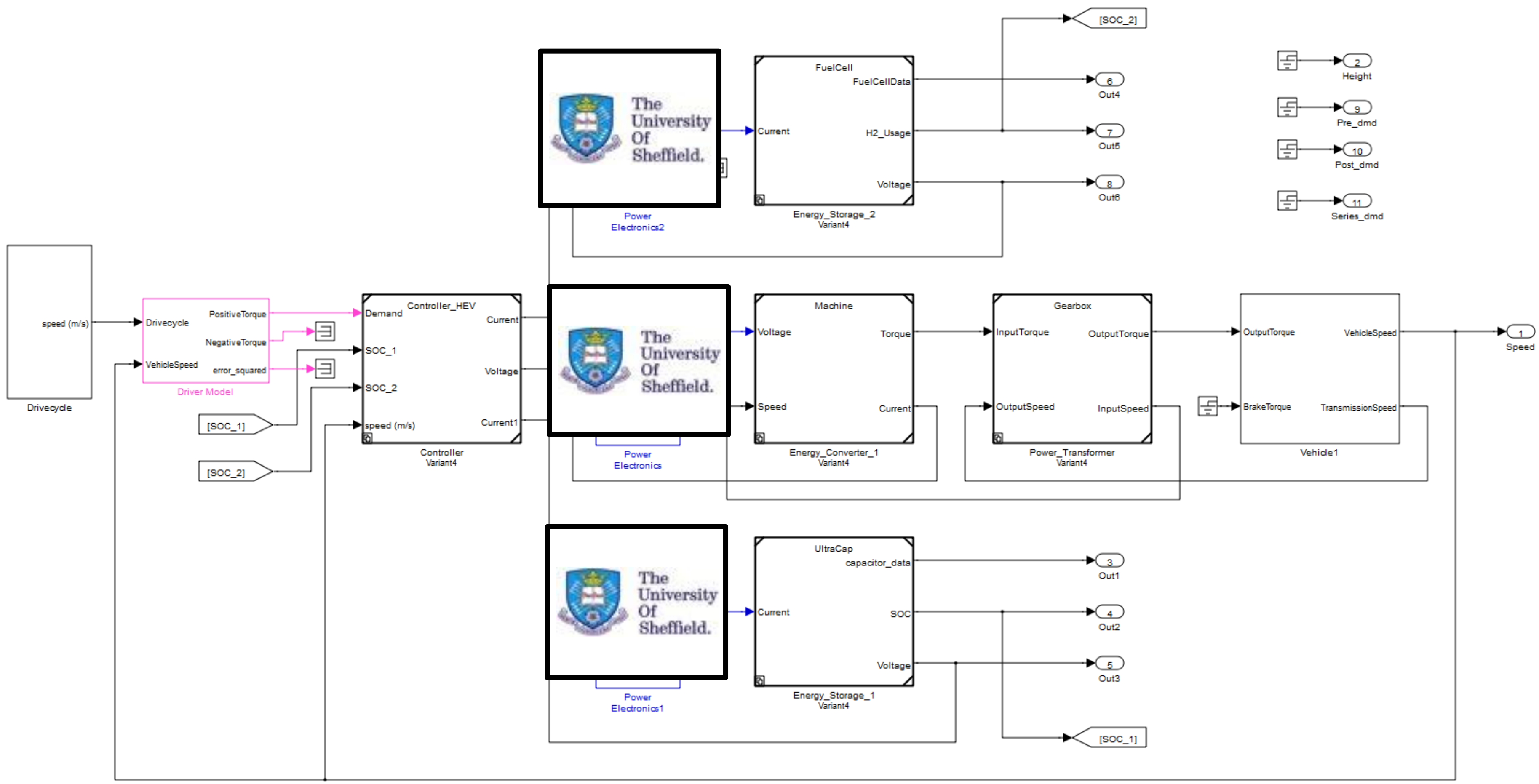
POWER ELECTRONICS



Reliability Assessment of Power Converters with Partial Redundancy and Variable Power Distribution

Challenges

(1) Reliability indicators

- Mean time to failure (MTTF) is not enough for reliability assessment when system's power distribution varies.

(2) Reliability models

2.1 Component-level reliability model

- Should we consider all the failure rates or not?

2.2 System-level reliability model

- Part-count and combinatorial models are simple but cannot evaluate the reliability of fault-tolerant system.
- Markov model can evaluate the fault-tolerant system's reliability but complex.

