Y9.ET3.1 7.2 kV Medium Voltage SST based on Direct AC/AC Conversion

Qianlai Zhu, Li Wang, Liqi Zhang, Alex Q. Huang

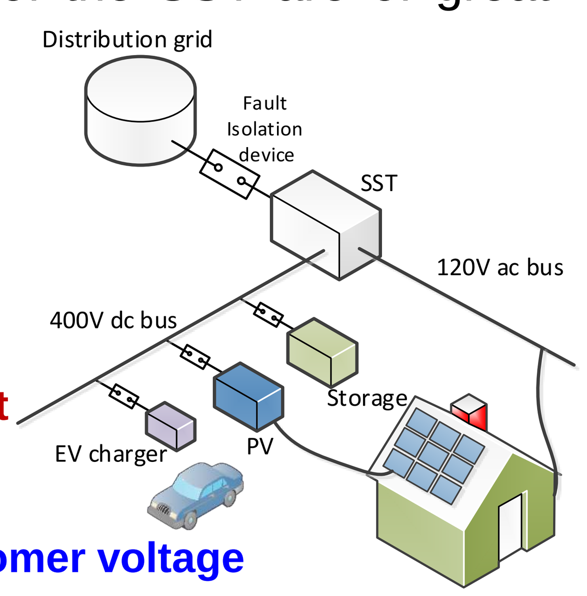
FREEDM SYSTEMS CENTER

NC STATE UNIVERSITY

Overview

1. Background

Using solid state transformer (SST) to replace the one hundred year old 60Hz transformer has been an attractive concept in existence for many years, dating back as early as the 1968 patent by William McMurry [1]. Modern interests of the SST were driven by the need to create a more resilient power grid suitable for integrating high penetration of distributed energy resources (DERs) [2]. In addition to potential reduction of the transformer size and weight, advanced power management and fault management features of the SST are of great interests.



- **Fault management**
  - **Current limiting**
  - **Disconnect/reconnect**
- **Power Management:**
  - **Control power factor**
  - **Change/Control customer voltage**
  - **Provide DC power**
  - **Eliminate harmonics**
  - **Low voltage ride through**
  - **Supports multiple islanding modes**
- **Energy Management**
  - **Monitor energy usage (AMI)**
  - **Can control/dispatch power *via microgrids (Energy Cell)***
  - **Demand side management**

2. Problem statement

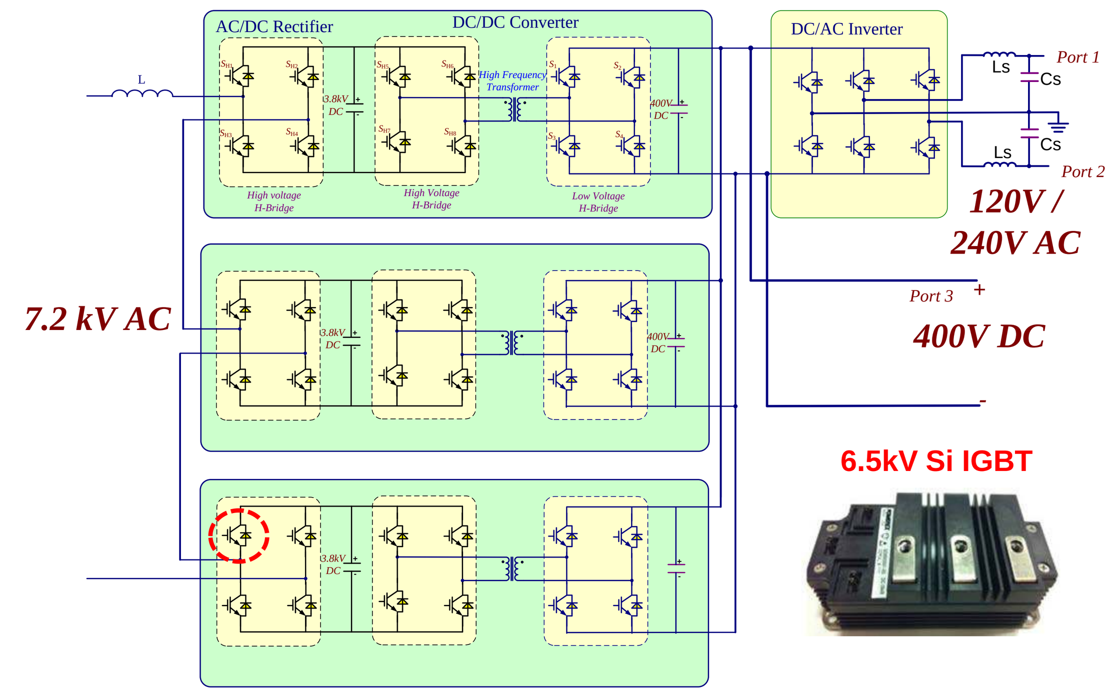
A single phase SST will need to connect to the 7.2 kV phase voltage. Commercially available device series connection or converter series connection are needed to achieve the 7.2 kV input voltage requirement.

