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Simulation of Grid-connected Wind Generator in Wind Power Flow Optimization System Experiment Platform

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Abstract

A simulation system of grid-connected wind power generator used for research and development of wind power flow optimization system is analysed and designed. It's key component parts, connection structure and working principle are introduced. As a core module, the DC/AC power condition system (DAPCS) is emphatically discussed and described with respect to topology, modeling and control strategy. Experimental results indicate that the simulated wind power generator can output fluctuant power meeting the demand of research and develop of wind power flow optimization system.

Keywords: Wind power generator; simulation; wind power flow optimization; DC/AC power condition system

1. Introduction

The ransom fluctuation of output power of wind power system changes grid power flow frequently in terms of direction and size, which will lead to voltage instability, frequency fluctuation and some other power quality problems, threaten the security and stability of power system[1-3].

As a new fast energy storage element, the supercapacitor which has high power density and long cycle life, combinated with the traditional battery and used for power conditioning or power flow optimization,

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can take full advantage of the battery's superiority of high energy density and the supercapacitor's superiority of high power density.

The wind power flow optimization control system based on hybrid energy storage including the supercapacitors and the battery can exchange two-way active power and reactive power with power system, so it can smooth power fluctuation, and inhibit or eliminate the above problems caused by the wind power generator. [4-5] The overall layout of the wind power system containing power flow optimization is shown in Figure 1.

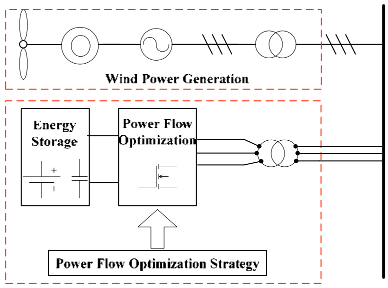


Fig. 1. overall layout of the wind power system containing power flow optimization

There are two ways about research and development of wind power flow optimization system. One way is by virtue of actual wind power generation system, which can debug power flow optimization system aim at operating conditions of wind power plant. But this way is confined by external factors such as meteorological conditions and geographical environment, which lead to long period and high cost of the development.

The other way[6-7], a popular way at present, is based on simulated wind power generation system that is composed of adjustable motor and generators, which may flexibly simulate operating conditions of wind power plant. But the simulation system has the disadvantage of complicated structure, difficult control and high cost.

In the process of research and development of wind power flow optimization system, only random active power and reactive one fluctuating as wind power plant output are necessary and enough. Hence, to simplify the structure and to diminish the cost, the paper constitutes a simulated grid-connected wind power plant using AC/DC converter and DC/AC power condition system (DAPCS).

2. Structure and Realization Idea of simulated Grid-connected Wind Power Generator

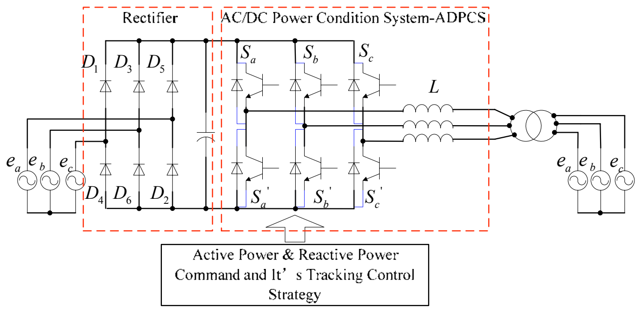


Fig. 2. connection topology of power converters

As illustrated by Fig. 2, the simulation system of the grid-connected wind power generator mainly contains two parts, one is power converters and another is control unit. Power converters include AC/DC converter (rectifier) and DC/AC power condition system (DAPCS). The rectifier is composed by diodes and filtered by capacitor, which can obtain a stable DC voltage. The DAPCS is composed by IGBTs and controlled by control unit, which can produces corresponding active power and reactive power. Control unit was composed of an upper computer and electronics circuit based on DSP, i.e. power command production section and command tracking control section. The upper computer provides fluctuant power command by virtue of random function or measured data of actual wind power generation system. The command tracking control section carry out sampling, computation, PWM pulses output, power protection and some other functions. The upper computer and the DSP exchange information by means of communication interface-MAX232. Fig.3 is the connection structure of control unit.

