Hybrid Switched Capacitor Circuit (HSCC) Development for Use of WBG Diodes in High Gain Step-Up Converters

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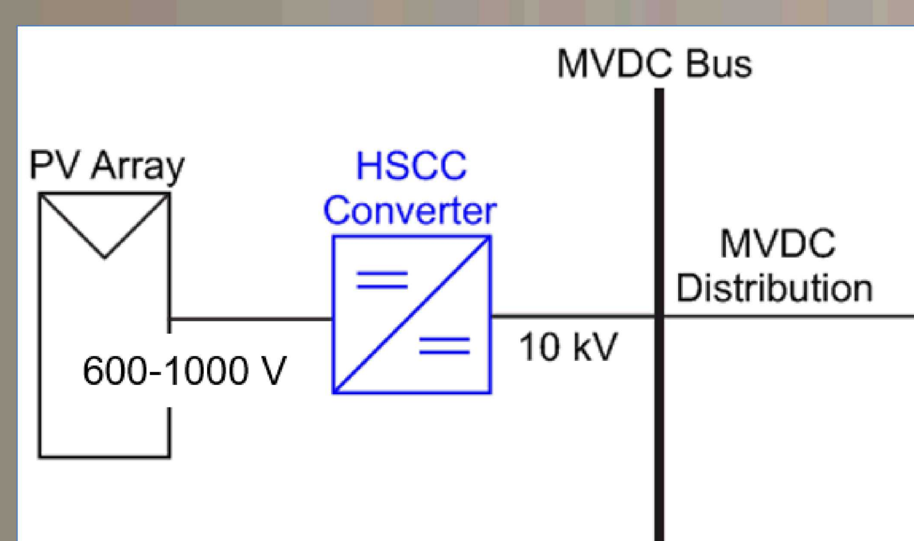
Motivation:

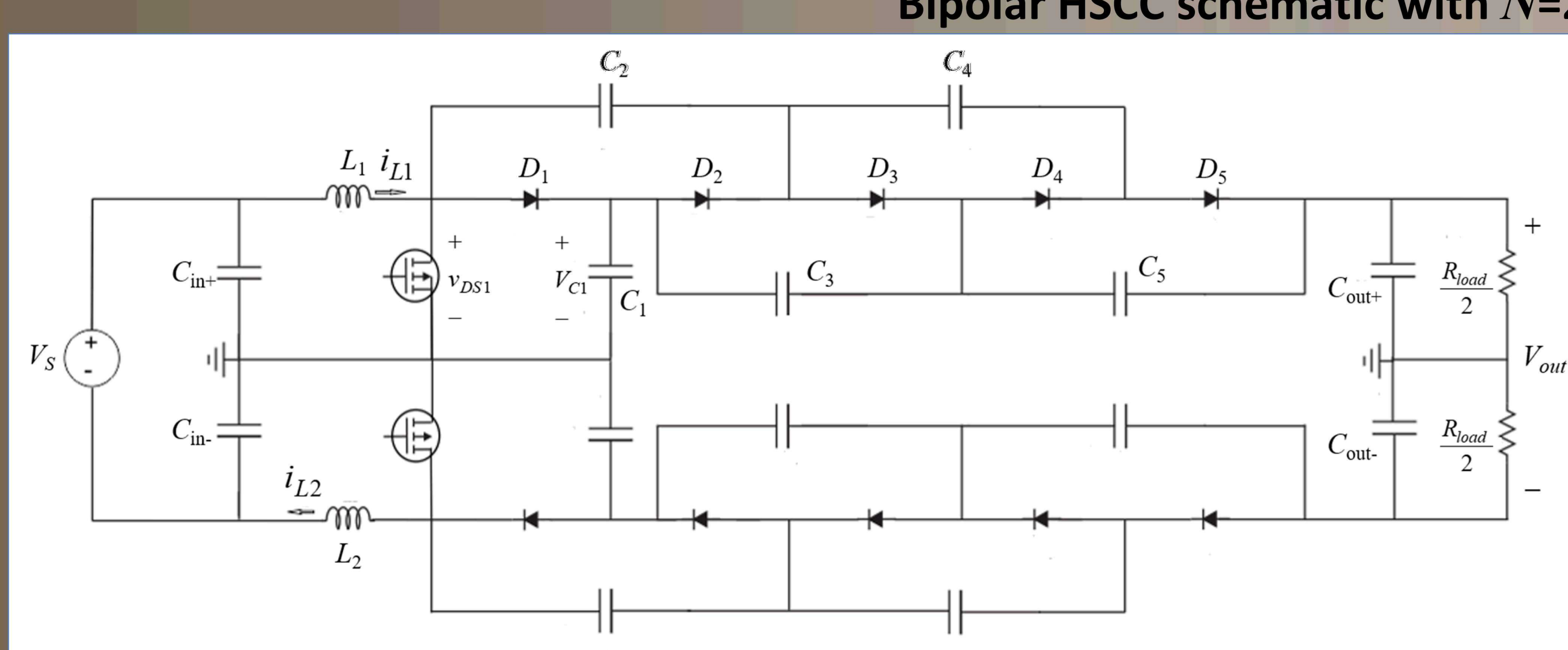
A large impediment to fulfilling state and utility renewable portfolio standards is the high levelized cost of solar PV energy ($109.8/MWh) compared to other sources (e.g. a conventional coal plant at $60.4/MWh). This disparity in cost is due primarily to the high installed cost of commercial and utility scale solar PV systems (relative to capacity factor). Changes to distribution architectures and converter design may realize cost reductions.

