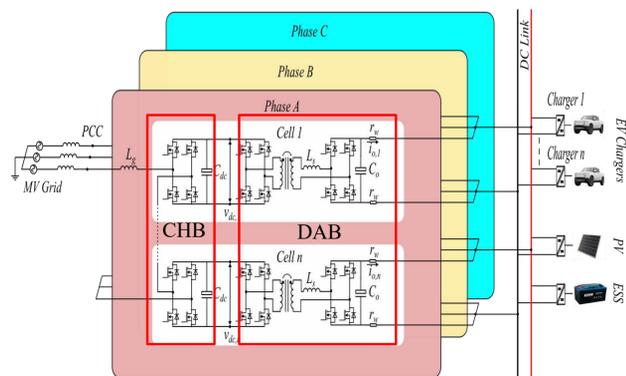


## Overview

- EV DC fast charging architecture.
- Includes energy storage and renewable resource integration.
- Modular and scalable structure.



### Advantages

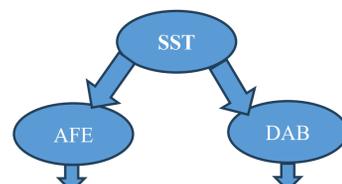
- Direct connection to MV grid.
- Compact and galvanically isolated.
- Implementable with commercially available components.
- Easily scalable.

### Challenges

- Complicated control approach.
- Voltage balance among series-connected CHB
- Power balance among parallel-connected DAB.

## Prior art and research gap

### Control functions needed in a CHB-SST



- MV grid tracking
- Power quality
- Maintenance of AFE DC link
- Voltage sharing of series-connected cells

- Maintenance of Output DC bus.
- Power sharing of parallel connected cells.

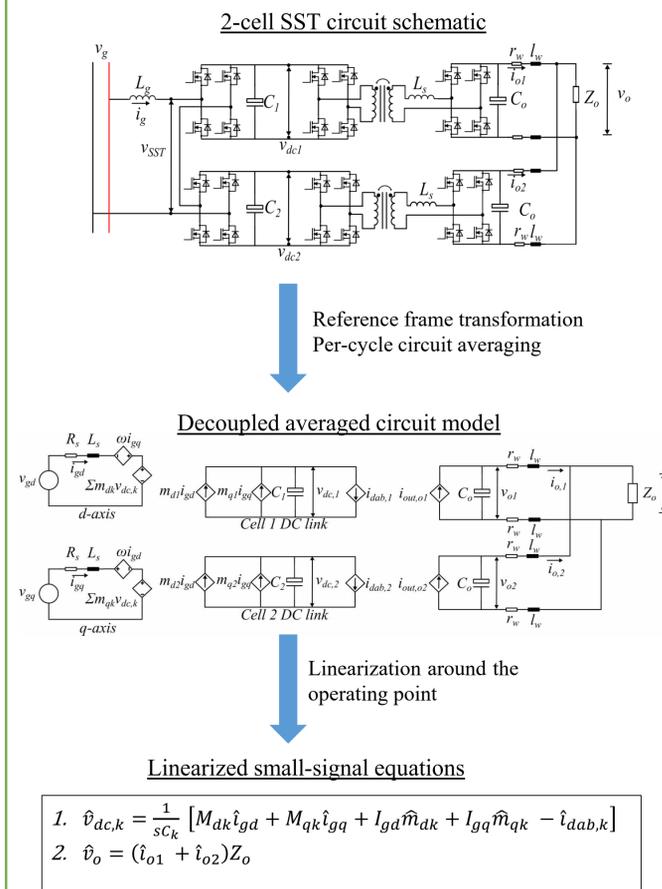
### Findings and gaps from the previous work

Method	Steady-state power balance	Voltage balance at rated loads	Voltage balance at light loads
State-of-the-art	✓	✓	✗
This work	✓	✓	✓

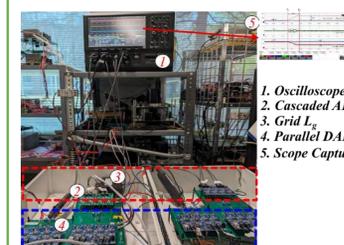
### Research questions

- Why does the state-of-the-art method fail at light loads?
- Can an alternate method achieve light load voltage balancing?

