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Partial Power Converters for Grid Energy Storage Systems

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Background and Objectives

- Grid integrated Battery Energy Storage Systems (BESS) architecture using Partial power converter (PPC) DC-DC stage helps in improving the total power conversion efficiency.
- For the BESS applications having DC-link voltage closer to the battery bank output voltage range, the required power rating for PPC circuit is low.
- The low power rated PPC not only reduces the total losses, but also improves the power density of the DC-DC stage.
- By adopting a variable DC-link voltage ($V_{DC-link}$) in relation to the voltage change across the battery terminals (V_{bat}), the efficiency benefit can be further extended over the complete charge and discharge cycle voltage range.
- A novel Step up/down PPC (SUD-PPC) topology is designed to serve this purpose and its operating principle is validated by a PLECS model.

Power Conversion Architecture

- The BESS power conversion architecture is shown in Figure (1).
- Galvanic isolation will be ensured by the grid side low frequency transformer.
- The $V_{DC-link}$ variation in relation to the V_{bat} as shown in Figure (2) is aimed to maintain a low partiality ratio for PPC.
- Intern the low partiality ratio is the deciding factor for maximizing the efficiency benefit from PPC.

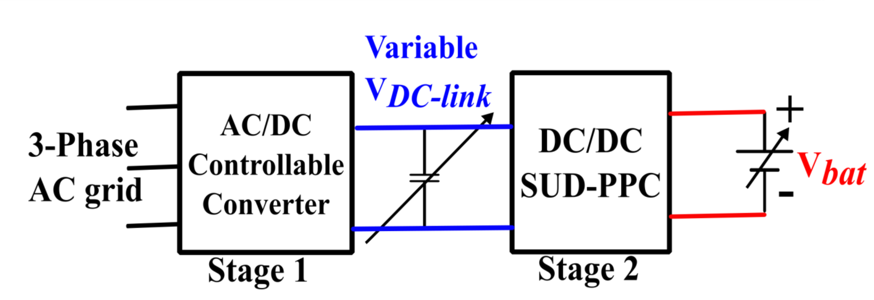

Figure (1) – Proposed power conversion architecture

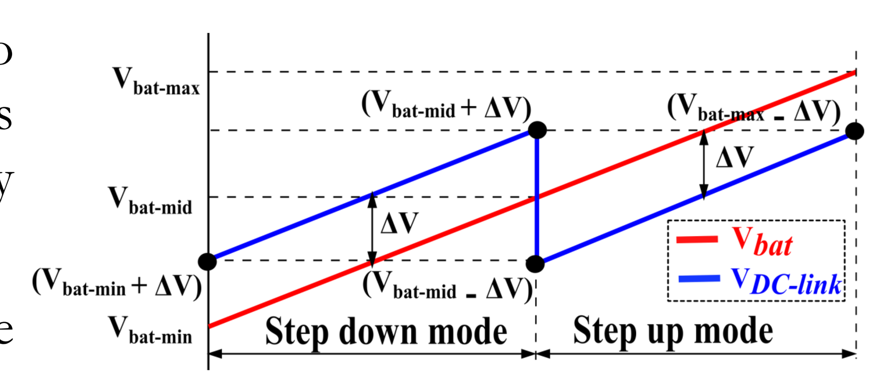

Figure (2) – Voltage variations at SUD-PPC

Proposed DC-DC topology

- The proposed SUD-PPC circuit is shown in Figure (3) which has separate power paths for each operating mode.
- The two low voltage MOSFET bridges at primary side are in series between $V_{DC-link}$ and V_{bat}, whereas the high voltage MOSFET bridge at secondary side is parallel to V_{bat} which makes it a type-I PPC.
- The DC power flow is controlled by LLC resonance operation using two LC-tanks, where only one LC tank operates in each mode.

