The Hydrogen Production System in Wind Power Micro Grid Modeling and the Simulation on Its Power Property

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Abstract. The fluctuation of wind power may easily cause the great impact on the grid while it was integrated in the grid in large scale, and resulted in the generally existed phenomenon of abandoned wind power and power brownouts accordingly. Aiming to such problem the academic circles have proposed the method of hydrogen production to consume the excessive wind power. In this paper, with the consideration of the power supply scheme for micro grid, it aims to enable the wind power better providing power for hydrogen production, and designs its structure according to the working principles of each module, and completes the system modeling of such micro grid based on Dig SILENT Power Factory software and carries out the flow analysis on such model and simulation of power control model, it proves that this system can be run stably theoretically.

Introduction

First of all, in this paper it does think of the method to consume the excessive wind power through hydrogen production by aiming to the phenomenon of abandoned wind power that generally existed in wind power industry. In order to use the power supply scheme of micro grid to enable wind power-such a distributed renewable energy - better providing energy for hydrogen production system, it then proposes the idea of the micro grid with hydrogen production by wind power, and designs its structure according to the working principles of each module, and completes the system model of such micro grid based on Dig SILENT Power Factory and carries out the flow analysis on such model and simulation of power control model, it then proves the theoretical feasibility of such system.

There has been many researches on the modeling of micro grid system which are mainly connect the distributed energy resource and the energy storage equipment as well as the power networks. But the research of direct consuming in distributed energy micro grid is now not mature. In this paper, the hydrogen production system in wind power micro grid would be discussed.

Modeling

The whole micro grid system mainly includes the three major parts of storage battery, wind turbine and hydrogen production equipment. First of all, it sets the model for the storage battery, wind turbine and hydrogen production module in the micro grid with hydrogen production by wind power, then completes the overall modeling of the whole micro grid, lays down the foundation for the followed flow analysis and running simulation.

The Model of Energy Storage System in Storage Battery

In this paper, it takes a direct-current source and a full power PWM converter to simulate the structure of storage battery, the model is shown in figure 1. There into, it makes some simplified treatments: to ignore the dynamic process of the battery’s discharge and charging process; to replace the actual generating unit with constant-voltage power source; to consider the voltage of storage battery always in a constant level; to omit the dynamic characteristic of storage battery. But with the consideration of that it mainly test the steady state of micro grid, and that it needs the storage battery to maintain the
stable voltage and frequency of the whole system while the micro grid is running in the status of the islanding, thus it then think that such simplification is reasonable.

![System model of storage battery](image1)

Figure 1. The system model of storage battery.

While running in the status of islanding, the converter of storage battery should be controlled by v/t, that is to adopt the droop control principle, so as to guarantee that the voltage amplitude and frequency of its AC bus can always keep in constant whatever the exact power level the system was running under, and the output voltage amplitude and frequency of its dual-direction converter shall have the droop characteristic as following:

\[
\begin{align*}
\omega - \omega_0 &= -k_p (P - P_0) \\
U - U_0 &= -k_q (Q - Q_0)
\end{align*}
\]  

(1)

There, \( \omega_0 \) and \( U_0 \) are respectively the rated angular power and rated voltage outputted by converter. \( k_p, k_q \) are the droop coefficient of converter. \( P, Q \) are respectively the active power and reactive power actually outputted by converter.

From above it then gets its control principle diagram as per shown in figure 2.

![v/t control chart of battery](image2)

Figure 2. The v/t control chart of battery.
In above figure, there are three measuring modules and 2 PI control links. The storage batter is integrated in the AC bus with phase-locked loop and feedback the measured parameters to converter. At the same time, it then sends the measured system frequency to the frequency control module in the system.

**The Model of Wind Turbine**

In this paper, it selects the direct-driven permanent magnet wind turbine to establish the model. The system uses a commutator and a DC-to-AC converter as the frequency transformer, to complete the grid connect of wind power. At the same time, by using dual PWM it can control the system more flexibly and precisely, to improve the running characteristic of the system accordingly.

Through a commutator and an AC-DC converter, the wind turbine can be connected with outer grid. The frequency transformer uses the dual-loop control strategy to achieve the effect of constant power control. At the side of generator rotor, both the motor’s rotation rate, active power and reactive power can be acquired through direct measurement. At the side of grid, it can directly measure the voltage, frequency, voltage of DC bus and reactive power of the grid connect point.

In order to guarantee the balance between the active power and reactive power in the whole micro grid system, it may also need to use Vdc-Q control on the converter at the grid connect side and Vac-P control at the motor rotor side, hereby the principle of the general PQ control algorithm is:

\[
\begin{align*}
P &= u_d l_d + u_q l_q \\
Q &= u_q l_d - u_d l_q
\end{align*}
\]

Equation (2)

\(u_d l_d\) and \(u_q l_q\) is the DC component which are transformed from the voltage and currant of AC gird by dq transform.

