A Centralized Shifted Power Control Scheme for Isolated Bidirectional DC-DC Converter in Standalone DC Distribution System

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Introduction

- When parallel converter systems are considered in modern DC distribution systems, several challenges are faced in the energy management system (EMS). For example, the circuit parameter mismatches of parallel isolated DC-DC converter modules will cause power imbalances, which is the most important concern in DC distribution system.
- To overcome this issue, we present a power management control scheme in the EMS to ensure the power balance of isolated DC-DC converters in DC distribution system.
- The proposed control scheme maintains a good power sharing performance even if the load power changes.

System Description

- Isolated DC-DC converters:
  - The isolated dual active bridge (DAB) converter is identified as one of the most promising converter topologies for modern power electronic systems, which requires bidirectional power flow, galvanic isolation, and efficient power conversion.
  - In a stand-alone DC distribution system, multiple RES and ESS converters are usually connected in parallel for maintainability and reliability, and autonomous power sharing is an important objective.
- Primary Power Sharing Control Loop:
  - The power sharing coefficient is set inversely as the rated capacity at the primary control level to share the load power, and the voltage reference is generated as
    \[
    v_{in}^{ref} = v_{in} - d_{i}v_{in}
    \]
  - The DC bus voltage and current sharing among isolated converters can be derived as
    \[
    v_{bus}^{ref} = v_{in} - d_{i}v_{in} - r_{i}i_{bus} = v_{in} - d_{i}v_{in} - r_{i}i_{bus} + u_{i}
    \]
  - \[
  \frac{d}{l} = \frac{d_{i}}{r_{i}} = \frac{d_{j}}{r_{j}}
  \]
- When the value of \(d_{i}(i = 1, 2)\) dominates the output resistance, the accurate current (power) sharing ratio is obtained. However, it is not feasible when increasing \(d_{i}\) because it will deteriorate the voltage at the DC bus.

Proposed EMS Control Loop

- Proposed EMS Shifted Power Control Scheme:
  - In the proposed control approach, an additional control signal \(u_{i}\) is designed in each local interfacing controller.
    \[
    v_{in}^{ref} = v_{in} - d_{i}v_{in} + u_{i}
    \]
  - Applying the above modified voltage reference to DC-DC converter circuit, the DC bus voltage is derived
    \[
    v_{bus}^{ref} = v_{in} - d_{i}v_{in} - r_{i}i_{bus} + u_{i}
    \]
  - \[
  \frac{d}{l} = \frac{d_{i}}{r_{i}} = \frac{d_{j}}{r_{j}}
  \]
  - To achieve the current sharing accuracy, the effect of \(r_{bus1} = r_{bus2}\) on the distribution system should be mitigated. There exists a constraint \(u_{i}\) that output currents are shared proportionally in the steady-state, i.e., \(u_{i} / u_{j} = d_{i} / d_{j}\).

Simulation Results

- TABLE 1 System parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Voltage (U_{bus})</td>
<td>100V</td>
</tr>
<tr>
<td>Rated Output Power and Current</td>
<td>200W</td>
</tr>
<tr>
<td>Duty cycle (D_{i})</td>
<td>0.5</td>
</tr>
<tr>
<td>Line resistance (R_{l})</td>
<td>10Ω</td>
</tr>
<tr>
<td>Load (L_{l})</td>
<td>10Ω</td>
</tr>
<tr>
<td>Control gain (K_{p})</td>
<td>1000</td>
</tr>
<tr>
<td>Switching Frequency (f_{sw})</td>
<td>300KHz</td>
</tr>
<tr>
<td>Control bandwidth (f_{BW})</td>
<td>100KHz</td>
</tr>
<tr>
<td>Output-Voltage (V_{out})</td>
<td>380V</td>
</tr>
<tr>
<td>Inductor L</td>
<td>10mH</td>
</tr>
<tr>
<td>Input Current (I_{in})</td>
<td>10A</td>
</tr>
<tr>
<td>Input Efficiency (\eta)</td>
<td>95%</td>
</tr>
</tbody>
</table>

Conclusion

- A centralized shifted voltage control scheme is presented for the isolated bidirectional DC-DC converters to compensate for the voltage mismatches in DC distribution system.
- Thanks to the proposed shifted voltage, all converter units can properly distribute the power to the DC loads.
- The power sharing performance is maintained despite the load condition changes.