Three-step assessment method

Step 1: Compare failure rates of all components at all states and select necessary ones

- List components in the system
- List the working conditions of components
- Calculate and compare failure rates $\lambda(t)$ of components at all states

Footstone

Step 2: Build Hybrid reliability model

- Distinguish the non-redundant subsystems and redundant subsystems
- Build part-count model for non-redundant subsystems
- Build Markov model for redundant subsystms

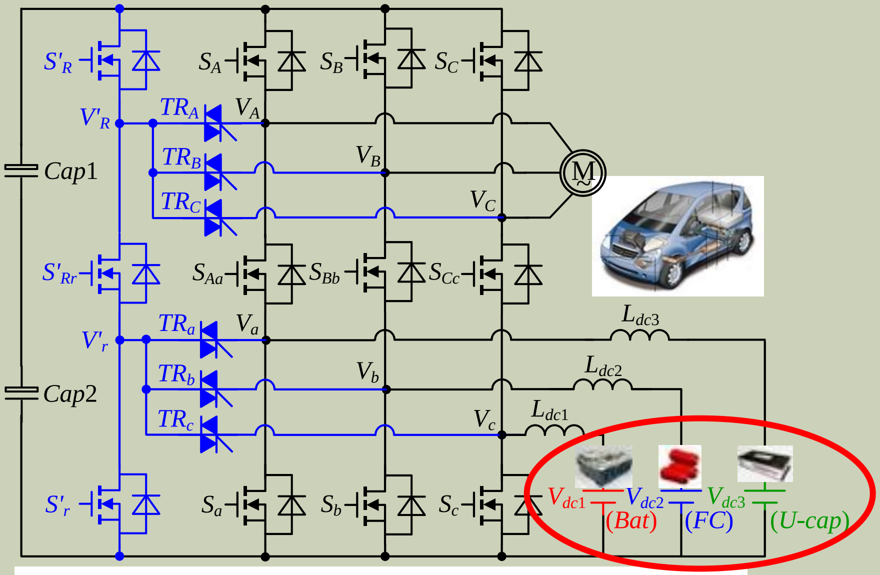
Core

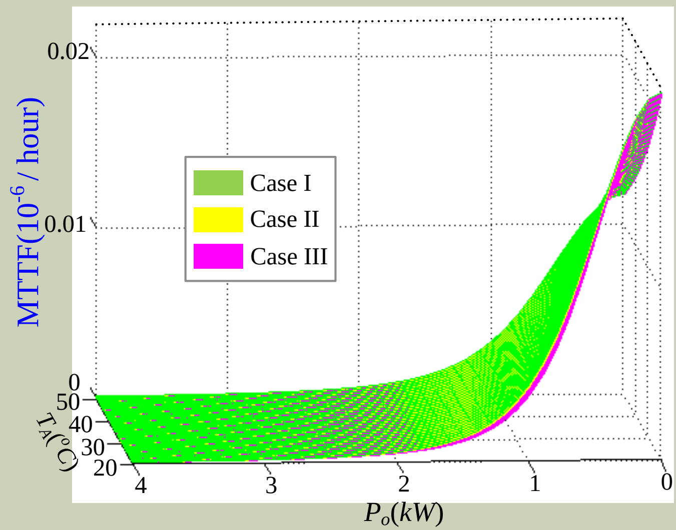
Step 3: Calculate MTTF and MTTFr

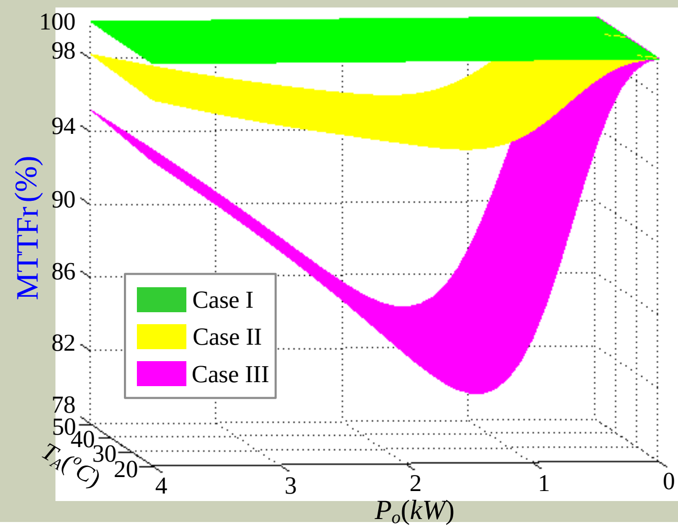
- Calculate MTTF
- Calculate MTTFr → Proposed metric

