Sandia National Laboratories

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Power Electronics & Energy Conversion Systems

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Analogous Boost Converter Switching Scheme for Single-Phase Direct Dual Active Bridge (DAB) Battery Charger with Optimal Setpoints

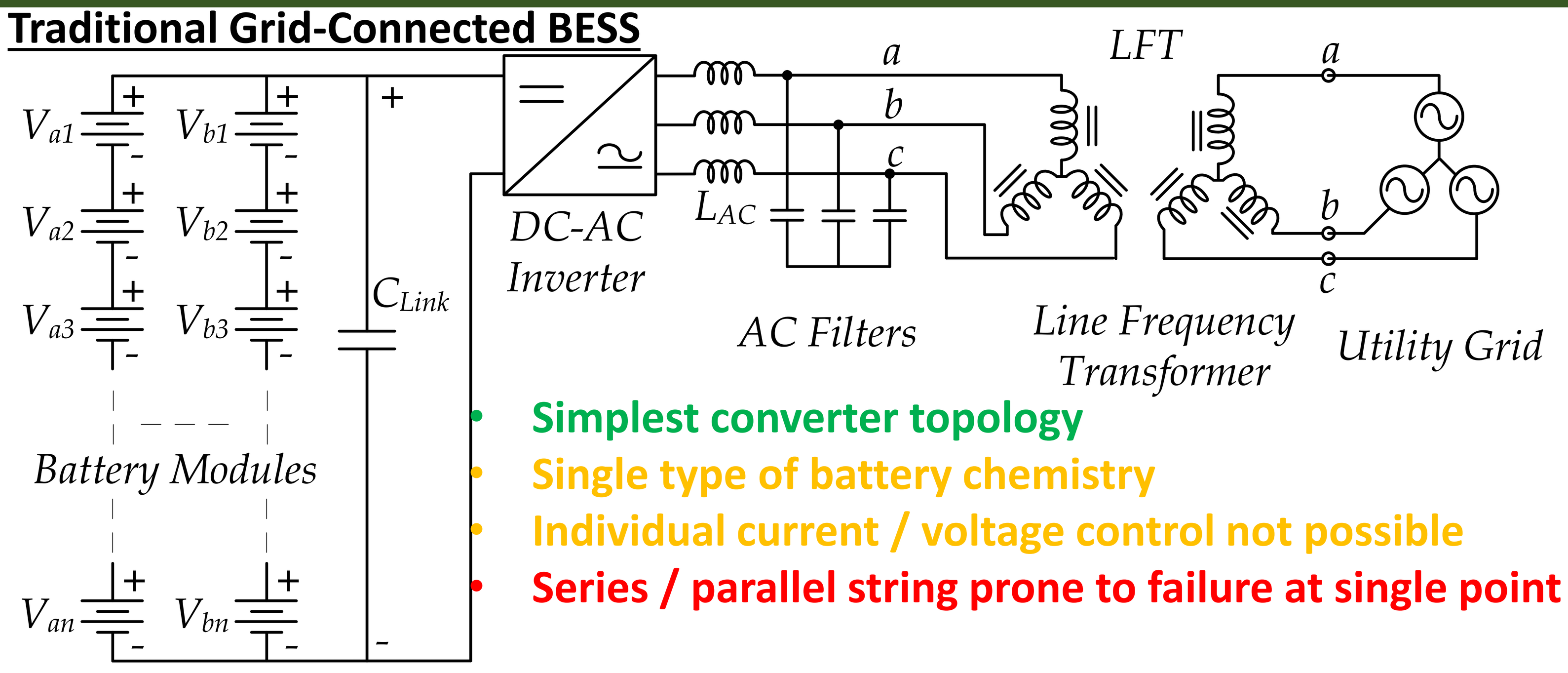
Overview

- The overall goal of this project is to develop a battery charger which can directly couple to any single AC phase of the grid with a minimal number of conversion stages.
- This module-integrated solution enables flexible interconnection of disparate storage resources within a single modular and scalable installation.
- This project aims to design an isolated DC-AC converter for integrating energy storage systems at the module level.
- Through the use of modular power electronics systems each battery module connects to a dedicated DC-AC converter to optimally manage its charge and discharge cycling.

