2011년도 대한전기학회 하계학술대회 논문집 2011. 7. 20 - 22

PMSG 타입 풍력 발전시스템의 Power-hardware-in-the loop simulation

황철상*, 김경훈*, 김남원*, 박정도**, 이동영**, 이상진**, 박민원*, 유인근*
창원대학교*, 위덕대학교**

Power-hardware-in-the loop simulation of PMSG type wind power generation system

Chulsang Hwang*, Gyeong-Hun Kim*, Namwon Kim*, Jung-Do Park**, Dong-Young Yi**, Sangjin Lee**, Minwon Park*, In-Keun Yu*
Changwon National University*, Uiduk University**

Abstract - This paper deals with a power-hardware-in-the loop simulation (PHILS) of permanent magnet synchronous generator (PMSG) type wind power generation system (WPGS) using a real hardware which consists of a motor generator set with motor drive, real time digital simulator (RTDS), and back-to-back converter. A digital signal processor (DSP) controls the back-to-back converter connected between the back-to-back converter and the RTDS. The proposed PHILS can effectively be applied to demonstrate the operational characteristics of PMSG type WPGS under grid connection.

1. Introduction

Wind power is one of the prominent renewable energy resources to solve the energy issues in the world. Among several different types of wind power generation systems (WPGS), permanent magnet synchronous generator (PMSG) offers better performance than others due to the self-excitation and less maintenance since it does not need rotor current, and could be operated without a gear box, respectively [1].

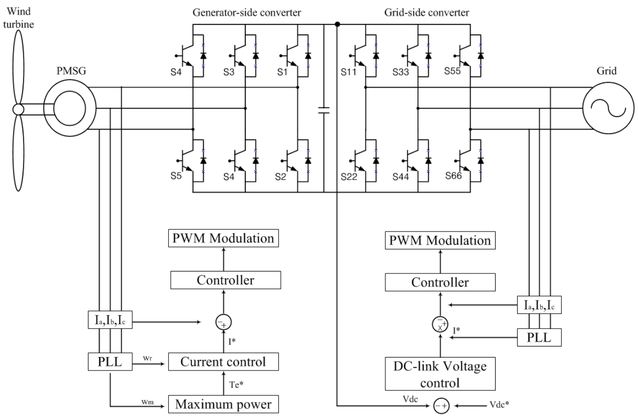
To improve the efficiency and reliability of PMSG type WPGS, it is necessary to analyze the operational characteristics of grid connected WPGS. In order to analyze the operation of PMSG type WPGS, the software-based simulation method has been employed usually because of the high expense of installation of WPGS. However, the software-based simulation result can not predict the actual hardware and controller performances [2].

In this paper, a power hardware-in-the loop simulation (PHILS) of PMSG type WPGS has been proposed to validate operational characteristics of grid connected PMSG type WPGS. A hardware-in-the-loop simulation (HILS) is a technique used to develop and test complex, real-time systems and includes the electrical emulation of sensors and actuators. The HILS technique has merits such as test environment, build-up time, and development cost for developing and testing a system [3]. Unlike computer simulation, the PHILS simulation uses one or several actual hardware system instead of their simulation model. For the PHILS, a wind velocity, and grid conditions are modeled in a real time digital simulator (RTDS). A motor-generator set (MG-set) with motor drive is used instead of a wind turbine. The back-to-back converter is interconnected between the grid and a wind turbine. The back-to-back converter controls a power coefficient for maximum power point tracking (MPPT) and keeps the voltage of DC-link capacitance constant by a digital signal processor (DSP).

The simulation results will enable us to recognize the impacts of grid conditions to the WPGS.

2. System configuration

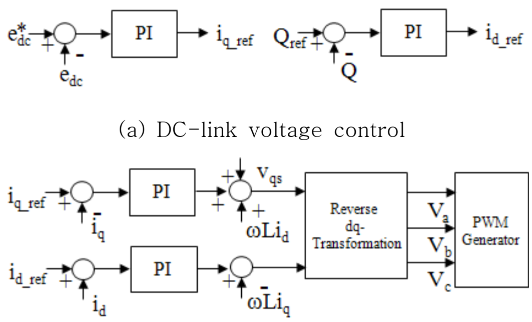
The topology with the PMSG type WPGS is illustrated in Fig. 1. The wind power generation system consists of a PMSG type wind turbine and a back-to-back converter. The back-to-back converter is employed to control the PMSG type wind turbine and to connect the WPGS with a utility grid. The back-to-back converter is composed of the generator-side converter, DC link capacitor, and grid-side converter. The generator-side converter is used to control a power coefficient for maximum power point tracking (MPPT). The grid-side converter is used to keep the voltage of DC-link capacitance constant and to regulate the active power given to the grid [4].



<Fig. 1> Permanent magnet synchronous generator with back-to-back converter

2.1 Grid-simulator

The grid-simulator is connected to the RTDS for implementation of grid condition. The variable grid conditions can be modeled in the RTDS which allows to investigate actual system environment. Through Fig. 2, the grid-simulator controls active and reactive powers, and the DC-link voltage is adjusted by exporting the active power from the grid while the reactive is to be zero.



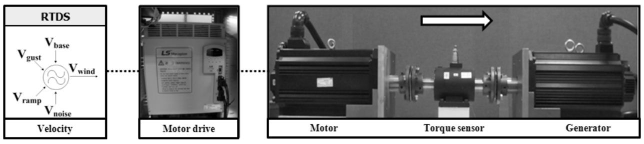
(a) DC-link voltage control

(b) Current control

<Fig. 2> (a) DC-link voltage control and (b) current control at grid simulator

2.2 MG-set

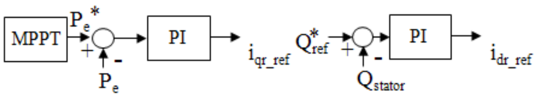
Fig. 3 illustrates a configuration of the MG-set for a wind turbine. A wind turbine is modeled with a AC servo motor and motor drive. The real pattern of wind velocity is modeled in RTDS.