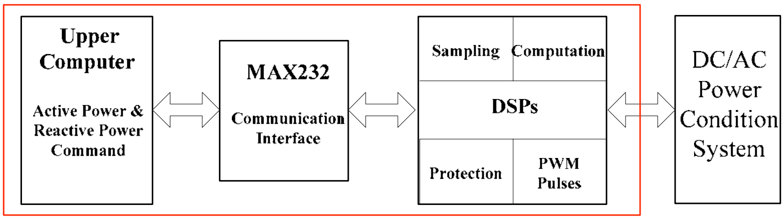


Fig. 3. connection structure of control unit

Obviously, DC/AC power condition system (DAPCS) is the core and also the difficult point in design and realization of the simulated grid-connected wind power generator. The paper emphatically analysis and describes modeling and control strategy of DAPCS.

3. Modeling and Control of DAPCS

The connection topology of DAPCS and the grid is shown by Fig.4, without considering the transform ration of the transformer.

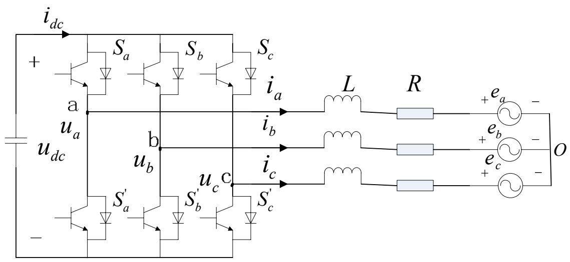


Fig. 4. connection topology of four- quadrant converter and the grid

To design control unit of the converter, quantitative relations of parameter disturbance in the rotating reference frame are deduced and the linear small signal model of the converter shown in Fig. 6.

Via Clarke and Park transformation, the currents i_a, i_b, i_c in the three-phase stationary reference frame can be converted to i_d, i_q in the rotating reference frame, which respectively stands for the active component and the reactive one of the current. [8]

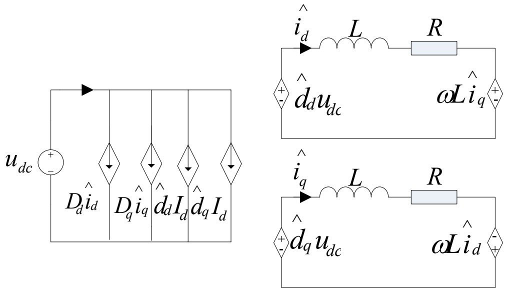


Fig. 5. linear small signal model of the converter

In Fig.5, the symbol marked" ∧ "represents the disturbance of corresponding parameter, the one denoted by capital letters means a parameter in steady state.

Ignoring the perturbances of the DC voltage and the grid voltage in a limited time, there is

$$\hat{i}_{dc} = D_d \hat{i}_d + I_d \hat{d}_d + D_q \hat{i}_q + I_q \hat{d}_q \tag{1}$$

$$\hat{d}_d u_{dc} + D_d \hat{u}_{dc} = \hat{i}_d (sL + R) - \omega L \hat{i}_q + \hat{e}_d \tag{2}$$

$$\hat{d}_q u_{dc} + D_q \hat{u}_{dc} = \hat{i}_q (sL + R) + \omega L \hat{i}_d + \hat{e}_q \tag{3}$$

In linear mall signal model, the d axis and q axis couples with each other. By virtue of feedforward decoupling strategy [8], the coupling terms can be eliminated, thus transfer function of duty to current in the d axis and q axis can be obtained :

$$\frac{\hat{i}_d}{\hat{d}_d} = \frac{u_{dc} / R}{1 + \frac{L}{R} s} \tag{4}$$

$$\frac{\hat{i}_q}{\hat{d}_q} = \frac{u_{dc} / R}{1 + \frac{L}{R} s} \tag{5}$$

The control strategy of DAPCS is proposed as shown in Fig. 6 based on the mathematical mode mentioned above.