Novel Contribution

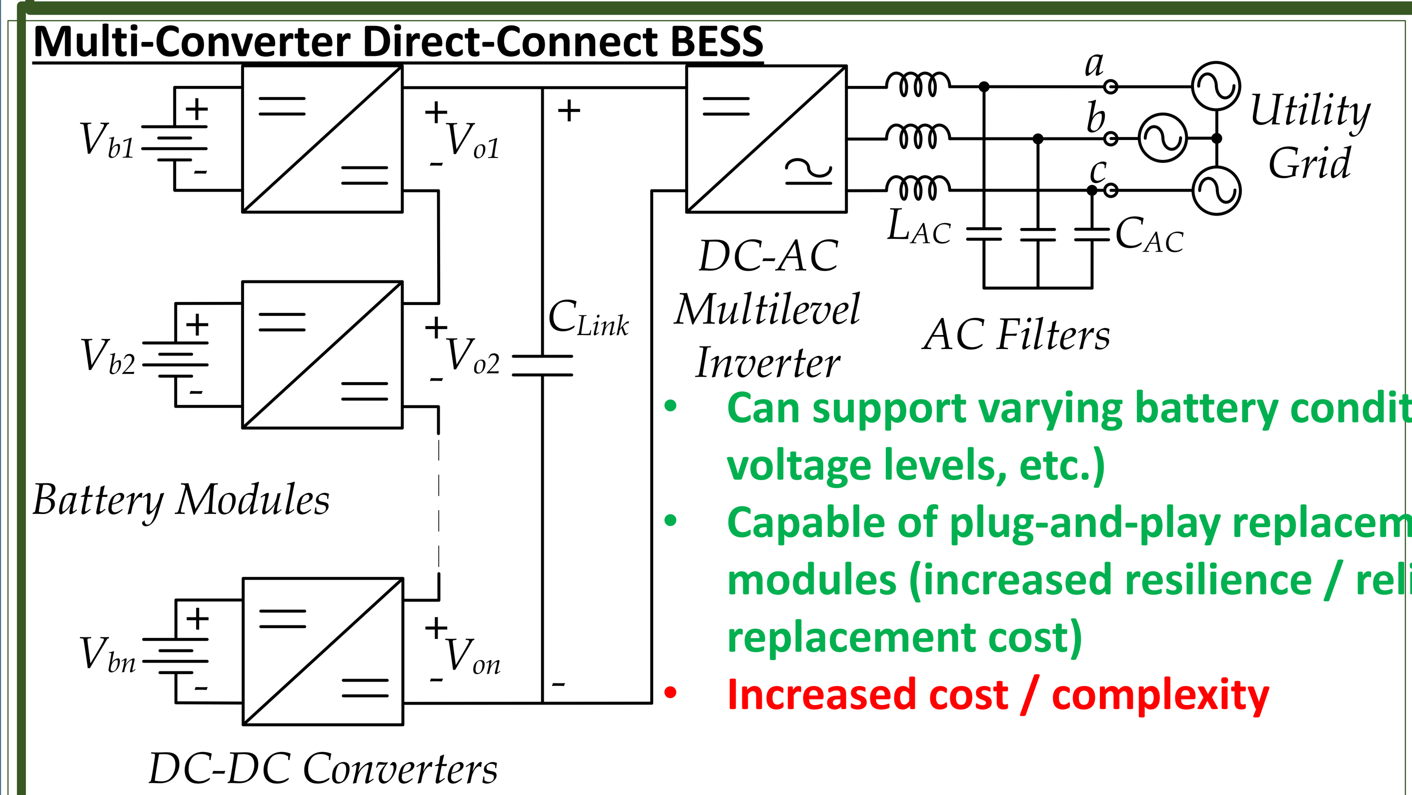
- The proposed DAB approach uses power flow optimization to predict the required AC waveform to drive to the desired DC waveform. This allows for lower AC waveform distortion than directly controlling a flat DC charging current.
- Additionally, a novel switching scheme is used to avoid current spikes in the high frequency transformer and potential damage to switching devices.
- The successful implementation of the proposed converter will allow for more flexible and reliable energy storage on the grid.