Results

Application of the Proposed Reliability Assessment Method







Most Vulnerable Components and Major Causes of Reliability Issues

- Power semiconductor devices
  - High temperature
  - Oscillation — High voltage or current stress
- Electrolytic capacitors
  - Used to reduce voltage ripples
  - Capacitance drops with time
  - Electrolyte can dry up
  - Electrolyte leaks when temperature increases
  - Ripple currents cause temperature to increase

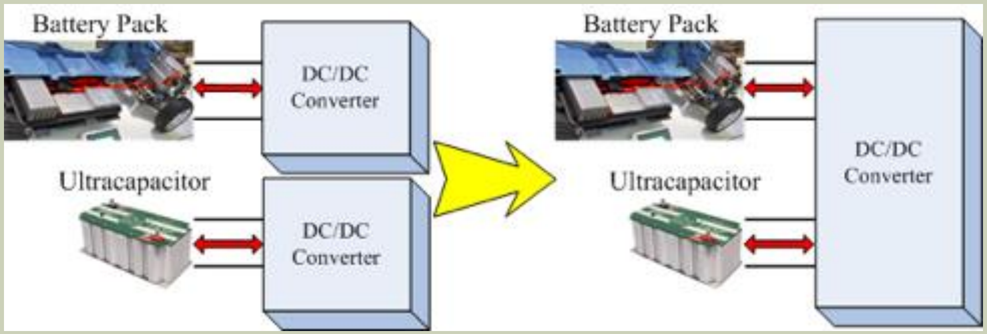
How to Improve the Reliability of Power Converters?

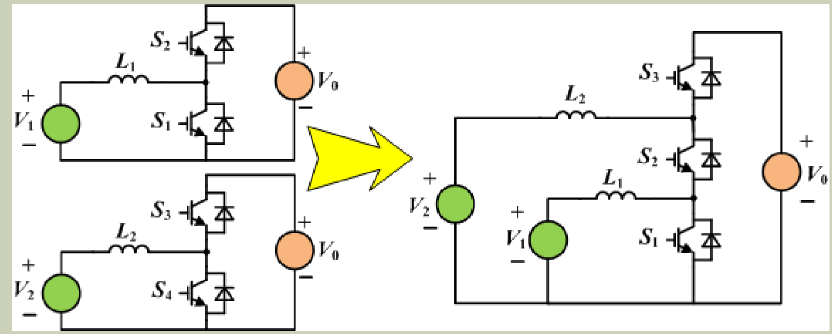
- Propose compact power converters to reduce the power semiconductor devices

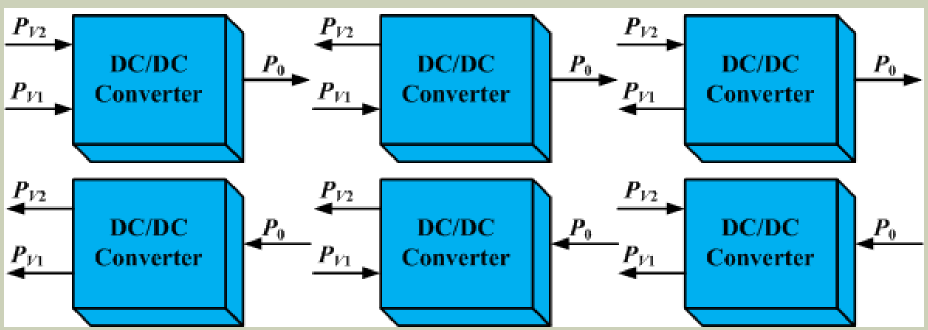
- Propose impedance-based stabilisation methods to eliminate the system oscillation and avoid the high voltage or current stress

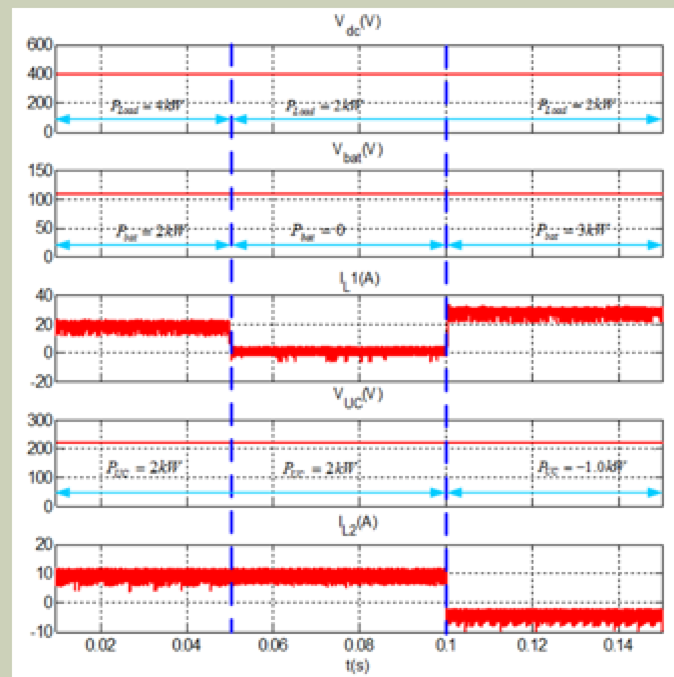
- Propose active ripple eliminator to remove Electrolytic capacitors

