An autonomous optimization model for multi-source heat-power combined microgrid considering hydrogen production

Ying ZHUANG[1] Wei PEI[1,2] Li KONG[1,2] Wei DENG[1,2] Shizhong ZHANG[2]

[1] Institute of Electrical Engineering ,Chinese Academy of Sciences

[2] School of Electronic, Electrical and Communication Engineering ,University of Chinese Academy of Sciences

Introduction

Hydrogen energy has become an important clean energy worldwide because of its characteristic of high calorific value, high combustion efficiency, completely pollution-free combustion products and flexible energy storage deployment. With the approach of the XXIV Olympic Winter Games which will take place in Zhangjiakou,China, the city decides to put into ground more hydrogen fuel cell vehicles during the competition which can reduce the pollution and promote the construction of Eco-city. Therefore, the demand of local hydrogen production significantlly increases.

Moverover, Zhangjiakou city possess abundant wind and solar resource. Using the above renewable energy to product hydrogen can be an wise choice to meet the local hydrogen demand and also an effectively way to improve the utilization ratio of renewable energy and reduce the wind and solar waste.

Thus,a multi-source heat-power combined microgrid considering hydrogen production has been proposed. Then an autonomous optimization model is employed to minimize the operating cost of the system and gives optimal output power for each unit in order to maintain its steady function and at the same time ensuring the hydrogen production of the system is able to meet the local demand.

Objective

The goal of this study is summarized as follows:

- The system take fully utilization of wind and solar energy, no waste of wind and solar energy occurs.
- The autonomous optimization model can ensure the steady function of the introduced multi-source heat-power combined microgrid in island mode.
- The hydrogen production of the microgrid can satisfy the hydrogen demand of the city.
- The total operating cost of the system can be minimized.

Methods

The structure of the microgrid

The model of the system is shown in Fig. 1. The direction of the flash indicates the direction of the electric and heat power flow. The microgrid includes wind turbine(WT), photovoltaic cell(PV), electric boiler(EB), fuel cell(FC), electrical energy storage system(EESS), thermal energy storage system(TESS) and hydrogen electrolyzer(HE). The microgrid is fully supplied by renewable energy and operates in off-grid mode.

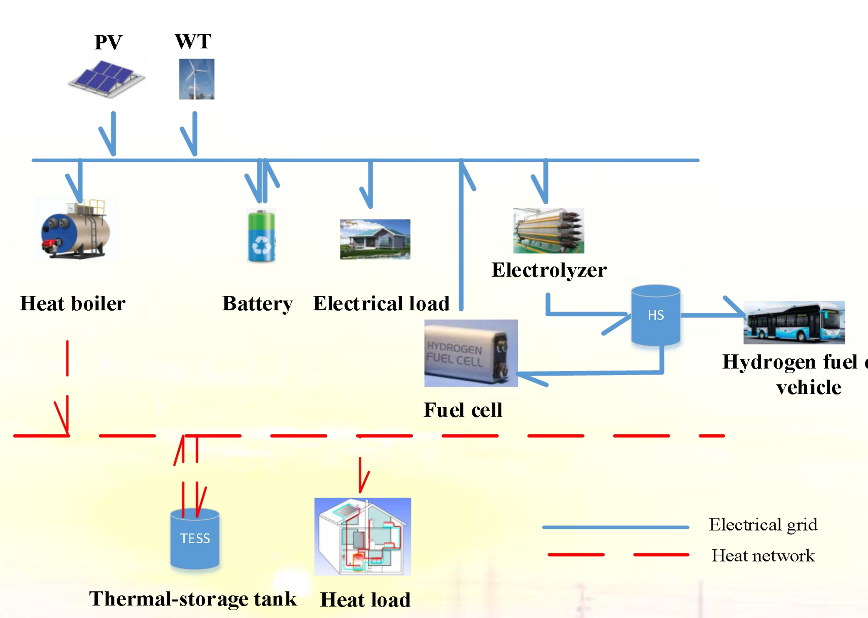


Fig.1 The structure of the microgrid

The optimization model of microgrid

The goal of the optimization process is to minimize the investment cost of the electric-heat combined network. Thus, the objective function is written as (1)：

$$\text{Min} \quad f = \min \sum_{t=1}^{N_T} (C_{oc}(t) + C_{FC}(t) + C_{ST}(t) - C_{sell}(t))\Delta t \qquad (1)$$

,where $C_{oc}(t)$ is the sum of the operating cost for PV cell, wind turbine, heat boiler, thermal storage tank, battery and the electolyzer at time t, $C_{FC}(t)$ is the operating cost of FC, $C_{ST}(t)$ is the starting cost for controllable machines(CM) like FC, EB and HE and $C_{sell}(t)$ is the total incoming of hydrogen selling at time t.