Traditional Grid-Connected BESS



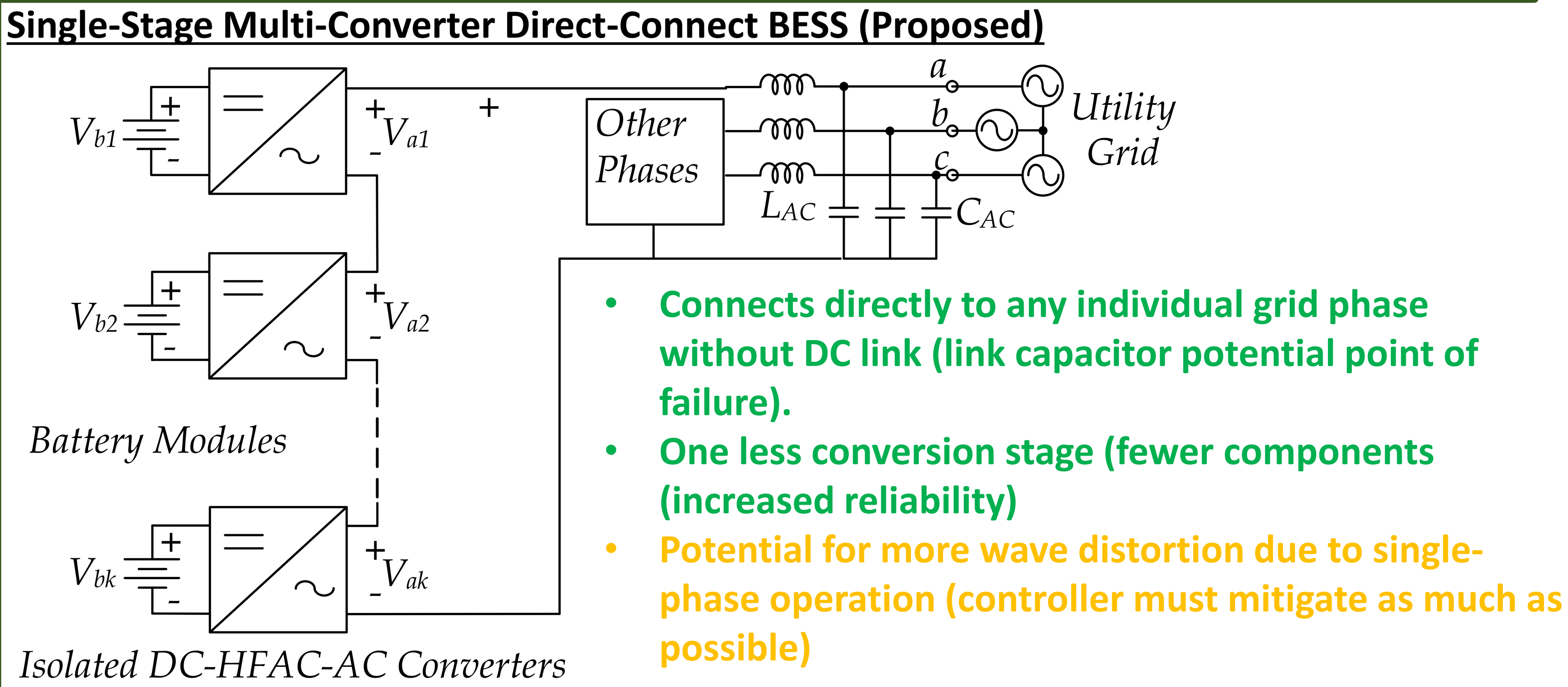
- Simplest converter topology
- Single type of battery chemistry
- Individual current / voltage control not possible
- Series / parallel string prone to failure at single point

