정출력 조정을 위한 풍력-연료전지 하이브리드 시스템의 운영 기법

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Operation Scheme to Regulate Constant Active Power Output of Wind Turbine and Fuel-Cell Hybrid System

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Abstract - A operation scheme to regulate the active power output of the hybrid system consisted of a doubly fed induction generator(DFIG) and a fuel-cell are presented. The power output of the wind turbine fluctuates as the wind speed varies and the slip power between the rotor circuit and power converter varies as the rotor speed change. A fuel cell system can be individually operated and adjusted output power. In this paper, a fuel-cell is performed to regulate the active output power in comparison with the active power output of a DFIG. Based on PSCAD/EMTDC power system tools, we simulated a DFIG and a fuel cell and investigated about dynamics of the output power in hybrid system.

Index Terms - fuel cell, hybrid system, output power regulation, wind turbine

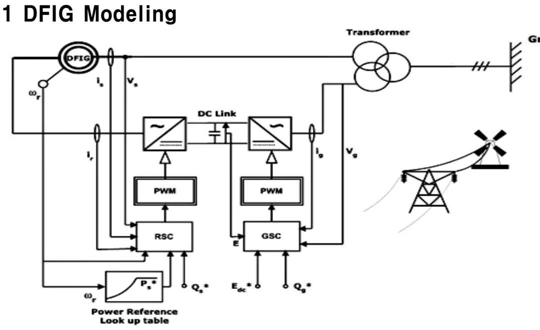
1. Introduction

Wind turbine is a energy resource that is growing in importance as a mean to address the national and global issue of air pollution, increment of power needs, foreign oil, climate change, etc. Wind is both plentiful and renewable-the fuel is free and does not need to be conserved. However from an operation point view, since the wind speed is inconstant, this disadvantage arduously makes to manage the power system. One possible solution to overcome this problem is to integrate wind turbine power source with other source. The fuel-cells are very attractive to be used with intermittent source of energy, like wind turbine, because of high efficiency, fast load-response, modularity, and fuel flexibility.

In this paper, a wind turbine and fuel-cell hybrid system connected to a 22.9kV network has been studied, with particular reference to the control system. The hybrid system, the power electronic interface with the grid and the control systems have been modeled in the PSCAD/EMTDC simulation environment.

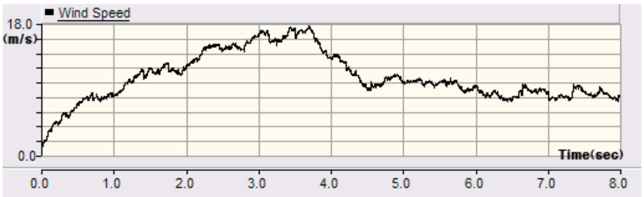
2.Wind turbine and fuel-cell hybrid system

2.1 DFIG Modeling



<Fig. 1> Doubly fed induction generator

In spite of various mechanical torque by wind speed fluctuation, a doubly fed induction generator(DFIG) can control the output power by using the inverter. Modeling the DFIG involves modeling of the wound rotor induction machine, the rotor side converter(RSC), the grid side converter(GSC), the back-to-back PWM converters with DC link between them. Through a slip ring and a brush in the DFIG, the rotor winding is connected to RSC and the stator winding is connected directly the grid. The objective of the GSC is to control the DC link voltage, which must be kept constant at all time. Independent control of P and Q power flowing through the GSC is done by using a reference frame oriented along the stator voltage vector. The RSC controls the induction machine and selecting the synchronously rotating reference frame attached to the stator flux vector allows decoupled control of the electrical torque and rotor excitation current. The P and the Q of the DFIG is controled by this control schemes[1].