Compact Power Electronics Interface



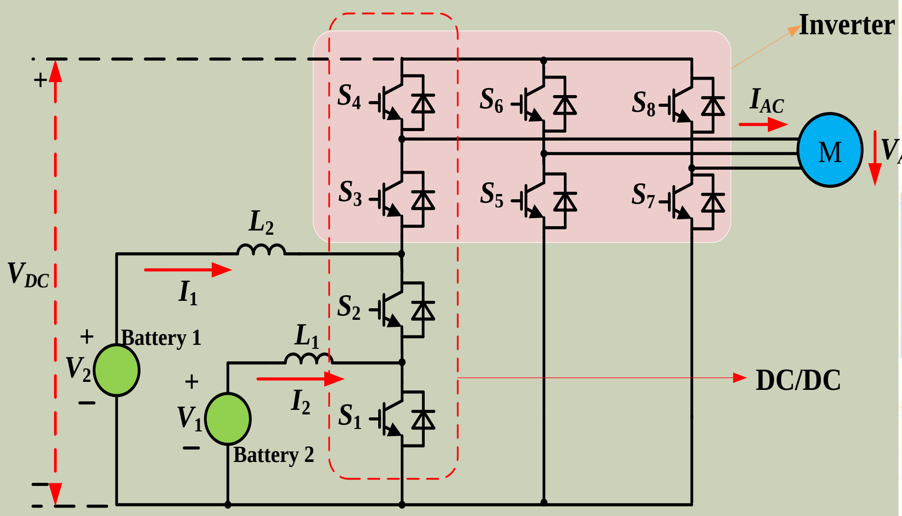


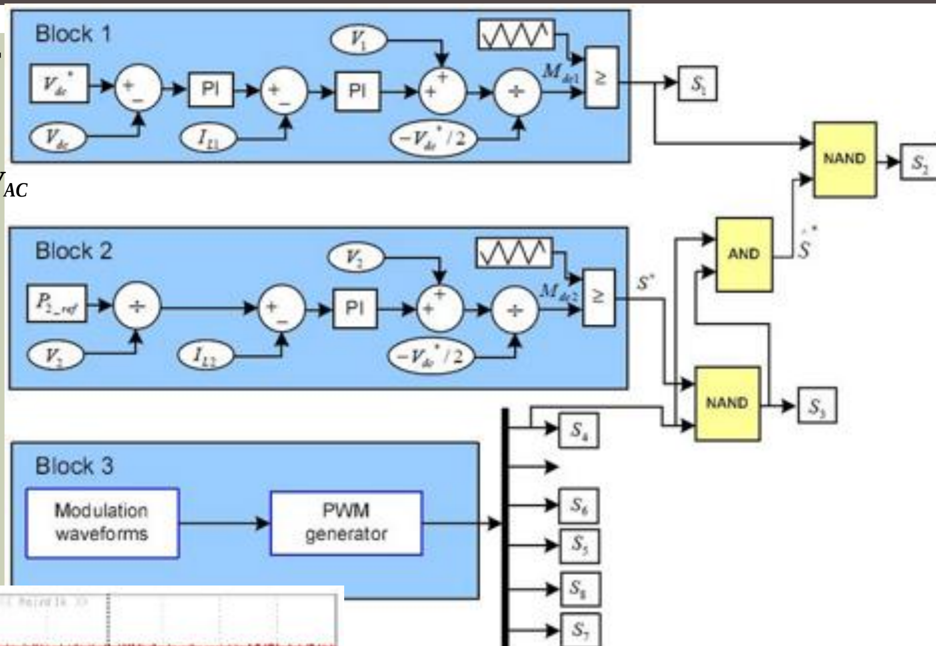


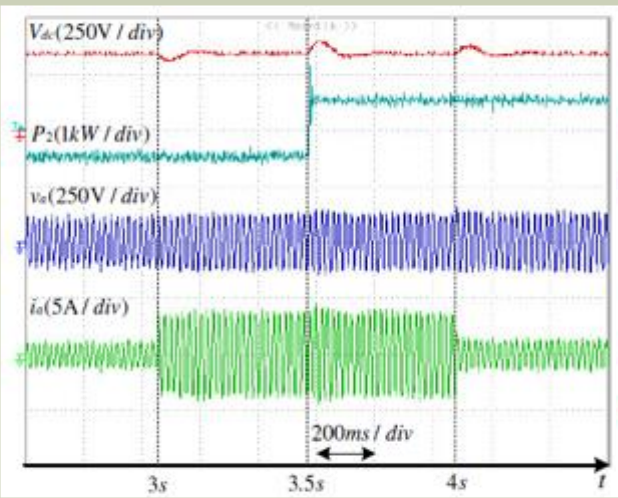


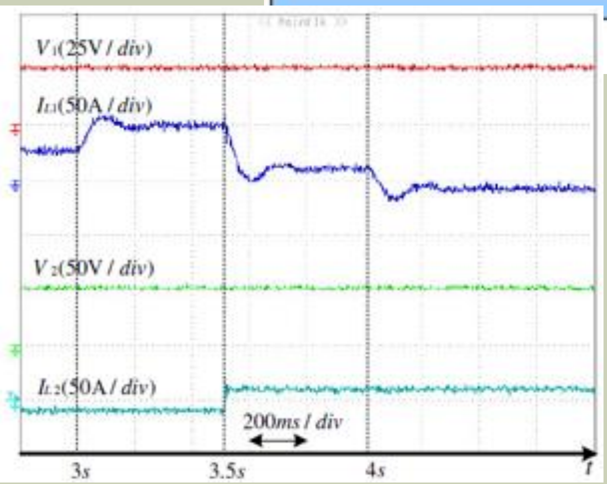
- ✓ Six possible power flow modes
- ✓ Bidirectional with reduced power switch
- ✓ Higher reliability but lower cost
- ✓ Flexible control of power/current/voltage
- ✓ Possible applications in B-UC HEV, FC-B-UC HEV and hybrid energy storage systems