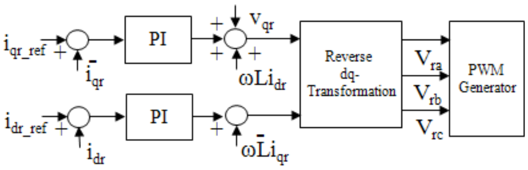
<Fig. 3> Configuration of the MG-set for a wind turbine

2.3 Wind PCS

Fig. 4 depicts the MPPT and current control of the wind PCS. In the wind turbine, an optimum value of tip speed ratio leads to a maximum power coefficient.



(a) Maximum Power Point Tracking control

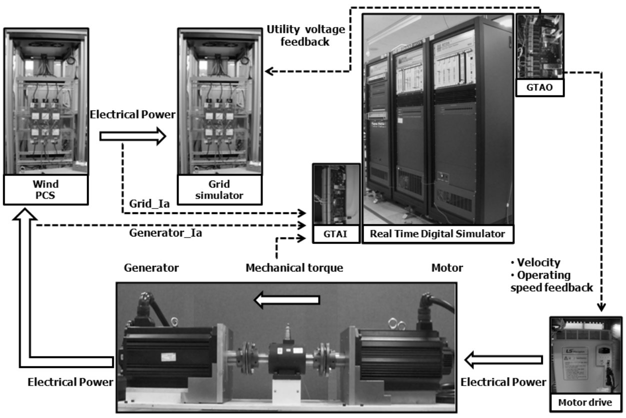


(b) Current control

<Fig. 4> MPPT contol of wind PCS

3. Implementation of PHILS

Fig. 5 shows a configuration of PHILS. The parameters of the MG-set and back-to-back converter are presented in Table 1, Table 2, respectively.



<Fig. 5> Configuration of PHILS

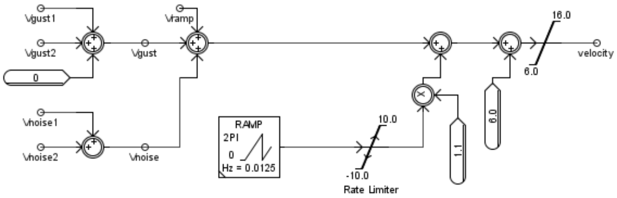
<Table 1> MG-set parameters

Items	Value
Motor rated power	15 [kW]
Motor rated speed	1500 [r/m]
Generator rated power	15 [kW]
Generator rated speed	1500 [r/m]

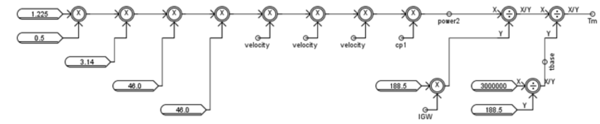
<Table 2> Back-to-back converter parameters

Items	Value
Generator-side converter capacitor	10 [kvar]
Grid-side inverter capacitor	10 [kvar]
Capacitor Capacity	3600 [uF]
Reactance	3 [mH]
Switching frequency	20 [kHz]
Grid voltage (Line-to-line)	380 [V]
Frequency	60 [Hz]

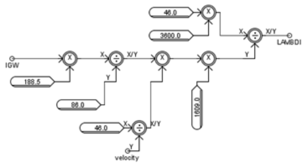
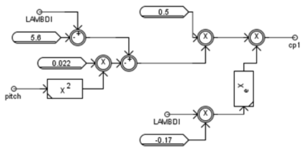
Fig. 6 shows the wind turbine and its control diagram in RSCAD. The model considers the tip speed ratio control and the maximum torque based on wind velocity profile.



(a) Wind velocity model



(b) Wind turbine torque model

(c) Tip speed ratio (d) Power coefficient

<Fig. 6> Wind turbine and its control diagram in RSCAD

4. Conclusions

In this paper, a PHILS based simulation architecture is implemented for the operation of a PMSG type WPGS using RTDS, MG-set, and back-to-back converter. The PHILS provides very similar properties of the grid connected PMSG type WPGS to real power system. The proposed PHILS method can effectively be applied to evaluate output power control and active and reactive power control schemes of PMSG type wind power generation system.

Acknowledgements

The authors of this paper were partly supported by the Second Stage of Brain Korea21 Projects

[References]

[1] E. Vittal, M. O'Malley, A. Keane, "A Steady-state Voltage Stability Analysis of Power Systems With High Penetrations of Wind," *IEEE Transactions on,* vol. 25, no. 1, pp. 433, Sep. 2009.

[2] C-H. Hwang, G-H Kim, M-W. Park, I-K Yu, J-D Park, D-Y Yi, and S-J Lee, "Controller-hardware-in-the loop simulation based transient analysis of PMSG type wind power generation system," *ICEMS 2010.* pp, 69, Dec. 2010.

[3] J-H. Jeon, J-Y. Kim, H-M. Kim, S-K. Kim, C-H. Cho, J-M. Kim, J-B. Ahn, K-Y. Nam, "Development of Hardware In-the-Loop Simulation System for Testing Operation and Control Functions of Microgrid," *IEEE Transactions on,* vol. 25, no. 12, pp. 2919-2929, December 2010.

[4] Chang kang, Xu Feng, Fang Yongjie, and Yu Yuehai, "Comparative Simulation of Dynamic Charateristics of Wind Turbine Introduction Generator Based on RTDS and MATLAB," *APPEEC 2010*, pp. 1-5, March 2010.