Research on method of mitigating instability of wind power generation system based on hydrogen production

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Abstract——Intermittent power generation of renewable energy power generation system is the active reason affecting the stability of power grid, and adjusting the load imbalance between power generation and power supply through hydrogen production unit is the main means to reduce the impact of natural conditions and ensure continuous and stable power supply. In this paper, the simulation model of permanent magnet direct drive fan system for hydrogen production load is established, and the permanent magnet direct drive wind power generation unit is used to supply power to hydrogen production load to achieve the effect of stable output power.

1. Introduction
Energy shortage and environmental problems caused by energy utilization restrict social progress and economic growth. With the increasingly severe situation of global energy and environmental protection, the international community has paid unprecedented attention to renewable energy. Countries all over the world not only actively encourage the development of renewable energy at home, but also work together for the sustainable development of the world.

One of the most developed renewable energy technologies is the use of wind energy converters to convert the kinetic energy of wind energy into electric energy. Under various circumstances in 2050, wind power generation is predicted to be one of the most important renewable energy sources. According to the data information released by the National Bureau of statistics in 2018, the total amount of wind power generation in China has reached 236.73 billion kwh in the first three quarters, so wind energy is one of the best energy options that people know today[1]. As a secondary energy, hydrogen energy can help to gradually replace fossil energy with renewable energy, promote energy transformation and build a new generation of energy system with high efficiency, low carbon, safety and efficiency[2].

2. Characteristics of permanent magnet direct drive wind power generation system
The principle of wind power generation is as follows: use the wind to drive the windmill blades to rotate, and increase the rotation speed of the booster engine to drive the generator to generate electricity.

The main feature of variable speed constant frequency wind turbine is that the propeller of variable speed wind wheel is adopted, and the transmission system adopts gearbox; Direct drive variable pitch variable speed constant frequency wind turbine uses direct coupling transmission, and the generator adopts multi pole synchronous motor and full power frequency conversion equipment to connect to AC three-phase power grid. The most important performance of direct drive system is stability, and its power generation efficiency is ideal.

Under certain operating parameters, the relationship among the output power, mechanical torque and
wind energy utilization coefficient of the wind turbine is based on Bates law, as shown in equations (1) to (3).

\[ P = \frac{\rho}{2} \pi R^3 v^3 C_p \]  
\[ C_p = 0.5176 \times \left( \frac{116}{\lambda} - 0.43 - 5 \right) e^{-\frac{21}{\lambda}} + 0.0068 \lambda \]  
\[ \frac{1}{\lambda} = \frac{1}{\lambda + 0.08} - \frac{0.035}{\beta^3 + 1} \]  

In the formula: \( P \) —— output power, W; \( C_p \) —— Wind energy utilization coefficient; \( \lambda \) —— Tip speed ratio; \( \omega \) —— Angular velocity of wind turbine, rad / s; \( \beta \) —— Pitch angle of blade, °.

The fan model in Figure. 1 is established according to the above mathematical model.

3. Electrolytic water hydrogen production system

Due to the fluctuation, randomness and intermittence of wind power, the serious wind abandonment problem caused by the failure to connect to the grid can be solved by converting wind energy into hydrogen energy\(^{[3]}\). As a device for producing hydrogen, the electrolytic cell can be equivalent to the DC load element in the circuit\(^{[4,5]}\). By inputting water and current into the electrolytic cell, the cathode and anode of the electrolytic cell will electrolyze to produce hydrogen and oxygen. The greater the current, the more hydrogen will be produced. See formula (4) for U-I characteristic equation of electrolytic cell.

\[ U_{\text{elec}} = U_{\text{rev}} + \frac{r_1 + r_2}{A} T_{\text{elec}} I_{\text{elec}} + k_{\text{elec}} \ln \left( \frac{k_1 + k_2 T_{\text{elec}} + k_3 T_{\text{elec}}^2}{A} I_{\text{elec}} + 1 \right) \]  
\[ U_{\text{elec}} \] —— unit working voltage (V); \( r_1, r_2 \) —— resistance related parameters; \( T \) —— electrolytic cell temperature (K); \( k_{\text{elec}}, k_1, k_2, k_3 \) —— overvoltage parameter; \( A \) —— unit electrode area; \( I_{\text{elec}} \) —— unit current (A); \( U_{\text{rev}} \) —— reversible open circuit voltage.

\[ U_{\text{rev}} = -\frac{\Delta G}{2F} \]  
\[ F \] —— faraday constant; \( \Delta G \) —— Gibbs change value.

\[ \Delta G = \Delta H - Q = \Delta H - T \Delta S \]  

Under standard conditions, \( \Delta S = 0.1631 \text{kJ/mol} \), \( \Delta H = 285.85 \text{kJ/mol} \).

The hydrogen production rate of the electrolytic cell composed of \( n \) units in series is

\[ q = \eta_{\text{f}} \frac{n I_{\text{elec}}}{2F} \]  
\[ \eta_{\text{f}} \] —— faraday efficiency coefficient.

U-I and hydrogen production rate model of electrolytic cell are shown in Figure. 2.
4. Research on operation of wind power hydrogen production

The permanent magnet direct drive fan system model for hydrogen production load is built in the software, and the simulation waveform of system operation under variable wind speed is obtained. Firstly, according to the above analysis, each module is encapsulated together to establish the simulation model of wind power hydrogen production system, as shown in Figure. 3.

The initial value of wind speed is $7 \text{m/s}$, adjust the wind speed to $13 \text{m/s}$ at $1 \text{s}$, and reduce the wind speed to $9 \text{m/s}$ at $3 \text{s}$. Figures. 4 show the output power when the wind speed changes.
As can be seen from the above figure, when the wind speed changes, the fan output power can reach the optimal value after a short fluctuation.

Figures 5 and 6 show the simulation waveforms of the electrolytic water system when the output power of the wind power generation system changes.

Figure 5 load power model of hydrogen production

Figure 6 hydrogen production model
It can be seen from the above figure that when the wind speed changes, the system can timely coordinate and control the fan unit and hydrogen production unit to maintain the high efficiency and stability of hydrogen production load.

5. Conclusion
The model of permanent magnet direct drive wind power generation system for hydrogen production load is established, and the working principles of wind power generation system and hydrogen production load of electrolytic cell are simulated and analyzed. The simulation results show that the simulation model built in this paper can be applied to the actual situation analysis and make better use of intermittent wind resources.

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