid, batteries storage connected to a DC–DC buck-boost bidirectional converter using controlled voltage source. The primary objective of the control of this converter is to maintain constant dc-link voltage as a reference value in addition to discharge/charge current from/to batteries bank.

The system comprises an AC/DC rectifier to connect the wind generator to the DC bus and DC/AC inverter must act as a unidirectional power controller between the DC bus and the grid.

Wind turbine model

The turbine converts the kinetic energy of wind into mechanical energy. According to Betz theory, the mechanical power harvested by a wind turbine P_m is expressed as [13]:

$$P_m = \frac{1}{2}\rho\pi R^2 v^3 C_p(\lambda,\beta) \quad (1)$$

where R is the blade radius of the wind turbine, ρ is the air mass density, v is the wind speed, λ is the tip speed ratio, β is the pitch angle, C_p is the wind turbine energy coefficient. The tip speed ratio is defined as:

$$\lambda = \frac{w_r R}{v} \quad (2)$$

w_r is a wind turbine rotor speed.

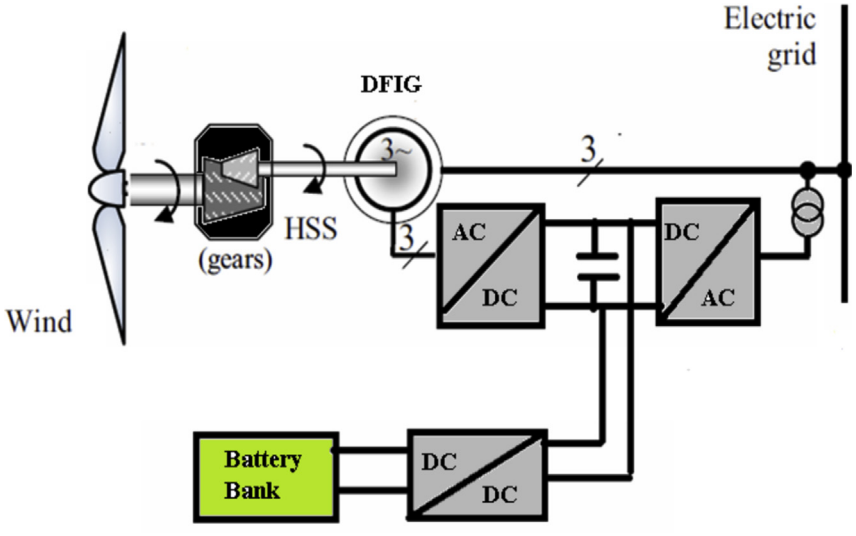

Fig. 1 – Wind energy based on doubly fed induction generator.