In this work, we developed a novel circuit topology for boosting PV power from the panel array to a medium voltage DC (MVDC) voltage for distribution. The circuit enables high gain, high efficiency, high power density conversion in support of MVDC distribution architectures.

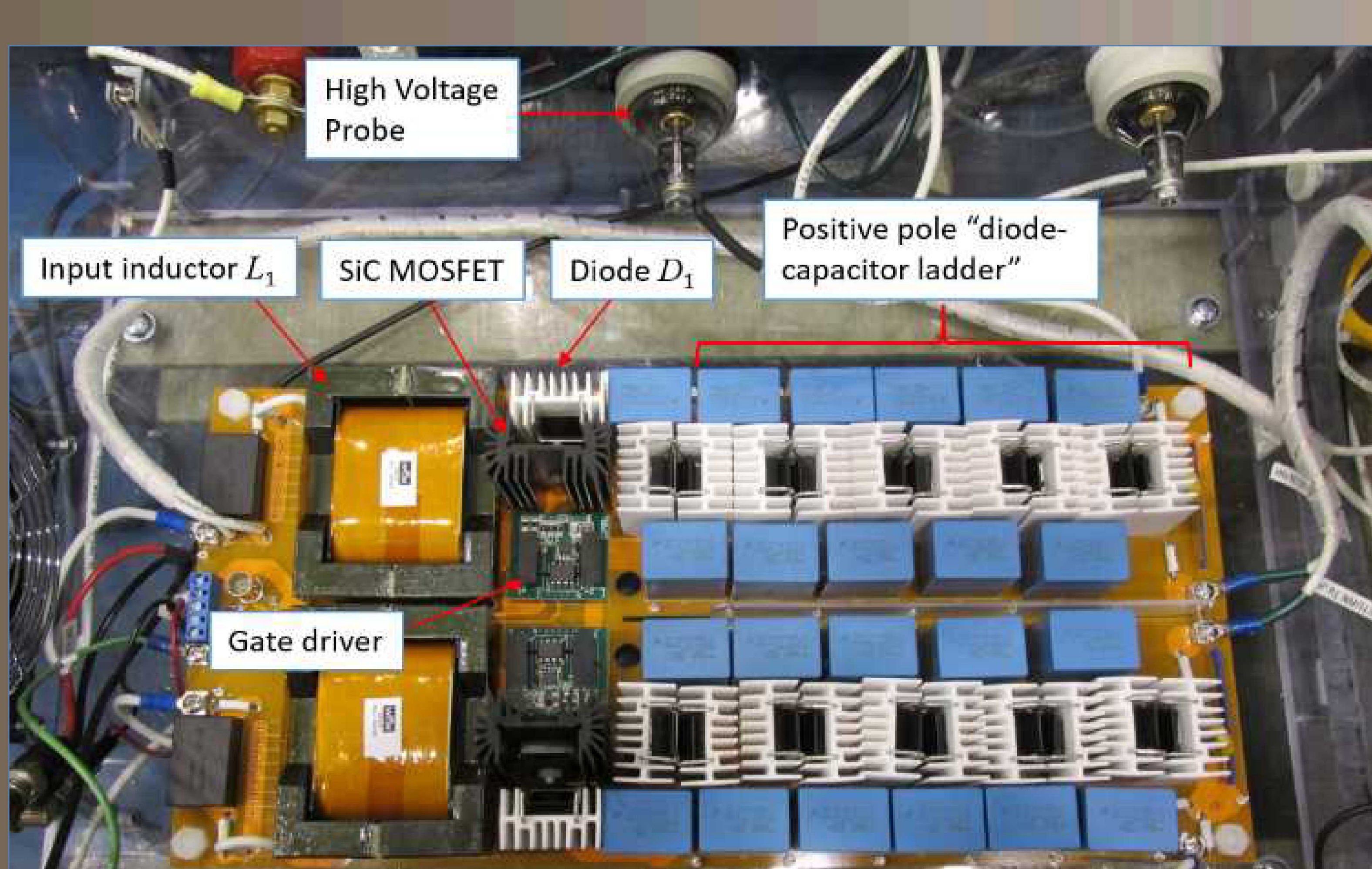


- The HSCC combines a traditional boost converter topology and a “diode-capacitor ladder” with N stages, to act as a voltage multiplier.
- A bipolar HSCC effectively contains two HSCC converters with a positive pole and a negative pole
- In the bipolar configuration, there are just two controlled switches that are synchronized.