Recently developed 15 kV SiC MOSFET and JBS diode enables the development of medium voltage SSTs using simpler converter topology without converter cell series connection. Three generation of medium voltage SST designs are presented which utilize three-stage, two-stage and single stage power conversion topologies respectively to achieve the medium voltage AC to low voltage AC power conversion.

Method

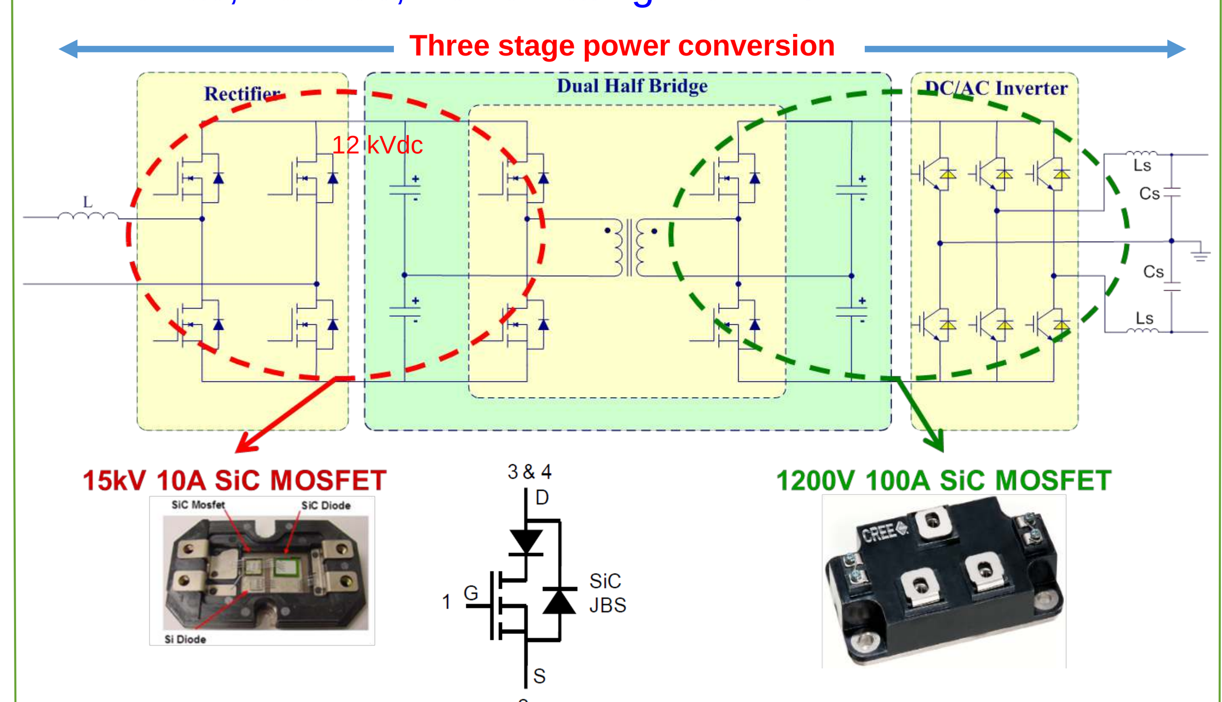
Gen-I SST 6.5kV Si IGBT Based

Input: 7.2kVac Output: 240Vac/120Vac; 400Vdc
Power rating: 20kVA



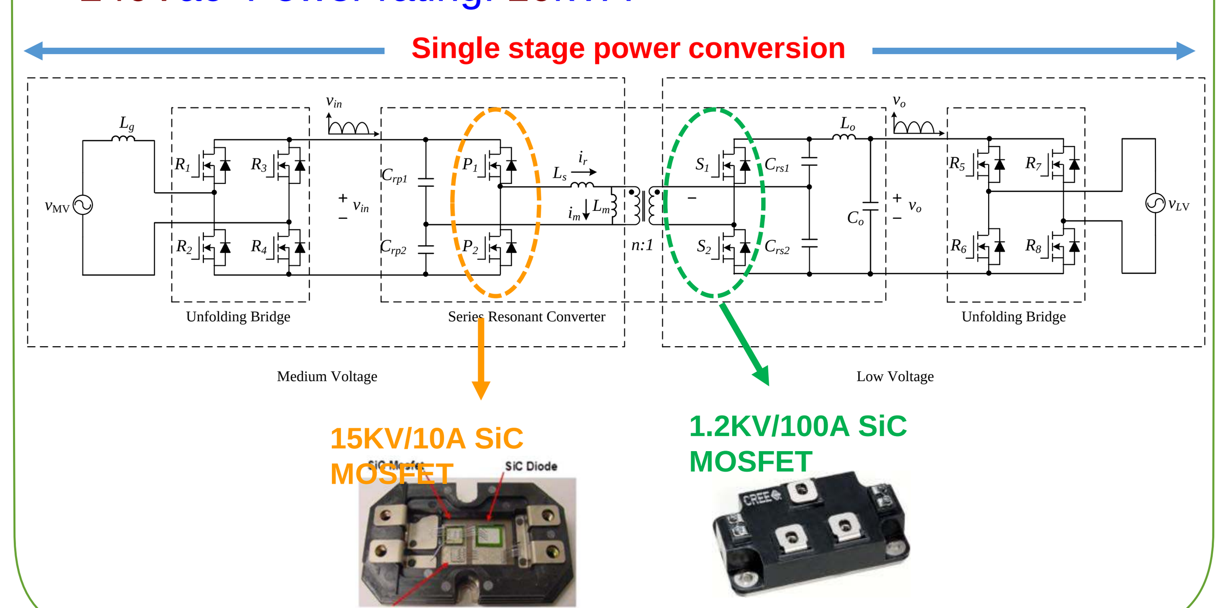
Gen-II SST 15kV SiC MOSFET Based

Input: 7.2kVac, Output: 240Vac/120Vac; 400Vdc; Power rating: 20kVA
Tested & Delivered(2014): Input: 3.6kVac; Output: 240Vac; 400Vdc; Power rating: 10kVA.