Multi-Converter Direct-Connect BESS

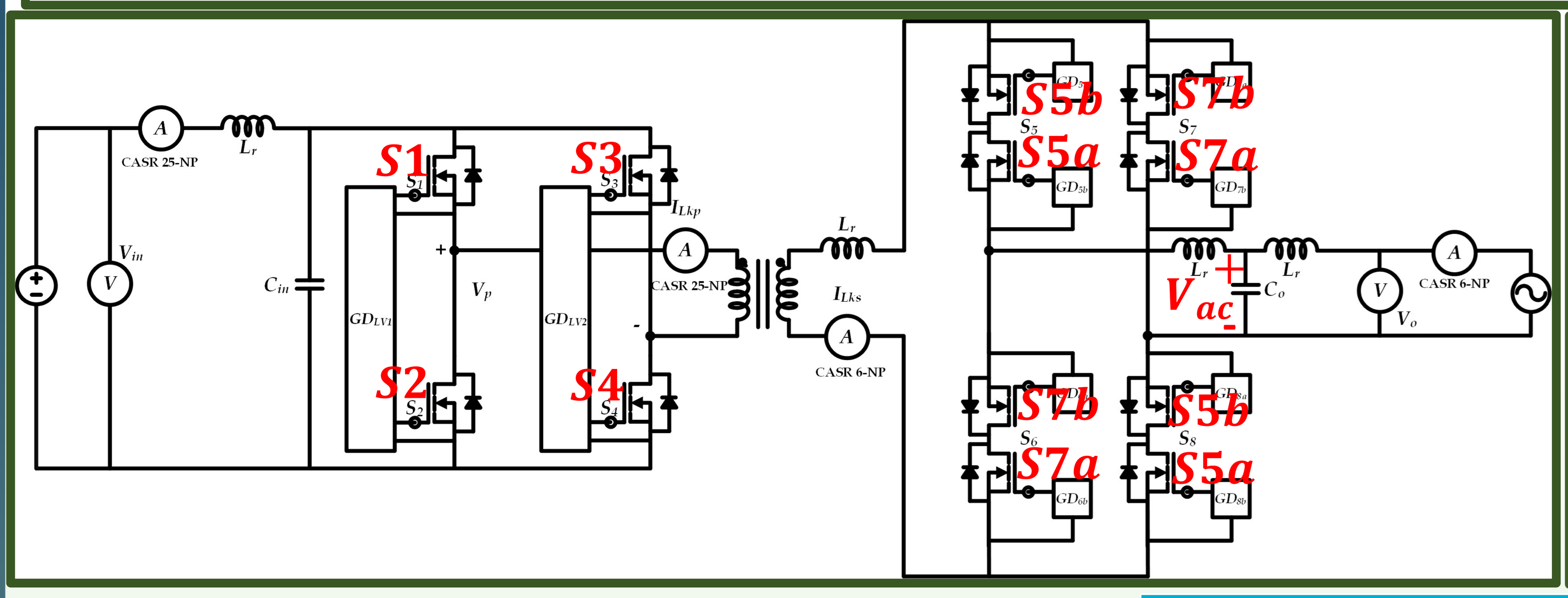


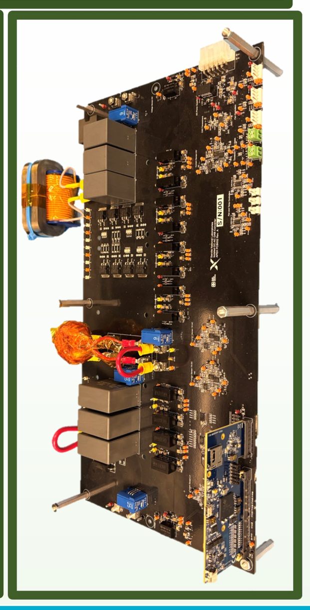
- Can support varying battery conditions (SOC, SOH, voltage levels, etc.)
- Capable of plug-and-play replacement of battery modules (increased resilience / reliability and reduced replacement cost)
- Increased cost / complexity

Single-Stage Multi-Converter Direct-Connect BESS (Proposed)



- Connects directly to any individual grid phase without DC link (link capacitor potential point of failure).
- One less conversion stage (fewer components (increased reliability)
- Potential for more wave distortion due to single-phase operation (controller must mitigate as much as possible)