Compact Power Electronics Interface





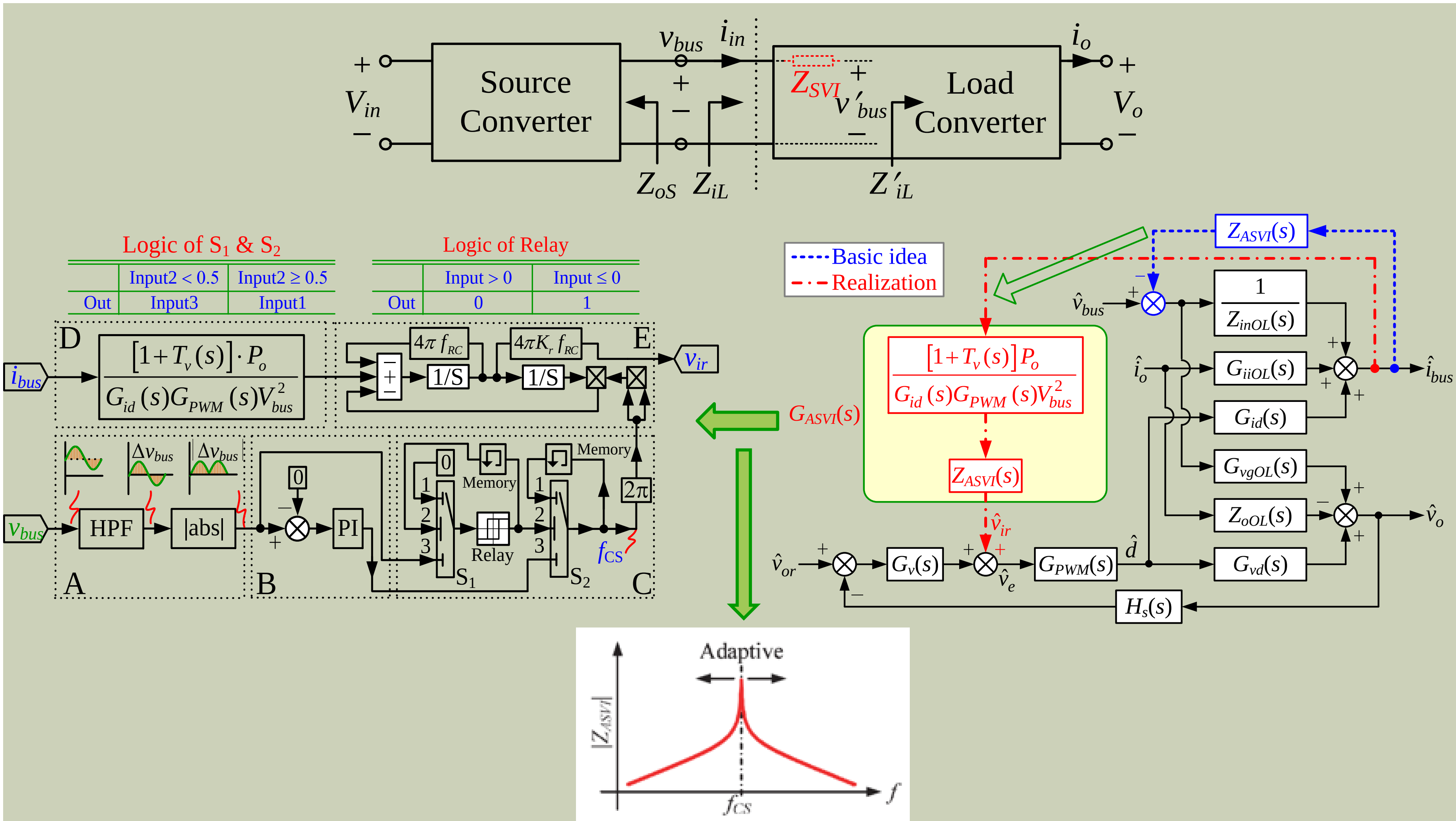




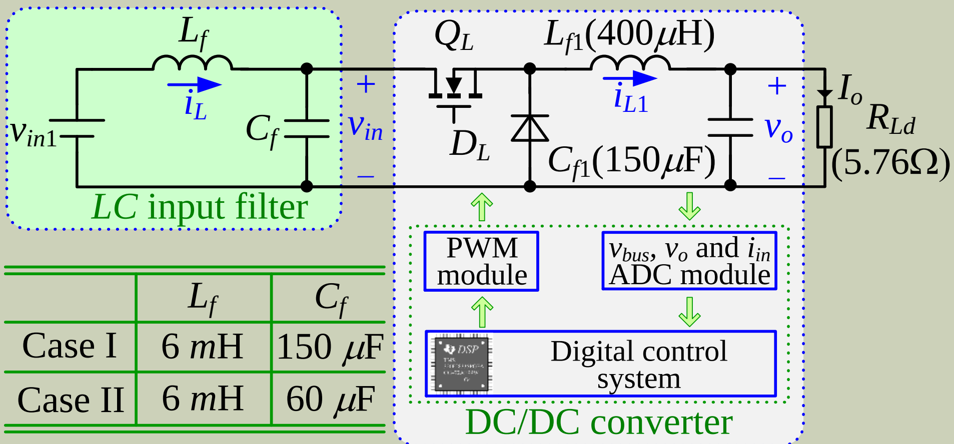
✓The inverter and the DC-DC converter are integrated

✓The DC-DC converter can interface two sources with only two additional power switches. More compact with higher power density, cost effective and less degradation for components

Stabilisation of Cascaded DC/DC Converters via Adaptive Series-Virtual-Impedance Control of the Load Converter