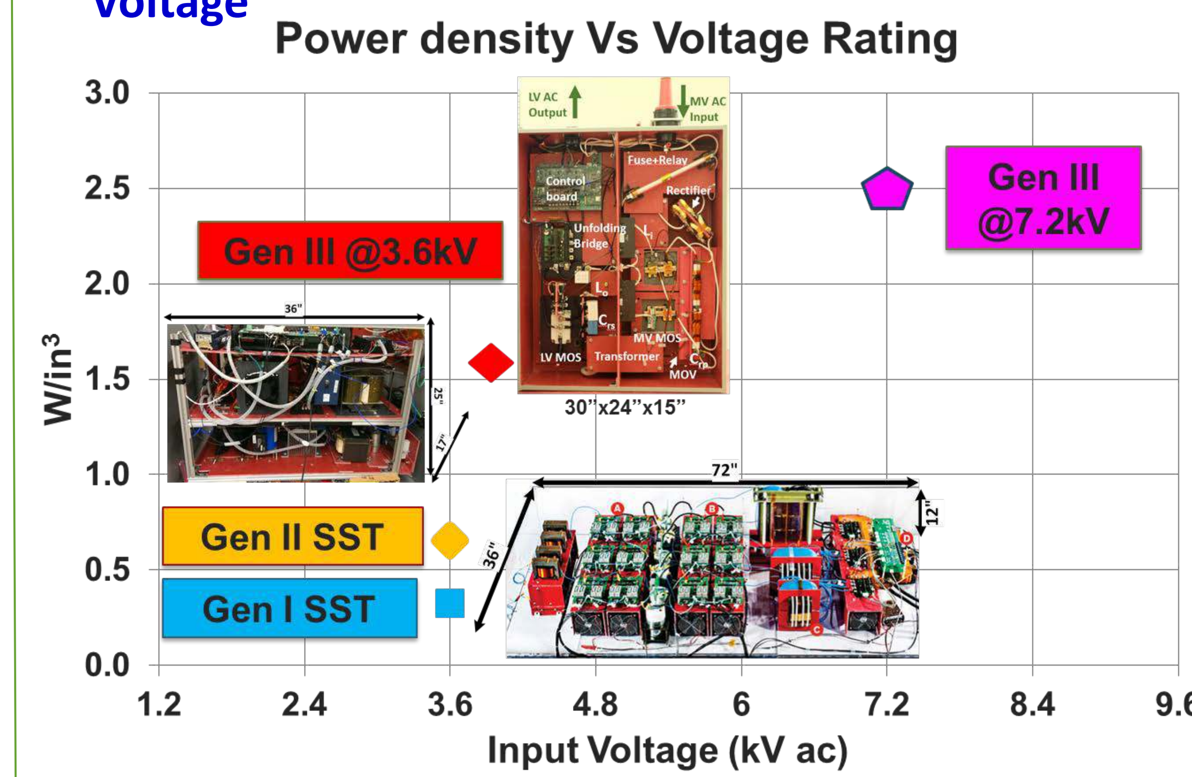
Gen-III SST 15kV SiC MOSFET Based

Input: 7.2kVac ; Output: 280Vac; Power rating: 20kVA
Tested & Delivered(2016): Input: 3.6kVac; Output: 280Vac Power rating: 10kVA
Tested & Delivered(2017): Input: 7.2kVac; Output: 240Vac Power rating: 10kVA