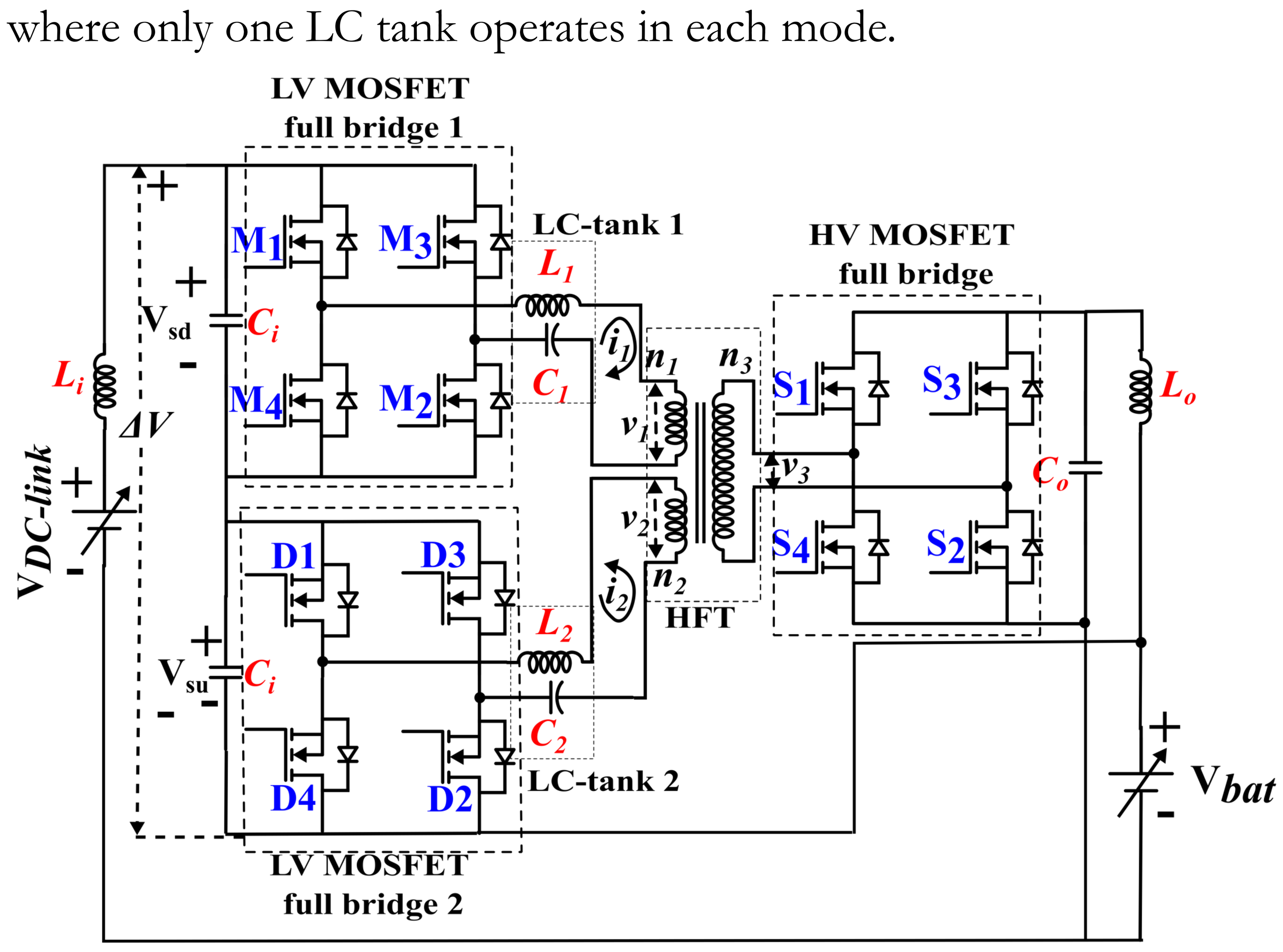

Figure (3) – Proposed SUD-PPC circuit topology

Operating Principle Evaluation in PLECS

- For $V_{DC-link} > V_{bat}$, in charging mode bridge 1 will be in active switching state, bridge 2 will be in bypassing state and the HV bridge acts as a simple rectifier.
- And for $V_{DC-link} < V_{bat}$ charging mode, HV bridge is in active switching state, bridge 2 is in rectification state and bridge 1 is bypassed.
- In battery discharging mode, the conditions are vice-versa.
- Each LC tank has its own resonating frequency that creates an individual power path for each operating mode.
- The soft-switching property of the active switching bridge 1 in step-down charging mode is shown in Figure (4).
- Figure (5) shows the voltage and current traces of SUD-PPC during charging operation of V_{bat} at 100 A constant output current.
- Practicing the proposed $V_{DC-link}$ variations given in Figure (2), the power rating of PPC i.e ($\Delta V * I_{DC-link}$) is maintained below 15% of the total DC output power.

