A research on integrated district energy system planning considering hydrogen production

Wanqiu Zhang1*, Li Liu2

1 Shenyang Institute of Engineering, Shenyang, Liaoning Province, 110136, China
2 Shenyang Institute of Engineering, Shenyang, Liaoning Province, 110136, China

*Corresponding author’s e-mail: iasm@woyoxin.com

Abstract. In this paper, the comprehensive energy system of wind power hydrogen production plant is considered. Firstly, wind power hydrogen production model, electrolysis hydrogen production model and comprehensive energy system model containing wind power hydrogen production are proposed, combining the operation model in the comprehensive energy system, electric heating load demand and the operation characteristics of the power system. Secondly, the objective function of the integrated energy system is to optimize for the lowest total operating cost, establish an optimization model, and restrict its overall power balance and the relevant constraints of each part. Finally, energy plan is adopted for simulation operation. The results show that the integrated energy system considering wind power for hydrogen production can better absorb wind energy, reduce the phenomenon of wind abandonment, and convert wind abandonment into hydrogen resources, which can improve economic benefits and make full use of energy.

1. Introduction

In recent years, the installed capacity of wind power has been increasing year by year, but now the proportion of renewable energy in the overall energy structure is still not very satisfactory. Therefore, in order to use renewable energy more fully, the concept of integrated energy system has emerged. And, there is a big difference between the integrated energy system and the traditional power system. The integrated energy system includes electricity, heat and other energy flow channels, etc. The energy flow of the integrated energy system is compared with the traditional power system. The system is more complicated. Therefore, under the premise of ensuring the safe operation of the system, by adjusting the output between different energy units, the expected goals are achieved, such as the smallest CO2 emissions, the least primary energy consumption, and the lowest total operating cost of the system, etc. And so on, which has a very important meaning.

In current integrated energy system, the problem of low utilization of renewable energy is widespread, mainly due to the volatility of renewable energy at present, when there is wind, when the wind power to meet the power demand of user side, because a large number of storage, electricity cannot therefore wind farms can only choose to give up part of the wind, which led to abandon the wind, in the integrated energy system model was constructed, if this part will be abandoned as electrolytic hydrogen energy, wind and hydrogen production by electrolytic hydrogen production link there are a variety of purposes, which has been widely applied current purpose is to use hydrogen and CO2 producing synthetic gas (CH4), and CH4 plays an important role in the future primary energy structure.
2. Principle and model of hydrogen production by electrolysis

In the process of hydrogen production by hydroelectric solution, water serves as both an oxidant and a reducing agent. A DC power supply is connected with a wire between the cathode and the anode, and the switch is closed. Water will be decomposed into hydrogen and oxygen in an electrolytic reaction. At a given temperature, the calculation formula of U is given as follows:

\[ U_{cell} = U_{rev} + \frac{R}{A} I + s \log\left(\frac{I}{A} + 1\right) \]  

(1)

In order to correctly simulate the relationship between overvoltage and temperature, Formula (1) is modified. Ohmic resistance parameter R and overvoltage coefficient S and T are taken into account. The model is as follows:

\[ U_{cell} = U_{rev} + \frac{r_1 + r_2}{A} I + s \log\left(\frac{I_1 + I_2 + T + I_1^2/T^2}{A} + 1\right) \]  

(2)

Electrolytic cell power consumption wind power expression is as follows:

\[ P_{HI} = U_{cell} I_{cell} \]  

(3)

3. Integrated energy system model of hydrogen production device with wind power

3.1. Integrated energy system optimization model

Under the premise of the priority consumption of wind power, the optimization model of the comprehensive energy system with wind power hydrogen generation device was established with the goal of minimizing the total operating cost of the comprehensive energy system, and the objective function was

\[ \min f = f - f_{H2} \]  

(4)

Where: \( f \) is the total operating cost of the system; \( f_{H2} \) is the profit from selling hydrogen.

