Hydrogen Optimization Model

Zhihan Wang

EME Summer Research Internship Program 2022

Introduction

Nowadays, the development of technologies and the influence of global warming have begun to receive attention, and our consumption on fossil energy start becoming an issue. With the high carbon emission and the non-renewability of fossil energy, the concept of energy transition is introduced to our society. Energy transition is a process of switching energy from fossil fuels to other low-carbon energy sources. More generally, the energy transition is a structural change in the supply and consumption of the existing energy system. A major step of the energy transition is to reduce or eliminate the usage of fossil fuels for automobiles. Hydrogen is considered as an alternative source for automobiles. Hydrogen can be generated from renewable energy sources, such as wind, and solar. Then, using electrolysis to split water into oxygen and hydrogen in a carbon-free manner.

Objective

- To build an economic optimization model for hydrogen facility using python.
- Define the total output and profit of the hydrogen facility.
- Use SciPy.optimize from python to construct an optimization function.
- To optimize the size of pipeline capacity to maximize facility’s profit.
- To optimize the size of storage capacity to maximize facility’s profit.
- To optimize the size of injection capacity to maximize facility’s profit.

Method

Assume a joint generator/storage/pipeline facility. The generator has attached to it a pipeline and a storage facility with certain amount of capacity and injection ability. Each time period, hydrogen will be generated from the generator. Here are some steps:

1. Send hydrogen to the market through pipeline.
2. Inject remaining hydrogen into the storage.
3. Release Hydrogen into the atmosphere if hydrogen generated beyond facility capacity.
4. Withdraw hydrogen from storage if pipeline capacity not filled.

Formulas

<table>
<thead>
<tr>
<th>Formulas</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( H_{L} = \frac{EE \cdot MW \cdot t}{EP} )</td>
<td>The amount of solar or wind energy the generator receives at period ( t ).</td>
</tr>
<tr>
<td>( H_{P_{\text{initial}}}=\text{H}<em>{P</em>{\text{initial}}}/\text{EP} )</td>
<td>Amount of ( H ) produced in period ( t ) that is sent to the pipeline.</td>
</tr>
<tr>
<td>( H_{P_{\text{available}}}=\text{H}<em>{P</em>{\text{available}}}/\text{EP} )</td>
<td>Amount of ( H ) available in the reservoir.</td>
</tr>
<tr>
<td>( H_{R_{\text{available}}}=\text{H}<em>{R</em>{\text{available}}}/\text{EP} )</td>
<td>Amount of ( H ) available to be injected into the reservoir.</td>
</tr>
<tr>
<td>( H_{R_{\text{remaining}}}=\text{H}<em>{R</em>{\text{remaining}}}/\text{EP} )</td>
<td>Remaining ( H ) in the reservoir.</td>
</tr>
<tr>
<td>( H_{\text{pipeline}}=\text{H}_{\text{pipeline}}/\text{EP} )</td>
<td>Amount of ( H ) delivered to the pipeline.</td>
</tr>
<tr>
<td>( H_{\text{storage}}=\text{H}_{\text{storage}}/\text{EP} )</td>
<td>Amount of ( H ) stored in the reservoir.</td>
</tr>
<tr>
<td>( H_{\text{injection}}=\text{H}_{\text{injection}}/\text{EP} )</td>
<td>Amount of ( H ) injected into the atmosphere.</td>
</tr>
<tr>
<td>( H_{\text{storage}}=\text{H}_{\text{storage}}/\text{EP} )</td>
<td>Amount of ( H ) delivered to the pipeline.</td>
</tr>
</tbody>
</table>

Result

Python algorithms are created using the defined variables and formulas.

Conclusion

The algorithm have defined the optimal scenarios for both solar plant and wind plant from PJM.

Solar:
Optimal pipeline capacity: 56.65
Optimal reservoir capacity: 10
Optimal injection capacity : 18.32
Maximum profit: $2,627,905.69

Wind:
Optimal pipeline capacity: 60.11
Optimal reservoir capacity: 10.05
Optimal injection capacity : 20
Maximum profit: $5,168,260.05

Acknowledgement

I would like to thank the Penn State EME Department for providing me with this excellent opportunity to gain research skills and experience.

I would also like to thank Dr. Kleit and Dr. Dahl for their guidance and support throughout the research process.

Contact

Zhihan Wang - EME Summer Research Internship
Email: zpw5162@psu.edu