Table I – System Specifications

Parameter	Value
DC-link voltage	650-750 V
Battery voltage	600-800 V
Charging current	100 A
HFT ratio	1:1.45:17
Operating frequency	67 & 88 kHz
LC tank 1	40 uH, 82 nF
LC tank 2	80 uH, 70 nF

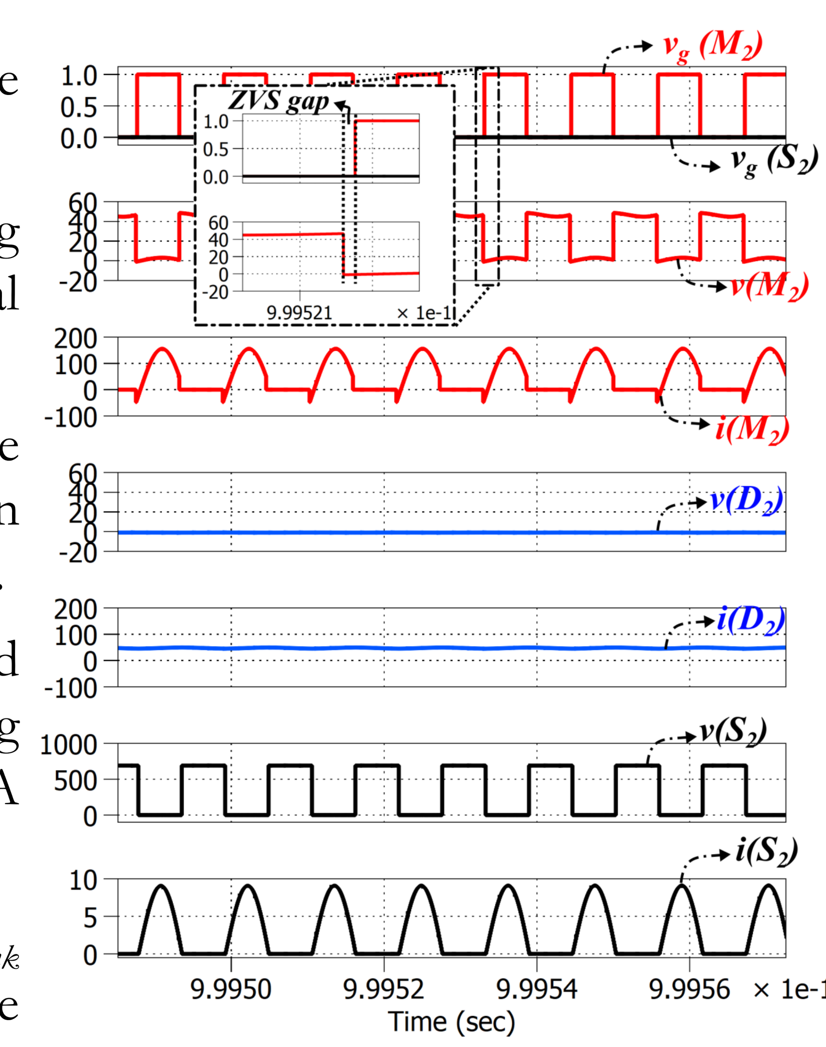

Figure (4) – Waveforms of switches for step-down mode while charging V_{bat}

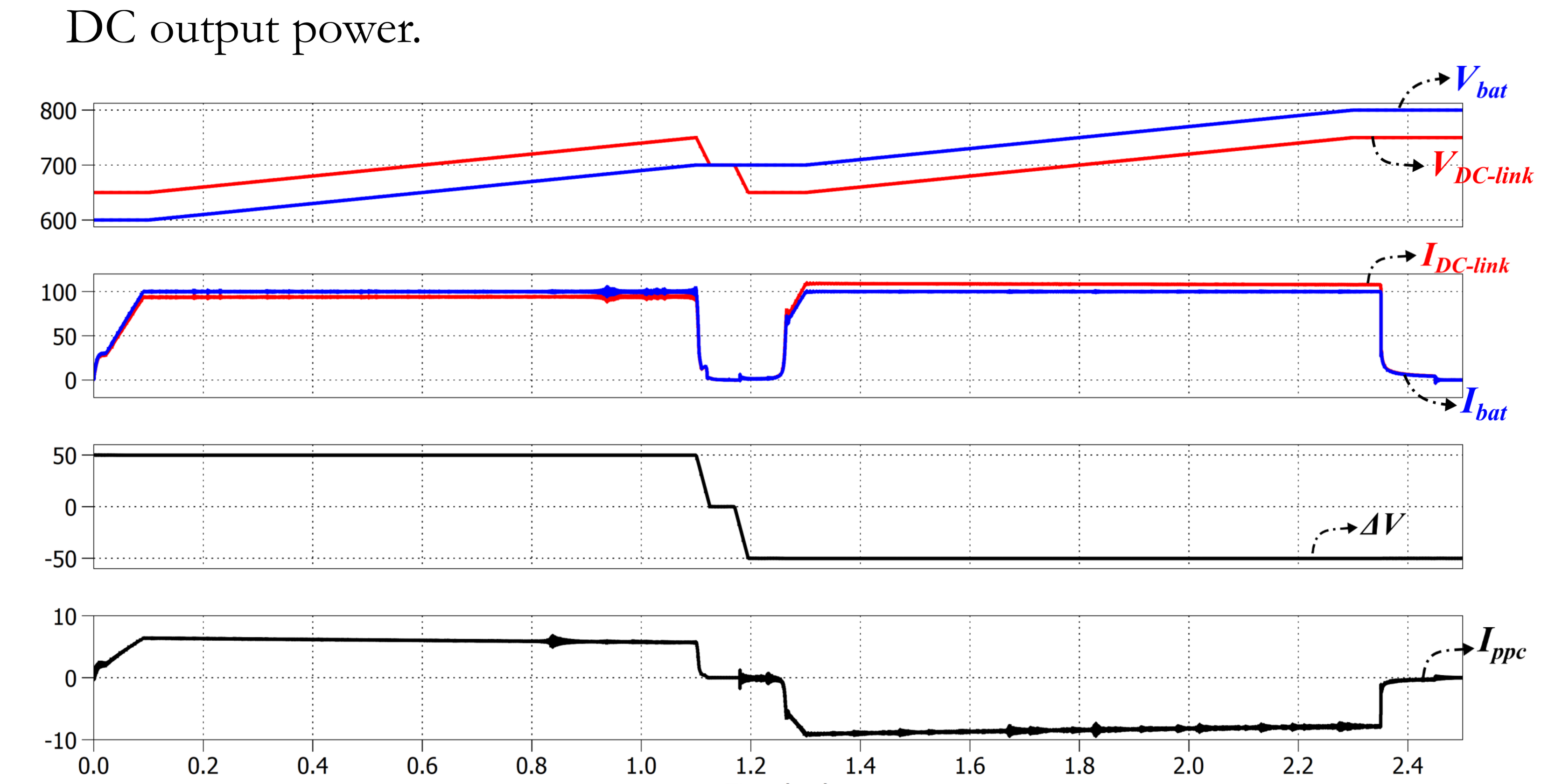

Figure (5) –SUD-PPC waveforms while charging V_{bat} (step-down mode followed by step-up mode with mode transitioning at time 1.2 sec)

Conclusions

- A power conversion architecture for the grid connection of BESS is realized by using a PPC DC-DC stage.
- The variable $V_{DC-link}$ in relation with varying V_{bat} helped in maintaining a low partiality ratio from the constant and optimal ΔV of PPC.
- This low partiality ratio intern helps to reduce the total power losses through power electronic path and improves the conversion efficiency when applied in practice.
- Together, the achieved 15% power rated PPC presents high power density of DC-DC stage when compared with the same rating of full power DC-DC converter stage.

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