Influence of Maximum Power Tracking to Photo-electrochemical Water-splitting Systems

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Introduction

• Comparison of two different water-splitting systems, one consists of stand-alone PV cells and polymer electrolyte membrane electrolyzers (PEMEC) connected via Maximum Power Point Tracking system and DC/DC converter (MPPT-DC/DC); the other one is a coupled PV-PEMEC system.
• Mathematical models are implemented in Matlab with consideration of different material choices of PV and PEMEC, irradiation concentration, current concentration. Sensitivity analysis is applied on various parameters such as degradation rate in PV and PEMEC, activation overpotentials.
• Solar-To-Hydrogen efficiency (STH) and H₂ production cost are the main performance indicators to assess two systems.

System definition

Two different PV materials (Si-based and III-V) and catalysts (Ni/Co3O4 and RuO2/Pt) are modeled. Combined with MPPT-DC/DC system, different design types are defined:

<table>
<thead>
<tr>
<th>MPPT-DC/DC</th>
<th>Photoanode/</th>
<th>Ni/Co3O4</th>
<th>RuO2/Pt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Without PV</td>
<td>Si-based</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>MPPT-DC/DC</td>
<td>ideal III-V</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>non-ideal III-V</td>
<td>9</td>
</tr>
<tr>
<td>Group 2</td>
<td>With MPPT-DC/DC</td>
<td>Si-based</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ideal III-V</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>non-ideal III-V</td>
<td>11</td>
</tr>
</tbody>
</table>

Two different pathways of energy conversion from sunlight to H₂: 1)Coupled PV-PEMEC device (Group 1), 2)Decoupled PV-PEMEC device with integration of MPPT-DC/DC system (Group 2). The area ratios: C is the concentrator area against PV area while F is the PEMEC area against PV area.

Results

Mean STH efficiency

Mean STH efficiency differences between: α)type 5 and 1, β)type 6 and 2, γ)type 7 and 3, δ)type 8 and 4. Pink stars in α) and β) indicate the maximum mean STH difference with varying F for every particular C. While triangles indicate the maximum STH difference with varying C for every particular F. Red stars in γ) and δ) indicate the negative difference. The blue stars in α) and β) indicate the maximum difference among all C/F combinations.

PV and PEMEC degradation rate

PEMEC and PV degradation influence on H₂ cost and efficiency. Percentage of C/F combinations in which γ)type 2 has better mean efficiency than type 6, δ)type 2 has lower H₂ cost than type 6, γ)type 3 has better mean efficiency than type 7, δ)type 3 has lower H₂ cost than type 7.

Conclusion

• Water-splitting devices with MPPT-DC/DC system generate low cost H₂ ($2.01 kg⁻¹) with high mean efficiency (15.33%), which is competitive to existing devices and worth further investigation.
• High efficiency MPPT-DC/DC system guarantees a higher resistance in devices in terms of PV and PEMEC degradation.
• More realistic PV model suggests a more complicated comparison result in reality: MPPT-DC/DC system is even more advantageous in some C/F combinations while less in some other specific C/F.