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 structures 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:

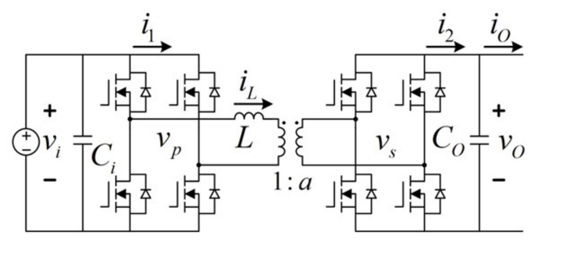

Fig. 1. Circuit diagram of the isolated dual active bridge (DAB) converter.

❖ 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

$$v_{Oi}^{ref} = v_{Oi}^{nor} - d_i i_{Oi}$$

➢ The DC bus voltage and current sharing among isolated converters can be derived as

$$v_{DC\_bus} = v_{O1} - d_1 i_{O1} - r_{line1} i_{O1}$$
$$= v_{O2} - d_2 i_{O2} - r_{line2} i_{O2}$$
$$\frac{i_{O1}}{i_{O2}} = \frac{d_2 + r_{line2}}{d_1 + r_{line1}} \approx \frac{d_2}{d_1}$$

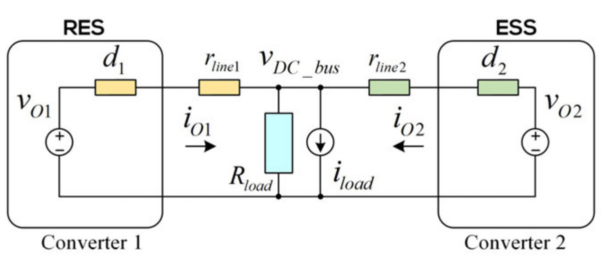

Fig. 2. Simplified circuit of stand-alone DC distribution system.

• 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:

$$v_{Oi}^{ref} = v_{Oi}^{nor} - d_i i_{Oi} + u_i$$

➢ Applying the above modified voltage reference to DC-DC converter circuit, the DC bus voltage is derived

$$v_{DC\_bus} = v_{O1} - d_1 i_{O1} - r_{line1} i_{O1} + u_1$$
$$= v_{O2} - d_2 i_{O2} - r_{line2} i_{O2} + u_2$$

➢ To achieve the current sharing accuracy, the effect of r_{line1} and r_{line2} 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., $i_{O1} / i_{O2} = d_2 / d_1$

❖ Block Diagram of Local A Centralized Shifted Power Control Scheme:

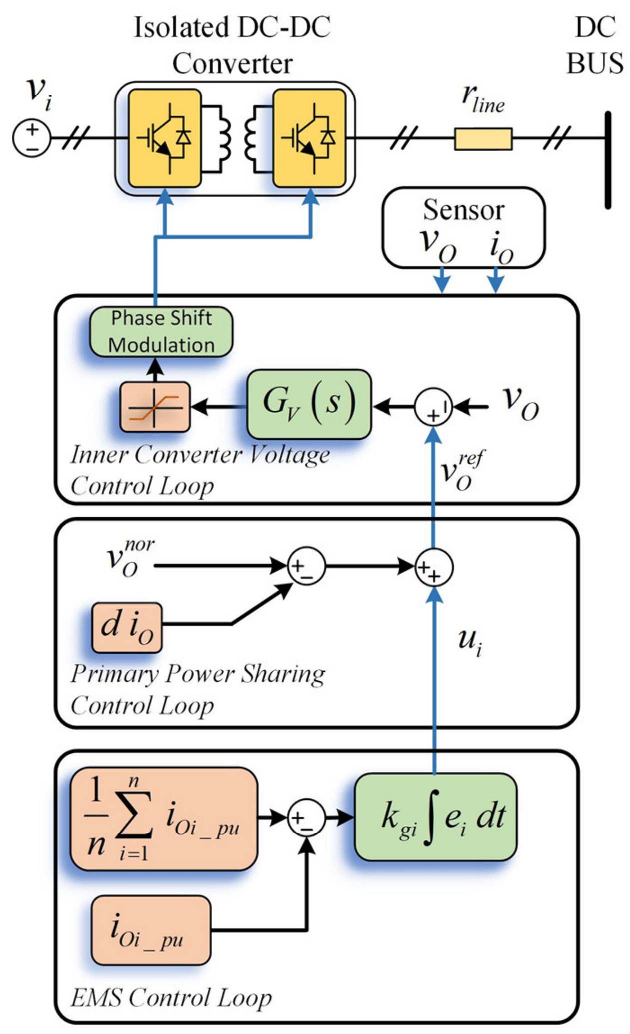

Fig. 3. Block diagram of a centralized shifted power control scheme.