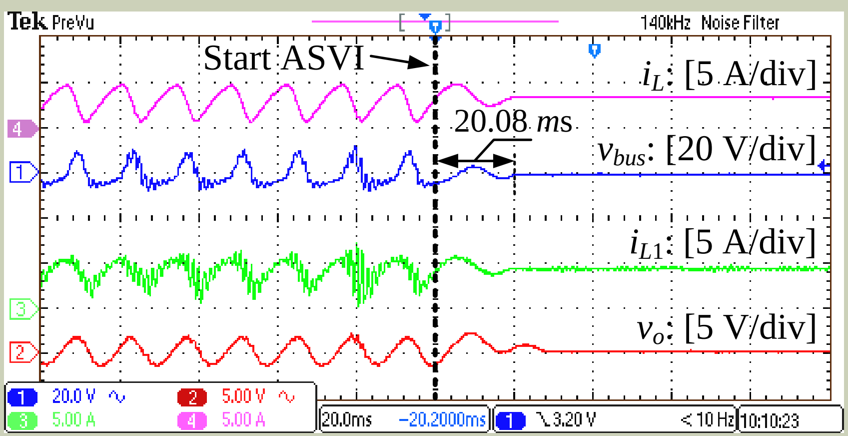


Experiment Verification of the ASVI Control Strategy

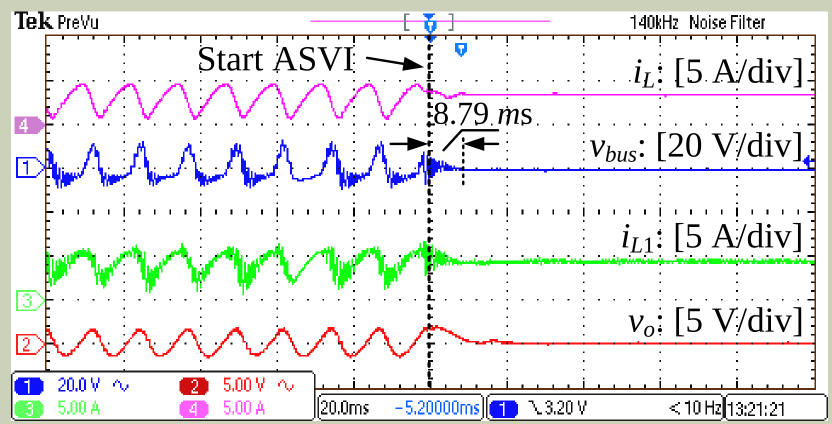


	L_f	C_f
Case I	6 *m*H	150 μF
Case II	6 *m*H	60 μF

Case I

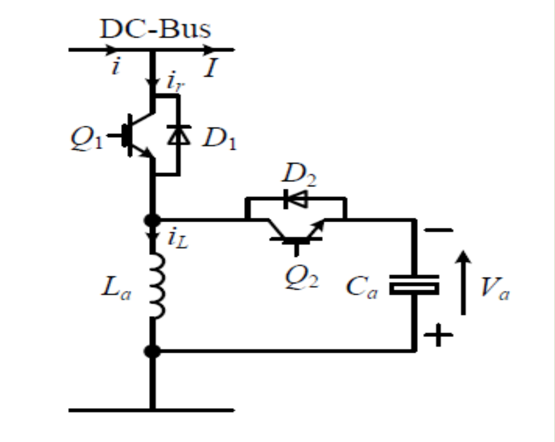


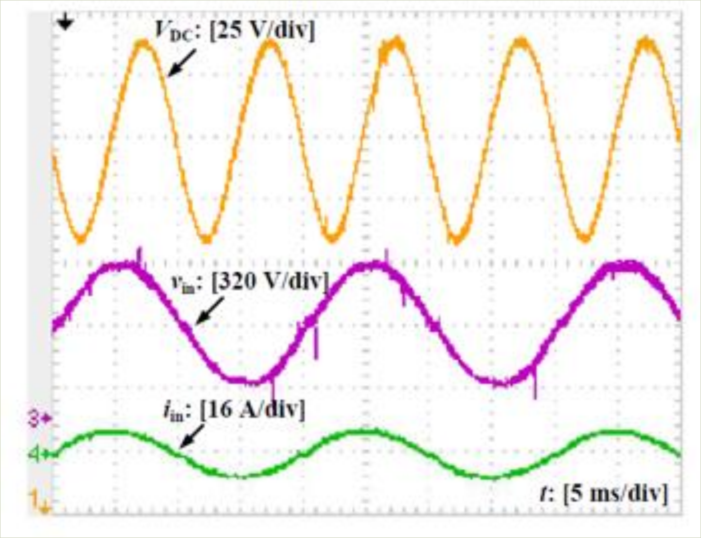