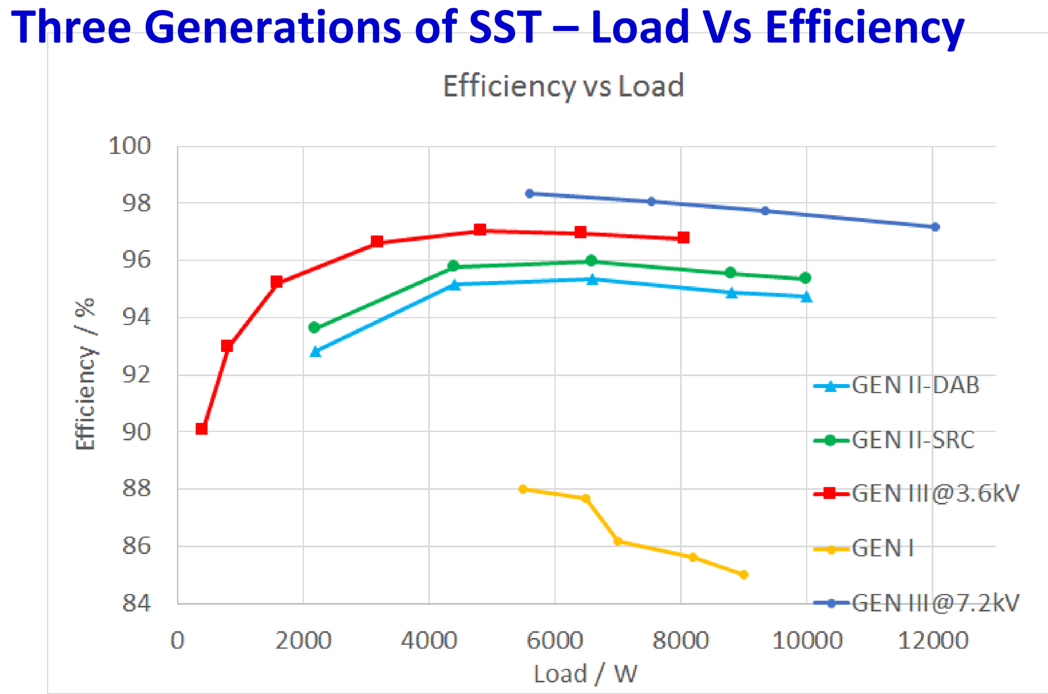


Results

- **Three Generations of SST – Power Density V.S. Input Voltage**

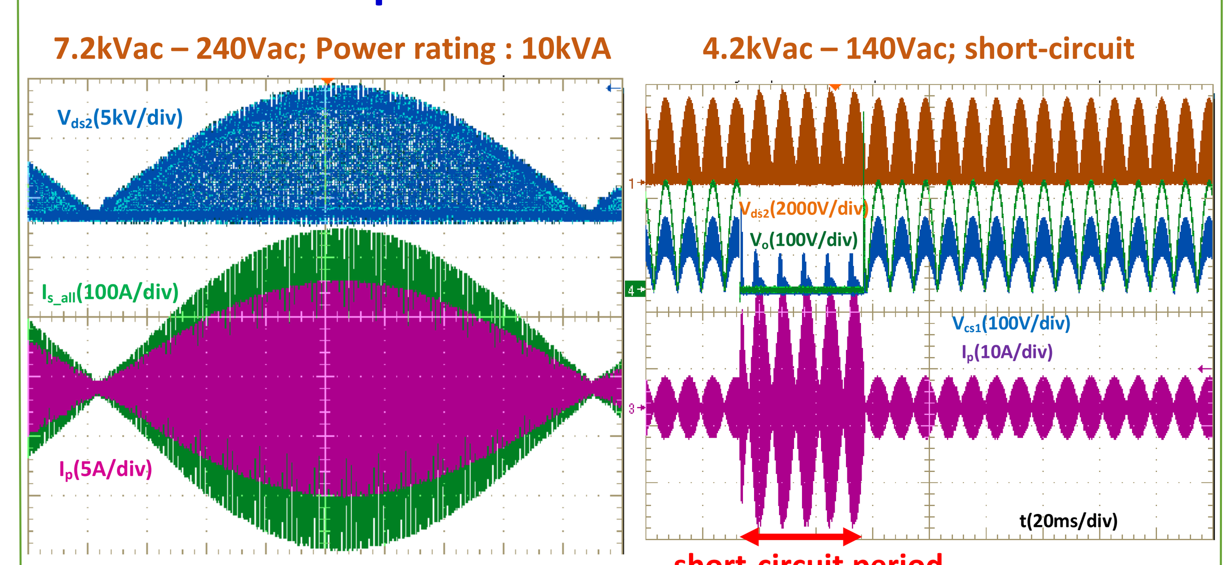


- **Three Generations of SST – Load Vs Efficiency**



- Gen-III SST @3.6kV have 2% improvement compared to Gen-II SST, 7% over Gen-I, reach >97% AC-AC target as originally envisioned in the ERC proposal.
- Gen-III SST @7.2kV have 1% improvement compared to Gen-III SST @3.6kV, achieve efficiency >97% at most load conditions and peak efficiency as high as 98.3%.