The generating cost of a power unit is as follows:

\[ f_i(P_{chp,i}) = a_i + b_i P_{chp,i} + c_i P_{chp,i}^2 \]  

(5)

3.2. The overall power balance constraints of the integrated energy system

The overall power balance constraint can be expressed as:

\[ \sum_{j=1}^{N_{chp}} P_{chp,j} - \sum_{i=1}^{N_{wind}} P_{wind,i} - P_{e,t} + P_{load,t} = \]  

(8)

Where, \( N_{wind} \) is the number of power units in the comprehensive energy system; \( P_{chp,i} \), is the output power of wind turbine i in time period t; \( P_{e,t} \), is the power absorbed by the hydrolysis device in time period t; \( P_{load,t} \) is the total load of the integrated energy system in time period t.Among them, the electrolytic device only produces hydrogen when the wind power of the system is surplus or when the hydrogen reserves are insufficient to meet the load demand, and the fuel cell only generates electricity when the new energy is completely consumed.

3.3. Constraint of wind power hydrogen production device

\[ P_{e}^{\min} w_{e,t} u_{e,t} \leq P_{e,t} \leq P_{e}^{\max} w_{e,t} u_{e,t} \]  

(9)
Where, \( P_{e}^{\text{max}} \) is the maximum power consumption of the electrolysis device; \( P_{e}^{\text{min}} \) is the minimum value of the power consumed by the electrolysis device. \( w_{e,t} \) is the initialization state parameter of the hydro-lysis device. \( u_{e,t} \) is the variable 0-1 of the operating state of the hydro-lysis device.

3.4. Thermal Constraint of integrated energy system
The balance of total thermal output is constrained by

\[
Q_{L,t} = \sum_{i=1}^{N_{r}} Q_{G,i,t} + Q_{t} + Q_{\text{chp},t} - Q_{\text{loss},t}
\]

Where, \( Q_{L,t} \) is the heat load of the integrated energy system at time period \( t \); \( Q_{\text{loss},t} \) is the thermal power loss in time period \( t \).

4. Case study
Design of integrated energy system including wind turbines, electric hydrogen production capacity of 9000 mw unit 1 capacity up to 700 mw, and a heat pump units, the capacity is 750 mw, COP coefficient is 3.5, the coal-burning CHP unit electricity capacity of 5000 mw, electrical efficiency is 0.42, automatic matching for 6341 mw heat capacity selection system, thermal efficiency is 0.52, CHP unit set minimum power is 1500 mw; Optimization period \( T=168h \), time interval \( \Delta t=1h \). The simulation analysis is carried out in EnergyPlan, and the data is based on the electric heating demand of residents and factories in a certain area of northern Liaoning Province. The annual electricity consumption is about 34.63TWh/year, and the heat consumption is 22.63TWh/year. Because the simulation data is too large in hours, there are 8784 sets of output data of different units. The electric load curve is used in the case studies as shown in Fig. 1. The heat load curves is as shown in Fig. 2.

![Figure 1 Electric load curve used in case study](image-url)
As shown in Figure 3, after adding P2H, wind power has been increased. According to the energy plan simulation, the input raw data, results, through the observation, which can be found clearly integrated energy systems containing wind power hydrogen production device with no wind power compared to hydrogen production device integrated energy system, and make the system run to save the cost of higher than the initial construction costs, improve economic efficiency, abandon the wind phenomenon, to promote wind power given.
5. Conclusion
In this paper mainly studies that the integrated energy system, including the effect of absorbing to abandon the wind wind power hydrogen plant, this paper uses the energyplan as simulation software. The conclusions are as follows: (1) Including wind power integrated energy system and hydrogen production device does not contain wind hydrogen production device integrated energy system can better absorb wind, improve the utilization rate of wind power; (2) The comprehensive energy system including wind power hydrogen generation device shows regular changes with the different capacity of the electro hydrogen conversion device, that is, the larger the capacity of the electro hydrogen conversion device is, the more abandoned wind it absorbs; (3) Compared with the integrated energy system without wind power hydrogen generation device, the comprehensive energy system with wind power hydrogen generation device can save the cost of system operation higher than the initial construction cost and improve the economic benefit; The larger the capacity of electrolytic cell, the higher the cost savings of system operation. However, when selecting the capacity of electrolytic cell, it is necessary to comprehensively consider various factors such as the amount of abandoned air and the demand of hydrogen to select the appropriate capacity of electrolytic cell.

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