Full Converter Ratings	
Nominal DC Voltage, V_{dc}	48V
Peak Nominal AC Voltage, $V_{ac,pk}$	240 V
Grid Frequency	60 Hz
Switching Frequency, f_{sw}	50 kHz
Transformer Turns Ratio, n	1:6

Optimal Power Flow Computation

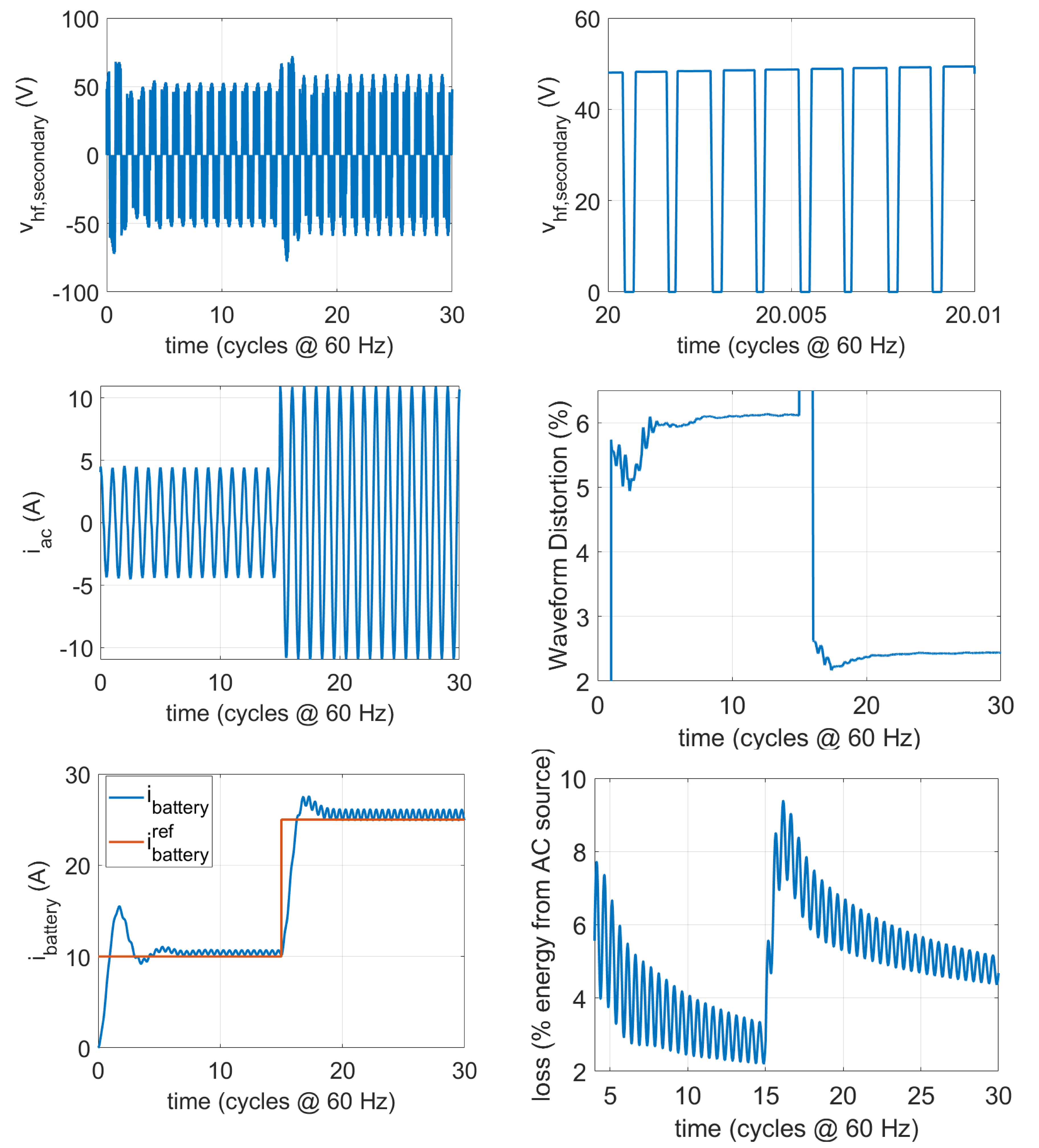
- A pseudo steady-state phasor / power balance-based model is used.
- The optimizer calculates the necessary AC current to drive to the desired DC charging current.
- The optimizer is also capable of computing necessary AC filter sizes to minimize losses.
- Does not need to run online (may be used to created a lookup table)