Simulation Results

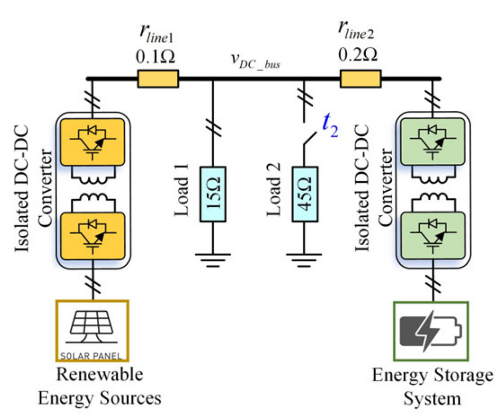

Fig. 4. Stand-alone DC distribution system used in simulation.

TABLE I
System parameters

Parameters	Value
Nominal Voltage (v_O^{nor})	180V
Rated Output Power and Current (P_{1_rate}; i_{O1_rate})	1800W; 10A
Droop coefficient (d_1, d_2)	0.5
Line impedances 1 and 2 (r_{line1}; r_{line2})	0.1Ω; 0.2Ω
Load 1	15Ω
Load 2	45Ω
Control gain K_{pV}, K_{iV}	0.0001, 0.080
Switching frequency (f_{sw})	20kHz
Centralized control sampling time	1ms
Output capacitor (C)	200μF
Inductor (L)	10μH
Input Voltage (v_{in})	96V
Transformer ratio (1:a)	1:2

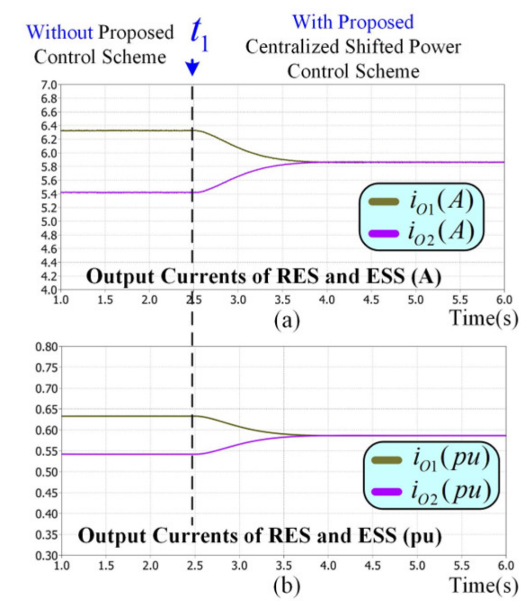

Fig. 5. Performance of the DC microgrid with and without the proposed shifted power control scheme.
(a) RES and ESS current sharing in ample unit
(b) RES and ESS current sharing in per-unit.

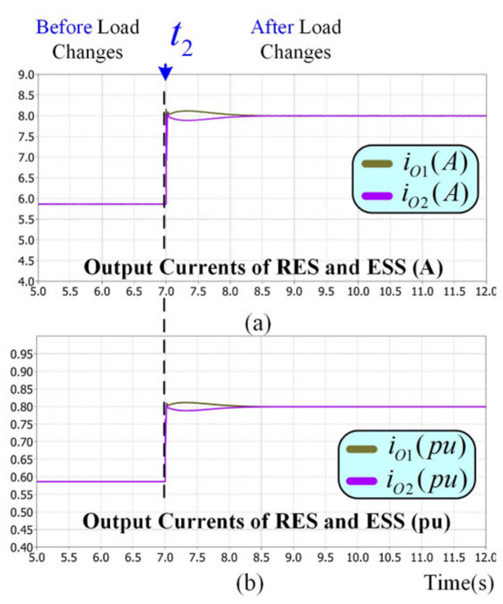

Fig. 6. Performance of the DC distribution system during load changes.
(a) RES and ESS current sharing in ample unit
(b) RES and ESS current sharing in per-unit.

At $t = t_1(2.5s)$, the proposed scheme starts to operate.
At $t = t_2(7s)$, load 2 is connected to the DC bus.

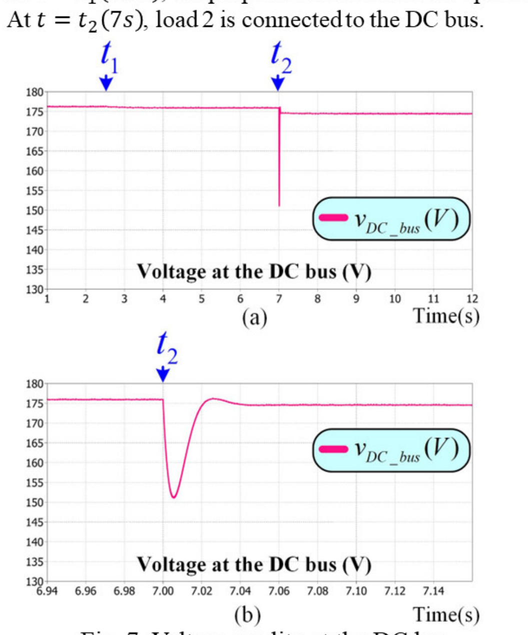

Fig. 7. Voltage quality at the DC bus.
(a) Overall waveform of DC bus voltage
(b) DC bus voltage waveform during load changes.

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.