**The Model of PEM Hydrogen Production System**

Most of electrode reactions can be regarded as the equivalent circuit consisting of capacitance, resistance or electrochemical elements. The equivalent circuit of electrolysis pool is shown in figure 3:

![Figure 3. The equivalent circuit diagram of electrolysis pool.](image)

It used 2 capacitive loads to represent the capacitance and reactance of the cathode and anode in the hydrogen production model that mentioned in above text. On one hand, the PWM DC-to-AC converter generates direct current to provide the power for electrolysis pool, on the other hand, it also coordinates with outer grid to carry out PQ control and guarantee the stable active power and reactive power of the system.

**The Overall Modeling of System**

The system mainly contains the three parts of storage battery, wind turbine and hydrogen production equipment.

During modeling process, due to too complex and fussy setting on each module and there’s already the relative model integrated the wind turbine in Dig SILENT Power Factory, thus it can directly call
such module and only need to set the parameter matching with the previously established model. In addition, aiming to hydrogen production model, it can also be further simplified, it can consider the anode and cathode with the load equivalent to a capacitive load, and it can be realized with the PWM DC-AC converter in storage battery. Thus the hydrogen production model can be regarded as an equivalent load.

By sorting above thinking and simplifying the model it then gets the micro grid model of wind power hydrogen production as per shown in figure 4:

There, the power of wind turbine shall be connected with 1Kv bus through step-up of transformer, then supply the power to hydrogen production load through step-down of transformer. In addition, the bus is also connected with the storage battery and outer grid, so as to stabilize the voltage and frequency of the grid. At the same time, by using PWM DC-AC converter with PQ control or v/f control, it then can guarantee the stable and continuous operation of micro grid, there into, the control module and control chart of it was already described in details in previous text, there’s no longer matching interpretation then.

**Simulation**

For the use of Dig SILENT Power Factory flow computing function module, its parameter setting is shown in table 5:

<table>
<thead>
<tr>
<th>Rated power of wind generator</th>
<th>Rated voltage of generator bus</th>
<th>Rated voltage of storage battery bus</th>
<th>Rated power of storage battery set</th>
</tr>
</thead>
<tbody>
<tr>
<td>2MW</td>
<td>690V</td>
<td>220V</td>
<td>1MW</td>
</tr>
<tr>
<td>Rated power of hydrogen production load</td>
<td>Rated voltage of hydrogen production bus</td>
<td>Rated voltage of general bus</td>
<td>Transformer capacity</td>
</tr>
<tr>
<td>1.5MW</td>
<td>500V</td>
<td>1000V</td>
<td>3MVA</td>
</tr>
</tbody>
</table>

To set the initial condition as AC flow with three-phase equilibrium, and with the consideration of the control on active power and reactive power and the automatic control of transformer, temperature in 20℃, other settings are both the default values, through flow computation it can get following results as per shown in figure 6:

From figure 6, it can be seen that, the flow of this system is convergent, and while there’s no interference in the stable system operation, all the components can run well at normal working condition. The active power and reactive power of each device are both steady, without the
phenomenon of overload and no-live load. In summary, the electrical parts of this system shall be feasible.

In this paper, it mainly investigate the various data of each component under stable operation, check whether it has the stability during operation. By carrying out the transient simulation on the motor, it then gets the data as following:

Figure 6. Flow analysis results.

In storage battery part, the simulation results for the active power and reactive power of PWM converter are shown in figure 7.

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The simulation results for the voltage and current of converter are shown in figure 8:
There, the horizontal ordinate shows the time with unit in second; the vertical ordinate shown the measured values with units in MW and KV respectively.

After running for quite a while, the converter can reach the stable active power and reactive power level, and its voltage and current are both becoming stable accordingly. Thus it can get the conclusion that both the PQ control and v/f control can effectively guarantee the stable operation of system. The simulation results for wind turbine operation are shown in figure 9:
The horizontal ordinate shows the time (s), and from the top to the bottom the vertical ordinates show the active power (MW) and reactive power (MVar) respectively. From figure 13 it then can be seen that, in quite short time, the wind turbine can provide the stable power output for the system and its reactive power level is still at the controllable status accordingly.

In addition, through simulation on the load characteristic of electrolysis pool, it can be seen that, after switching the operation status, although there’s the sudden changes in the current and voltage deviation of electrolysis pool in slight range, later on it still maintains such a value approaching to the status before switching, thus such changes could be ignored.

**Conclusion**

Through the analysis on overall system flow, operation status of wind turbine, converter of storage battery, the simulation operation results of electrolysis pool load, it comprehensively expounds that, this micro grid has not only the ability to achieve the stable grid connected operation, but also has the ability to achieve the stable islanding operation accordingly.

**References**