- **Gen-III SST Experimental Waveforms**



- The first time using a two level direct AC-AC Conversion at 7.2kV voltage level.
- Short circuit test is conducted and the results verify the calculation results. The converter can transit smoothly back to normal operation once the short circuit is gone.

References

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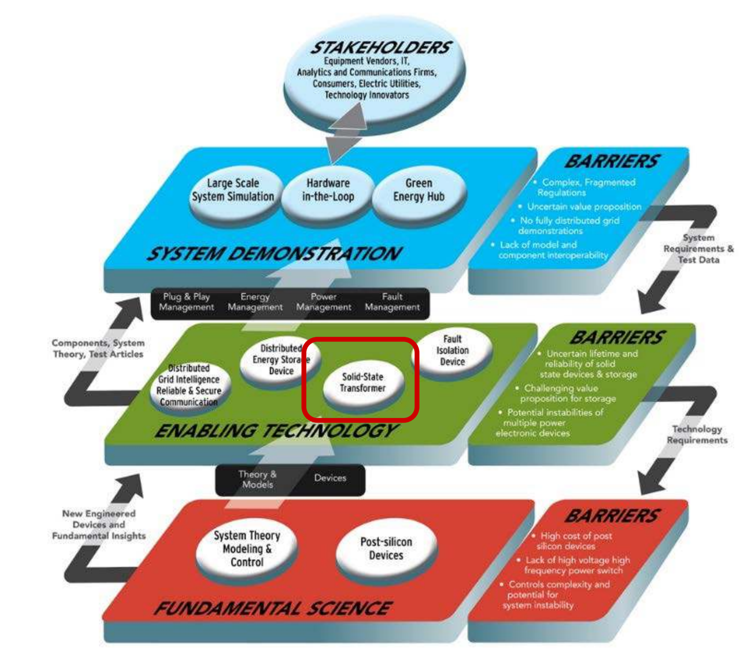

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