Y9.ET5.1: Distributed Energy Storage Device (DESD)

Project Leader: Alex Huang

Students: Fei Xue (Ph.D., EE)

1. Project Goals

In Year 7 & Year 8, the DESD subthrust has developed a compact GaN and Si mixed 1kWH 380VDc based plug-and-play modular energy storage device (DESD module). Ultra-high efficiency of 98% was reported. This has been successfully demonstrated at the Y7 NSF SV and three DESD units have been delivered to the GEH testbed. In Year 8, the DESD have been integrated into the GEH testbed. They have been used in the demonstration of IEM based applications. Communication protocol and interfaces were also developed so that charge and discharge of the DESDs are accomplished.

The objective of Y9 is to finish an activity that was started in Year 8, focusing on a 10 kW high power DESD development and its delivery to the GEH testbed. The high power DESD activity utilizes an innovative fraction power converter (about 1/5 of the battery power rating), therefore the effective efficiency is extremely high. It is expected to demonstrate >99% efficiency in Y9. The converter will be based on low voltage GaN power devices which fulfill another objective of the center in utilizing WBG devices in DESD subthrust.

2. Role in Support of Strategic Plan

Developing highly efficient and compact energy AC and DC interfaced energy storage systems is critical to release FREEDM vision in which dispatch of energy is needed for grid stability and market transformation.

3. Fundamental Research, Technological Barriers and Methodologies

Low efficiency and high cost have been two major challenges in any energy storage system. We are address both issues this year with the proposed novel fractional power converter architecture.

4. Achievements

In Year 9, the DESD sub-thrust has proposed a low cost, high efficiency fractional Buck-boost converter for high voltage (>200V) battery energy storage device. A proof-of-concept converter was fabricated based on the state-of-art low voltage (100V) GaN HEMT. The system has a charging and discharging power of 1.2kW in a wide input/output voltage range. With the proposed converter, a peak equivalent system efficiency of 99.63% is achieved. The analysis and experimental results show that the proposed fractional converter is capable of achieving high efficiency, high power density and low cost by using lower voltage stress switching device in the high voltage DESD application. This is a major achievement as it not only follows the critical roadmap for development and makes the deliverable to the testbed, but also represents a major technical progress needed to facilitate large scale application of energy storage. From the system point of view, the developed high voltage DESD is a beneficial supplement to the existing 380V DESD module based on 12V battery pack.

1) Fractional converter for high voltage DESD

   Originated in the 1990s, fractional converter or partial power converter, a converter that processes partial input/output power has become attractive to researchers who design high-efficiency, low device power rating and low-cost power supplies recently in PV and motor drive applications. Fractional converters are not new topologies but special connections between sources and loads in comparison with a conventional power converter. Fig. 1(b) shows the concept circuit of a partial power converter. By feeding a considerable amount of input power

directly to the battery, partial power converters in Fig. 1(b) have a much lower voltage rating. Moreover, the power loss is also limited, so the equivalent system efficiency could become very high.

Fig. 2 shows the structure of DESDs based on 3 basic non-isolated fractional converter topologies. V_{LV} can be part of the battery V_{HV} or a separate battery. Fig. 2(a), (b) and (c) show the fractional Buck, fractional Boost and fractional Buck-boost converter respectively. Similarly, isolated topologies can be used too. Topology should be selected based on the input and output voltage range and filter type. A comparative study has been conducted and the final design based on Buck-Boost topology has been selected in our implementation.