Each device in the grid need to follow certain constraints. In order to ensure the steady opeartion of the system,the energy exchange inside the microgrid has to satisfy the power and thermal flow balance shown in (2) and (3):

$$P_{PV}(t)+P_{WT}(t)+P_{FC}(t)=P_{eload}(t)+P_{HB}(t)+P_{EESS}(t)+P_{HE}(t) \qquad (2)$$

$$Q_{HB}(t) = Q_{tload}(t) + Q_{TESS}(t) \qquad (3)$$

, where $P_{eload}(t)$ and $Q_{tload}(t)$ are the electrical load and thermal load of the system at time t. $P_{EESS}(t)$ and $Q_{TESS}(t)$ are the power absorbed or discharged by the battery and the thermal-storage tank at time t respectively

Results

The daily electric and heat consuming data using during the simulation is collected from a local village near Zhangjiakou during winter. The wind and solar energy resource is predicted based on the data collected from a real local wind and solar field.The typical daily forecast of the output of PV, WT, heat and electrical load is shown in Fig. 2.The output power of each unit given by the model is shown in Fig. 3. The daily operating cost is around 628$ and the incoming of hydrogen sale is 2583$.

The results show that by applying the autonomous optimization model, the system can realize the 100% usage of the renewable energy. And based on different weather condition, the model can correctly arrange the output of each device to make sure the steady function of the system in island mode. Moreover, the model can also calculate the anticipated annual hydrogen production. The total amount of hydrogen production is quite considerable with a number of approximately 1.228×106 m^3 which can satisfy the hydrogen demand of the city. In addition, the total incoming of hydrogen sell is around 8.53×105$ which proves that the system also has good economic efficiency and the operating cost can be minimized.

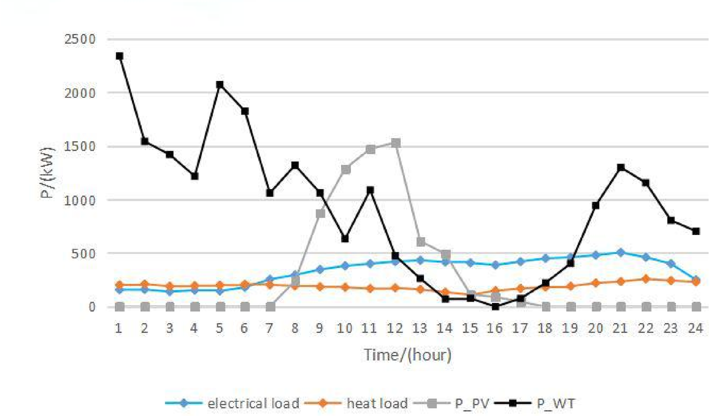
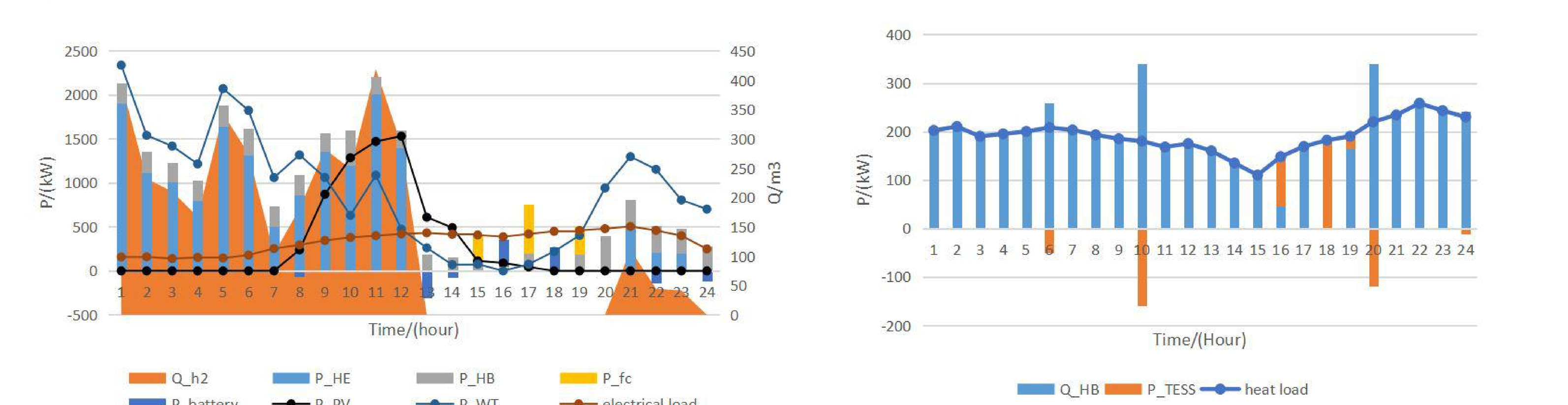


Fig. 2 Typical daily forecast of PV, WT, heat and electrical load



(a)Power balance condition for the microgrid with the output power of each unit and the hydrogen production

(b)Heat balance condition for the microgrid with the output power of each unit

Fig. 3 The output power of each unit in the microgrid

Conclusion

The results prove that the propsed heat-power combined microgrid is 100% powered by clean energy and can operate in island mode and no waste of wind and solar energy occurs. Moreover, the renewable energy can power the hydrogen production thus meet the requirement of the local government. With the introduced optimization model,the operating cost of the system can be reduced and the steady function of the system is ensured.

In the future, more renewable energy can be integrated into the system and the combustion heat waste of fuel cell can be reused to power the heat network. It is also interest to research the multi-objective optimization model or do the capacity optimization for a more comprehensive network with more complicated structure.