The parameters of k_p and k_i in the current close loop can be obtained according to engineering design method of typical type I control system,

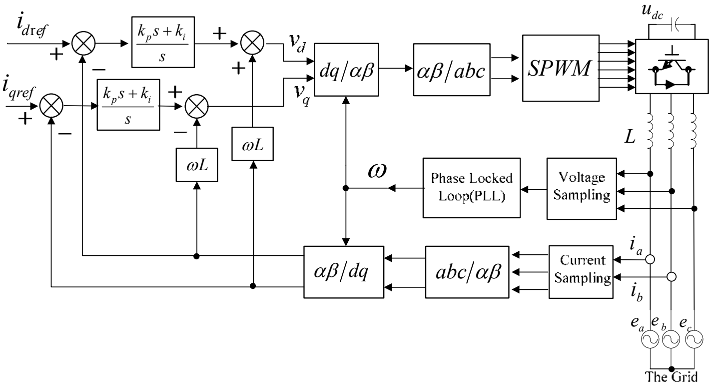
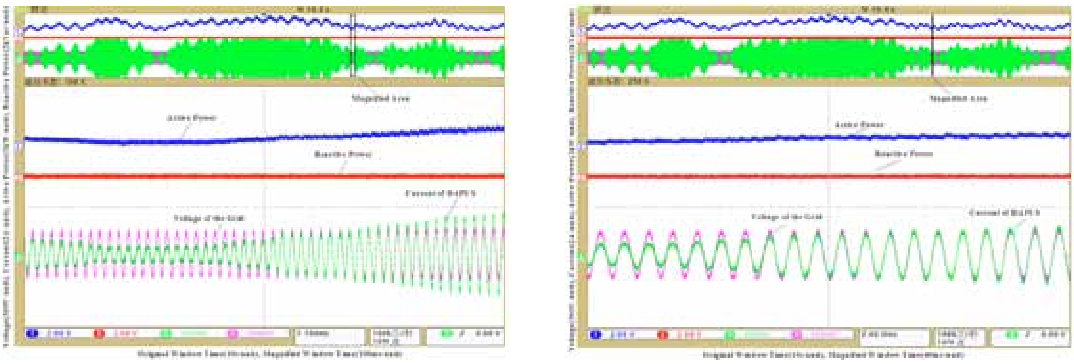


Fig. 6. control strategy of DAPCS

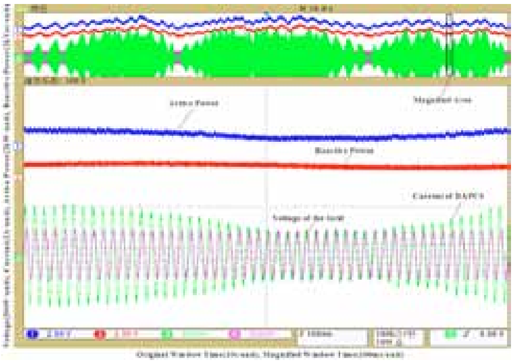
4. Experimental Results

A 5kW simulated wind power generator prototype is designed and realized, whose control unit is composed a PC and electronic circuit relying on TMS320LF2407A (DSP). Fig.8 illustrates the waveform of the prototype system under various working conditions. Of which, (a) and (b) are the operating conditions when the system only outputs fluctuant active power, while (c) and (d) are the operating conditions when the system outputs fluctuant active power as well as fluctuant reactive power. In oscilloscope images showed by Fig.8, the upper part is the waveform in a comparatively long time(10 seconds per time unit), while the lower part is magnified state about a short while(100 milliseconds per time unit) of waveform in upper part. (1)~(3) in the oscilloscope images respectively are active power, reactive power, the current injected in the grid and the grid voltage.

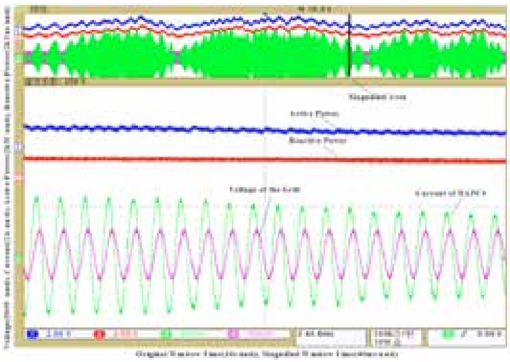
Seen from the experimental results, the prototype system can output random active power and reactive power fluctuating as real wind power plant output power.



(a) (b)



(c)



(d)

Fig. 7. waveform of the prototype system

5. Conclusions

The design of a simulated wind power generator in wind power flow optimization system experiment platform is analyzed and discussed. Topology, modeling and control strategy of DAPCS, which is used to trace active current command and reactive one respectively, are described in detail. The experimental results indicate that the simulated wind power generator proposed in the paper can flexibly output active power and reactive power in fluctuant size, so it can meet the requirements of wind power flow optimization system.

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