Case II



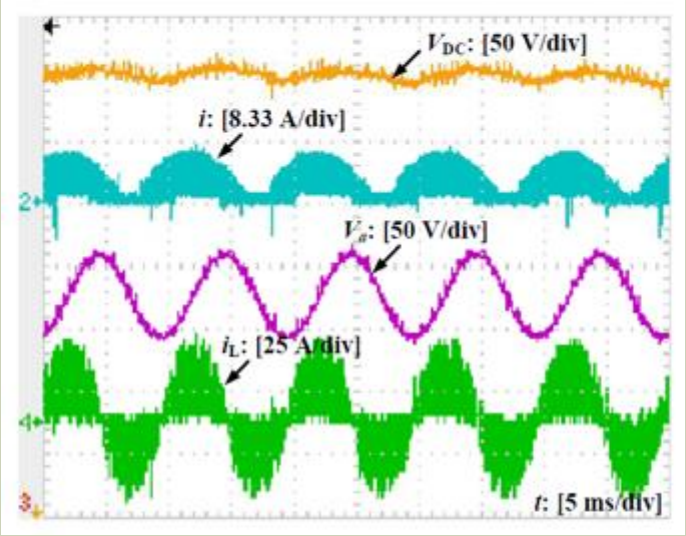
Active Ripple Eliminators

Adding a ripple eliminator to compensate the current ripples so that the voltage ripples on the DC bus are maintained small without using large electrolytic capacitors.