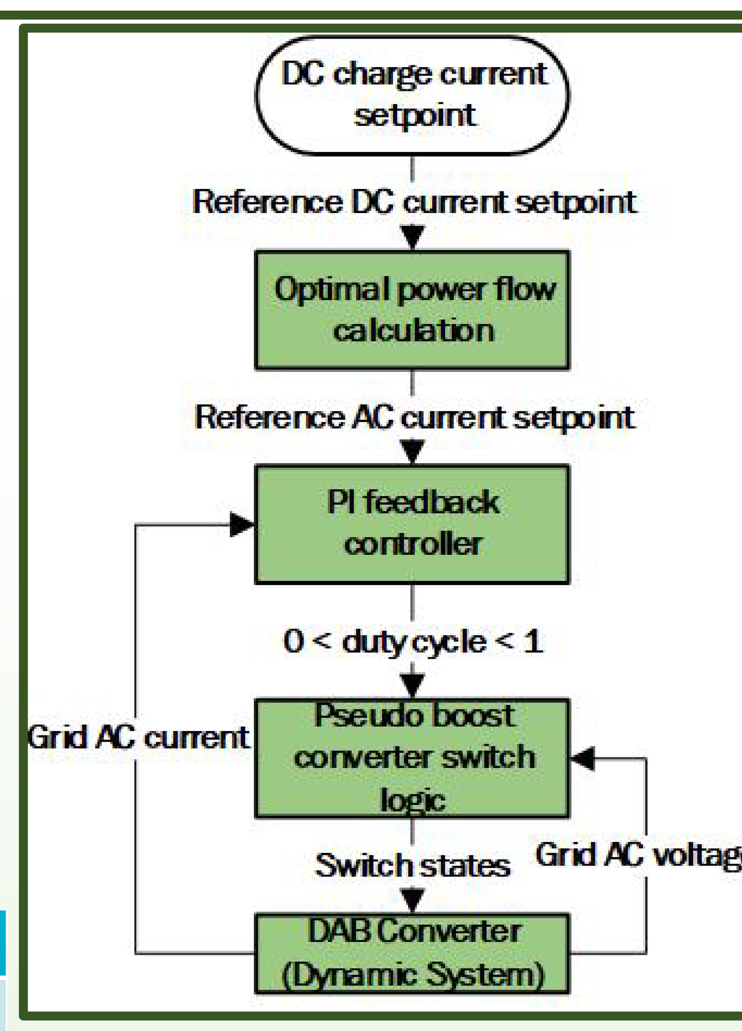
Proposed Simplified Switching Scheme (Charging Only)

- Treated as pseudo boost converter from in AC-HFAC (high frequency AC conversion state).
- Logic for AC-HFAC switches
  - Vac >0 : all 'b' switches on; S5a on
    - S7a toggles based on duty cycle
  - Vac <0 : all 'a' switches on; S5b on
    - S7b toggles based on duty cycle
- Switches at HFAC-DC stage (S1,S2,S3,S4) are all in blocking mode for charging.

Simulation Results (PLECS toolbox in Simulink)

- Initially charges battery at 10A, then step to 25A.





Conclusions

- The proposed control scheme is able to successfully manage the current flow into the battery.
- The proposed control scheme operates with minimal AC waveform distortion (work in progress)
- Losses are relatively low, but ongoing work seeks to further decrease losses.

Future Work

- Hardware tests have been successful for battery discharge. But, are in progress for the proposed charging scheme presented here.
- Additional work to further improve the THD and losses in progress.

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