## Modeling Method



## Experimental validation

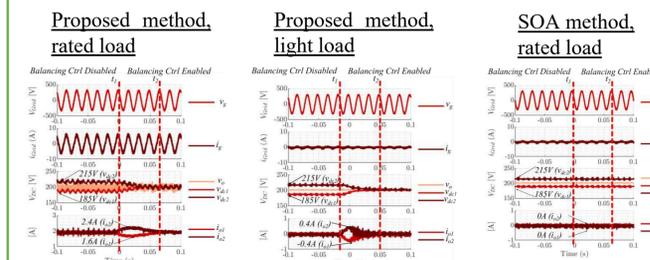


- Oscilloscope
- Cascaded AFE
- Grid  $L_g$
- Parallel DAB
- Scope Capture

Parameter	Value
Interconnection voltage	220 V (l-n), 60 Hz
Rated Power	800 W
Number of cells per phase	2
Rated power per cell	400 W
Output DC link Voltage	200 V
AFE DC link Voltage	200 V

### Experiments conducted for validation

- Proposed method at rated load
- Proposed method at no-load
- SOA method at no-load



- Experimental results agree well with the analysis and simulations.

## Conclusions

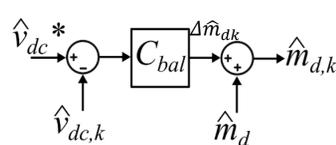
- The state-of-the-art method fails at no-load due to control saturation.
- The proposed method is effective throughout the operating range.
- Steady-state power balancing is retained.

## References

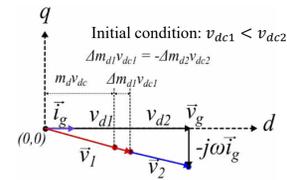
- T. Zhao, G. Wang, S. Bhattacharya and A. Q. Huang, "Voltage and Power Balance Control for a Cascaded H-Bridge Converter-Based Solid-State Transformer," in *IEEE Transactions on Power Electronics*, vol. 28, no. 4, pp. 1523-1532, April 2013, doi: 10.1109/TPEL.2012.2216549.
- V. Burugula *et al.*, "Improved DC Link Voltage Balancing in an MV-Compliant Solid-State Transformer," *2024 IEEE Energy Conversion Congress and Exposition (ECCE)*, Phoenix, AZ, USA, 2024, pp. 1418-1425, doi: 10.1109/ECCE55643.2024.10861784.

## State-of-the-art (SOA) method

### Voltage Balancing Control Method



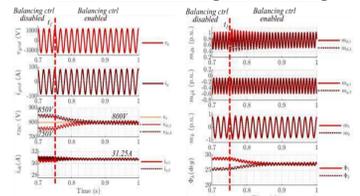
### Balancing mechanism



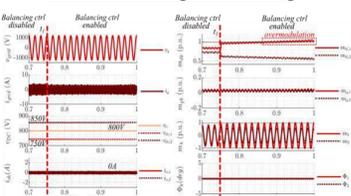
### Simulation system parameters

Parameter	Value
Interconnection voltage	1200 V (l-n), 60 Hz
Rated Power	50 kW
Number of cells per phase	2
Output DC link Voltage	800 V
AFE DC link Voltage	800 V

### Rated load voltage balancing



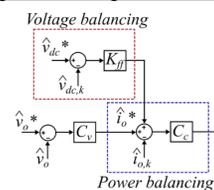
### No load voltage balancing



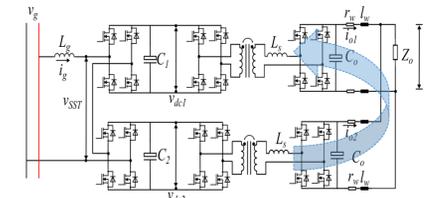
- Based on CHB controls.
- Control saturation during no-load operation.

## Proposed method

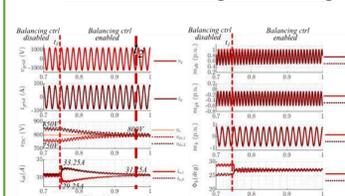
### Voltage Balancing Control Method



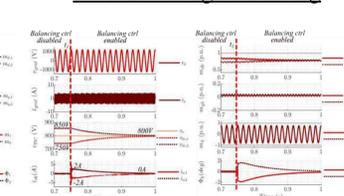
### Balancing mechanism



### Rated load voltage balancing



### No load voltage balancing



- Based on DAB controls.
- Voltage and power balance across the loading range.