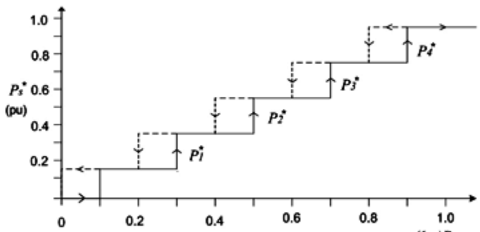
<Fig. 2> Modeling of wind speed variation

2.2 Control scheme to regulate active power of DFIG

As can be seen Fig. 2, the wind speed has inconstant variation in a mount because it depends on natural characteristics. Owing to wind speed fluctuation, the scheme to adjust constant output power of the hybrid system needs in the DFIG and is possible to control by the RSC.

$$i_{qr}^{*} = \frac{2}{3}\frac{L_s P_s^{*}}{L_m v_{qs}} \qquad (1)$$

In the equation (1), the active power reference in the stator(P^*_s) can be controled by q-axis rotor current(i^*_{qr}). The stator active power can be controlled by current controller by applying following q-axis reference current signal. The P^*_s is decided by mechanical torque. To prevent the output power fluctuation, the output power is adjusted by using the P^*_s setting using hysteresis[2].

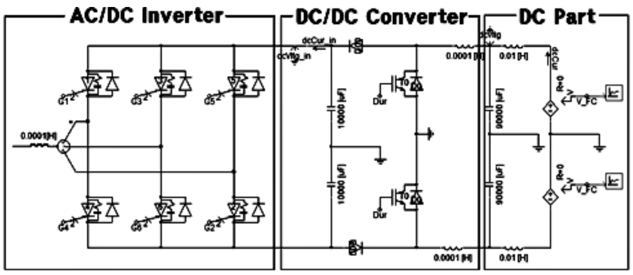


<Fig. 3> Reference power setting using hysteresis

2.3 Fuel-cell system modeling

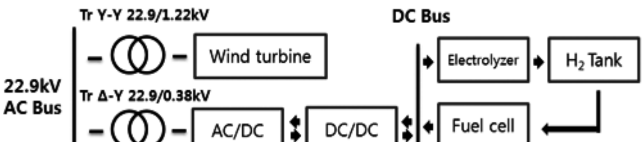
A proton exchange membrane fuel cell(PEMFC) has electrolyte that is a solid polymer in which protons are mobiles. It is widely used for CHP(small scale application), and on mobile power systems especially for vehicle and electronic equipment such as portable computer and mobile telephone. Compared other fuel-cell, It has quick starting, simple structure and wide range of applications of the fuel-cell power, from a few watts up to megawatt. But a fuel-cell has a defect of slow response because of the velocity of chemical reaction of the hydrogen ion(H^+) and principle of the operation[3].

Fig. 4 shows modeling of the fuel-cell system. A fuel-cell modeling involves characteristic of internal voltage, ohmic losses, activation losses, mass transport loss, concentration loss and traits of the catalyst and the temperature responses. Because the cells are connected in series and the stacks are connected in parallel, a PEMFC can generate 2MW. DC output power in a fuel-cell is risen by a DC/DC booster converter, finally the ouput power is changed to alternating power by a AC/DC inverter which controls P and Q.



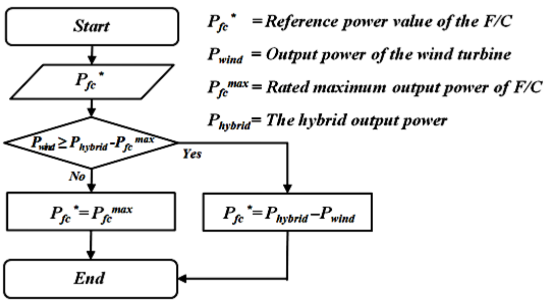
<Fig. 4> Fuel-cell system

2.4. Hybrid system modeling



<Fig. 5> The structure of hybrid system

A 2MW DFIG and a 2MW fuel-cell are connected to 22.9kV AC bus, through the transformers. Algorithm to regulate the constant active power output in the Fig. 6 is used to operate for a DFIG and a fuel-cell hybrid system. In the study, the active power of the hybrid system(P_{hybrid}) is set at 3MW. A fuel-cell of a few MW scale is always maintained turned on mode in the simulation because when a fuel -cell is connected to grid, it is a hard performance to turn on/off instantaneously. A fuel-cell is sent out active power output(P_{fc}^*) according to subtraction the various active power output of the DFIG(P_{wind}) from the P_{hybrid}. But when the P_{wind} is lowered to 1MW, the P_{fc}^* is set to maintain rated maximum output power(P_{fc}^{max}) because the P_{fc}^* can not be raised above 2MW.