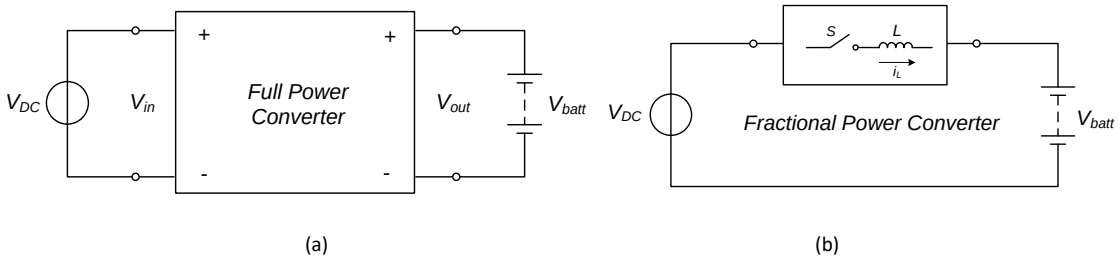
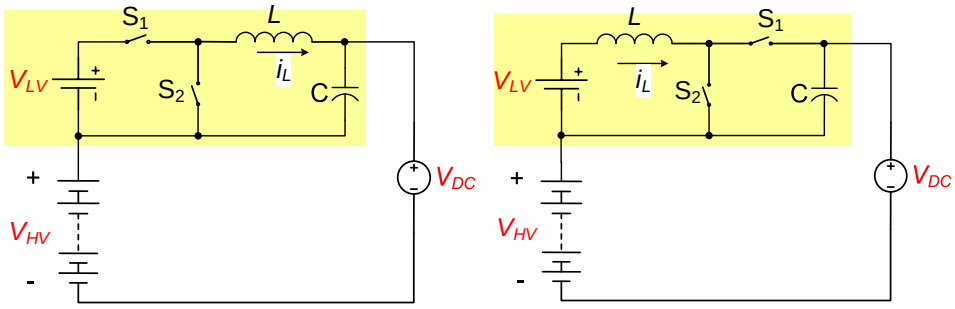


Fig. 1 Different battery charging/discharging system structures



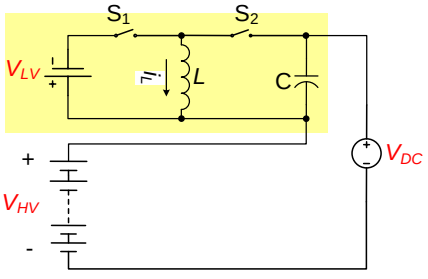


Fig. 2 **BESS based on four basic non-isolated fractional converter**

2) Hardware Demonstration

In the first half of Y9 program, the GaN bi-directional fractional converter has been developed and tested. The developed converter is shown in Fig.3 and the tested efficiency is higher than 90% (as a standalone DC/DC converter). Low voltage GaN devices are used in the porotype. The effective efficiency when used in a 200V high voltage DESD system is higher than 99.63%. The converter specifications are listed in Table I. The DESD system specs are also shown.

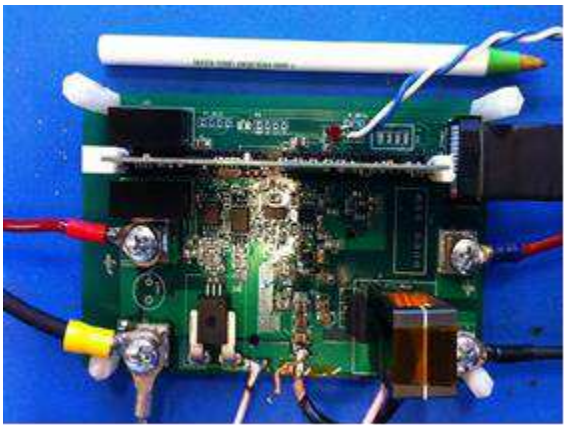


Fig. 3 Prototype of proposed converter

Table I System specs

Converter	Circuit topology	Buck-boost
	Input voltage	12 V
	Output voltage	0~60 V
	Switching frequency	100 kHz
	Load current	0A~6A
	Inductor	10uH
System	DC supply voltage	200V
	High voltage battery	140V~200V
	Power rating	1.2kW
	Capacity	50Ah

5. Other Relevant Work Being Conducted Within and Outside of the ERC

There is currently no other high power DESD development activity in the center. Outside the center, developing utility scale and higher power storage systems are extremely active and companies such as Tesla, Enphase, Siemens, Toshiba all have announced high storage product. As PV penetration becomes higher and higher, the need for higher power storage system will increase.

6. Milestones and Deliverables

- Oct. 2016: Layout of the 2nd version of GaN fractional converter (100% accomplished
- Dec. 2016:New converter tested and evaluated (100% accomplished)
- Jan. 2017: Efficiency analysis and report the performance testing. (done)
- May. 2017 Integration of battery system and testing as a DESD

Deliverable by SV (05/2017):

1) High voltage high power 200V, 1.2 kW/1 kWh DESD prototypes with protection and communications

7. Plans for Next Five Years

8. Member Company Benefits

A novel technology to implement high power DESD

9. References