WITH THE STRATEGY



Outcomes

Journal papers:

1. X. Zhang, Q.-C. Zhong and W.-L. Ming, Stabilization of Cascaded DC/DC Converters via Adaptive Series-Virtual-Impedance Control of the Load Converter, **IEEE Trans. on Power Electronics**, 2016.
2. X. Zhang, Q.-C. Zhong and W.-L. Ming, Stabilization of a Cascaded DC Converter System via Adding a Virtual Adaptive Parallel Impedance to the Input of the Load Converter, **IEEE Trans. on Power Electronics**, 2015.
3. Xin. Zhang, Xinbo Ruan, Qing-Chang Zhong, "Virtual-Impedance-Based Control Strategy of Regulating the Input Impedance of Load Converter for Improving the Stability of Cascaded Systems," **IEEE Trans. Industrial Electronics**, 2015.
4. Wen-Long Ming, Qing-Chang Zhong, and Xin. Zhang, "A single-phase four-switch rectifier with significantly reduced capacitance," **IEEE Trans. Power Electronics**, 2015.
5. Xin Cao, Qing-Chang Zhong, Wen-Long Ming, "Ripple Eliminator to Smooth DC-Bus Voltage and Reduce the Total Capacitance Required", **IEEE Trans. Industrial Electronics**, 2015.
6. X. Zhang, Q.-C. Zhong and W.-L. Ming, A Virtual RLC Damper to Stabilize DC/DC Converters Having an LC Input Filter while Improving the Filter Performance, **Submitted**, 2016.

Outcomes

Conference papers:

1. Xin. Zhang, Qing-Chang Zhong, Wen-Long Ming, “Fast Scale Instability Problem and Phase-Shifted-Carrier Solution of Buck Derived Cascaded System,” ***IEEE ECCE*** 2015.
2. Xin. Zhang, Qing-Chang Zhong, Wen-Long Ming, Xinbo Ruan, “Stabilization of a Cascaded DC System via Adding a Virtual Impedance in Series with the Load Converter,” ***IEEE PEDG*** 2015.
3. Xin. Zhang, Qing-Chang Zhong, Wen-Long Ming, Xinbo Ruan, “Stabilization of a Cascaded DC System via Adding a Virtual Impedance in Parallel with the Load Converter,” ***IEEE PEDG*** 2015.
4. Xin. Zhang, Qing-Chang Zhong, Wen-Long Ming, “Impedance-Based Local Stability Criterion for Standalone PV-battery Hybrid System,” ***IEEE PEDG*** 2015.
5. Jun Cai, Qing-Chang Zhong, David Stone, “A new power converter for hybrid energy storage systems,” ***IEEE IECON*** 2014.
6. Jun Cai, Qing-Chang Zhong, “An Asymmetrical Gamma Z -source Hybrid Power Converter with Space Vector Pulse-width Modulation ,” ***IEEE ECCE*** 2014.
7. Jun Cai, Qing-Chang Zhong, “ A compact bidirectional DC-DC converter with two sources,” ***IEEE PEDG*** 2014.
8. Jun Cai, Qing-Chang Zhong, David Stone, “A ΓZ-source converter based hybrid power converter for battery FCHEVs,” ***UKACC*** 2014.

Outcomes

Conference papers:

9. Xin Cao, Qing-Chang Zhong, Wen-Long Ming, "Analysis and Control of Ripple Eliminators in DC Systems", ***IEEE Green Tech*** 2014.
10. Q.-C. Zhong, W.-L. Ming, and M. Krstic, "Improving the power quality of traction power systems with a single-feeding wire," in Proc. ***IEEE Green Technologies Conference***, 2013.
11. Q.-C. Zhong, W.-L. Ming, X. Cao, and M. Krstic, "Reduction of DC-bus voltage ripples and capacitors for single-phase PWM-controlled rectifiers," in Proc. ***IEEE IECON*** 2012.
12. Xin. Zhang, Qing-Chang Zhong, Wen-Long Ming, "A Virtual RLC Damper to Stabilize a DC/DC Converter Having an LC Input Filter while Improving the Filter Performance," ***Submitted*** 2016.
13. Xin. Zhang, Qing-Chang Zhong, Wen-Long Ming, "Source-side Series-virtual-impedance Control Strategy to Stabilize the Cascaded System with Improved Performance," ***Submitted*** 2016.
14. Xin. Zhang, Qing-Chang Zhong, Wen-Long Ming, "Stabilization of Cascaded DC/DC Converters via Shaping the Load Input Impedance by Adaptive Series-Virtual-Impedance Control," ***Submitted*** 2016.
15. Xin. Zhang, Qing-Chang Zhong, Wen-Long Ming, "Reliability Assessment of Power Converters with Partial Redundancy and Variable Power Distribution," ***Submitted*** 2015.