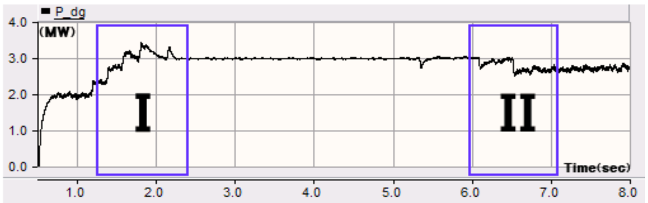


<그림. 6> Flow chart of reference power values setting

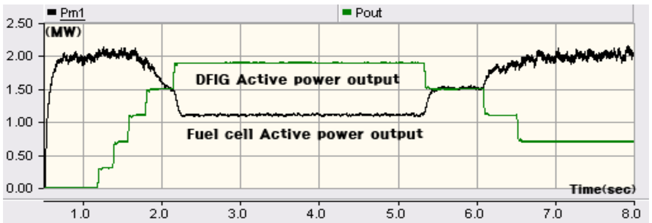
3. Simulation result

Fig.7 shows the hybrid system is adjusted on 3MW output power. A DFIG and a fuel-cell system are initialized after 0.5s and a fuel-cell is generated alonely on the P_{fc}^{max} scale from 0.5s until a DFIG is started(1.2s). Fig. 8 is shows a fuel-cell is compensated its power for adjustment to 3MW in the hybrid output power. The hybrid output can be divide Ⅰ and Ⅱ in the Fig. 7. Ⅰ is a part that a DFIG output is decreased and a fuel-cell output is increased. Ⅱ is a part that a DFIG output is increased and a fuel-cell output is decreased.

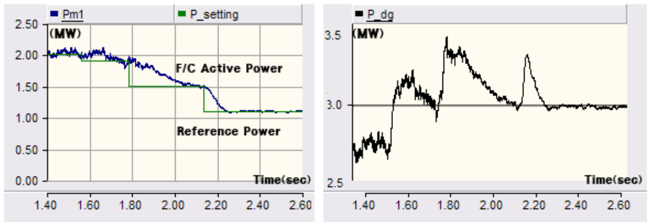
The overshoots of power are occurred by subtraction a fuel-cell output from reference value in the hybrid system since a fuel-cell dynamics is slow according to variation of the reference value. On the other hands , when a DFIG is controled to become low and a fuel-cell is controled to become high, the undershoots are occurred by subtraction reference value from a fuel-cell output.



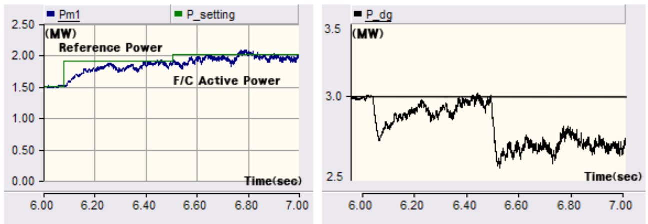
<Fig. 7> Active power of hybrid system



<Fig. 8> Active power of DFIG and fuel-cell



<Fig. 9> Active power response to decreasing P_{fc}^*



<Fig. 10> Active power response to increasing P_{fc}^*

4. Conclusion

For this study, models of a variable speed wind turbine and a PEMFC were combined to simulate a hybrid system. First of all, the variation of a DFIG system has been driven through scheme of active output power regulation of a DFIG using hysteresis. A hybrid system has been operated through the function of a PEMFC which is to supply the rest of the average power to the AC infinite bus. To investigate the output power performances of the hybrid system, simulation studies have been modeled in the PSCAD-EMTDC simulation environment. For the efficiently scheme of active output power regulation of a hybrid system, a DFIG have been worked at the maximum power point tracking (MPPT) mode. The output power compensation in a hybrid system has been used by a PEMFC. Simulation results shows adjusted on 3MW output power of a hybrid system that is controlled a scheme of active output power regulation. When the output power in a PEMFC supply to the AC infinite bus, overshoots and undershoots are occurred because response of a fuel-cell is late. This problem can overcome to use a battery system and we will deal out at the next investigation.

As a consequence, the control of a wind-fuel cell hybrid system can be regulated through constant output power and the system management can be driven under steady-state.

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