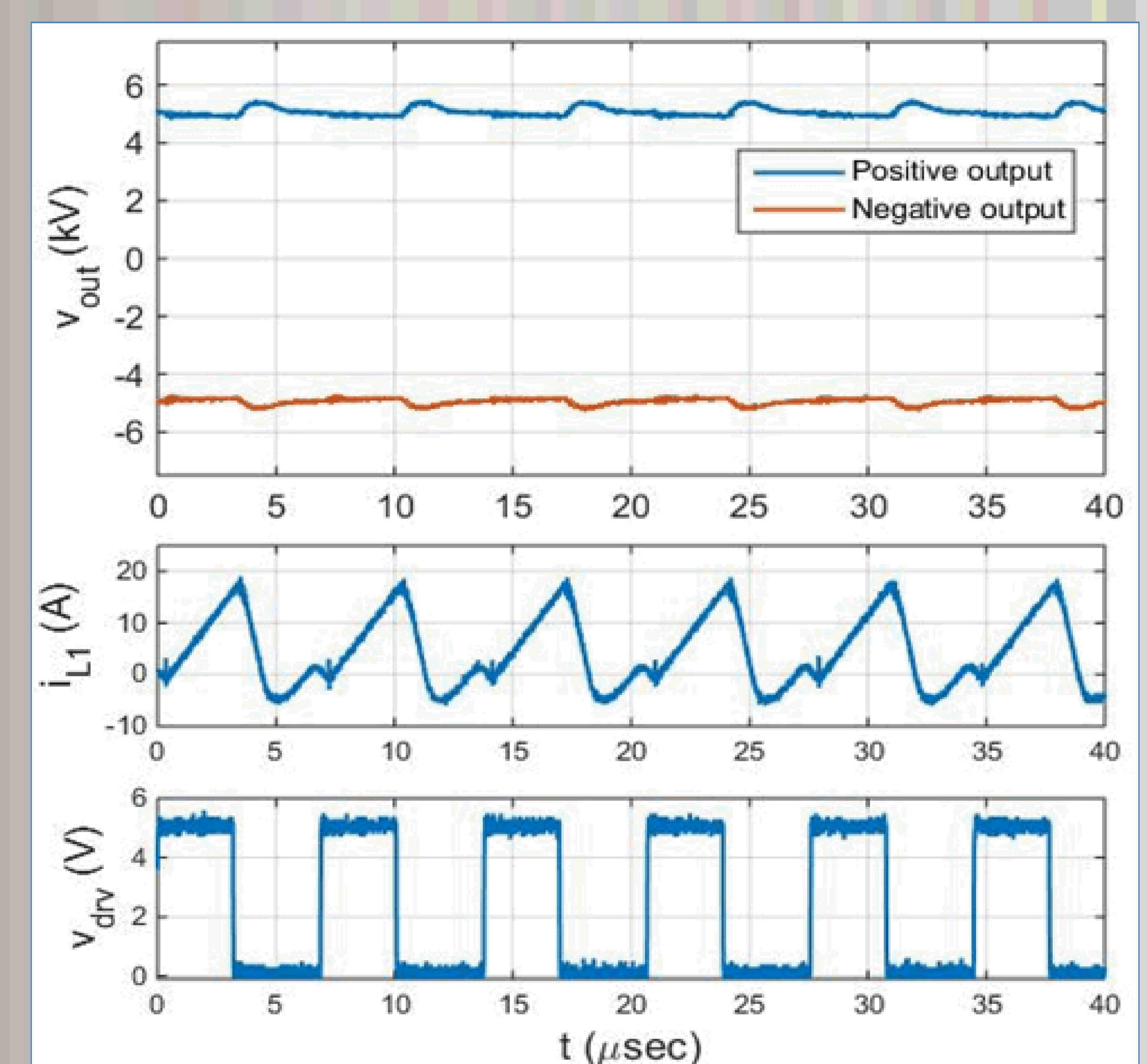
Bipolar HSCC schematic with N=2



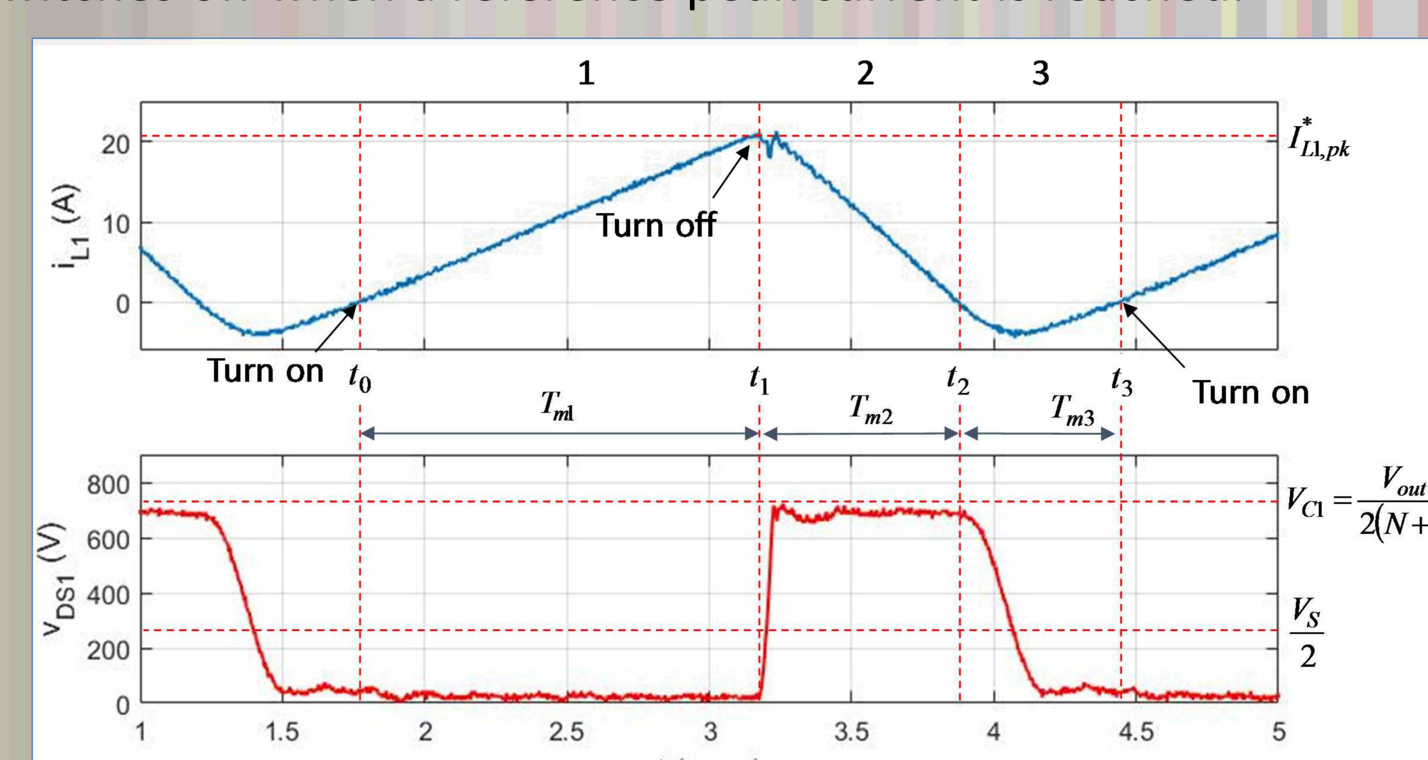
Two prototypes were built and evaluated. Shown here is Prototype 2 with N = 5 stages; the positive and negative poles of the converter occupy the top and bottom halves of the circuit.



10 kV / 2.57 kW output with 95.3% efficiency was achieved with simple constant duty cycle control on Prototype 1.

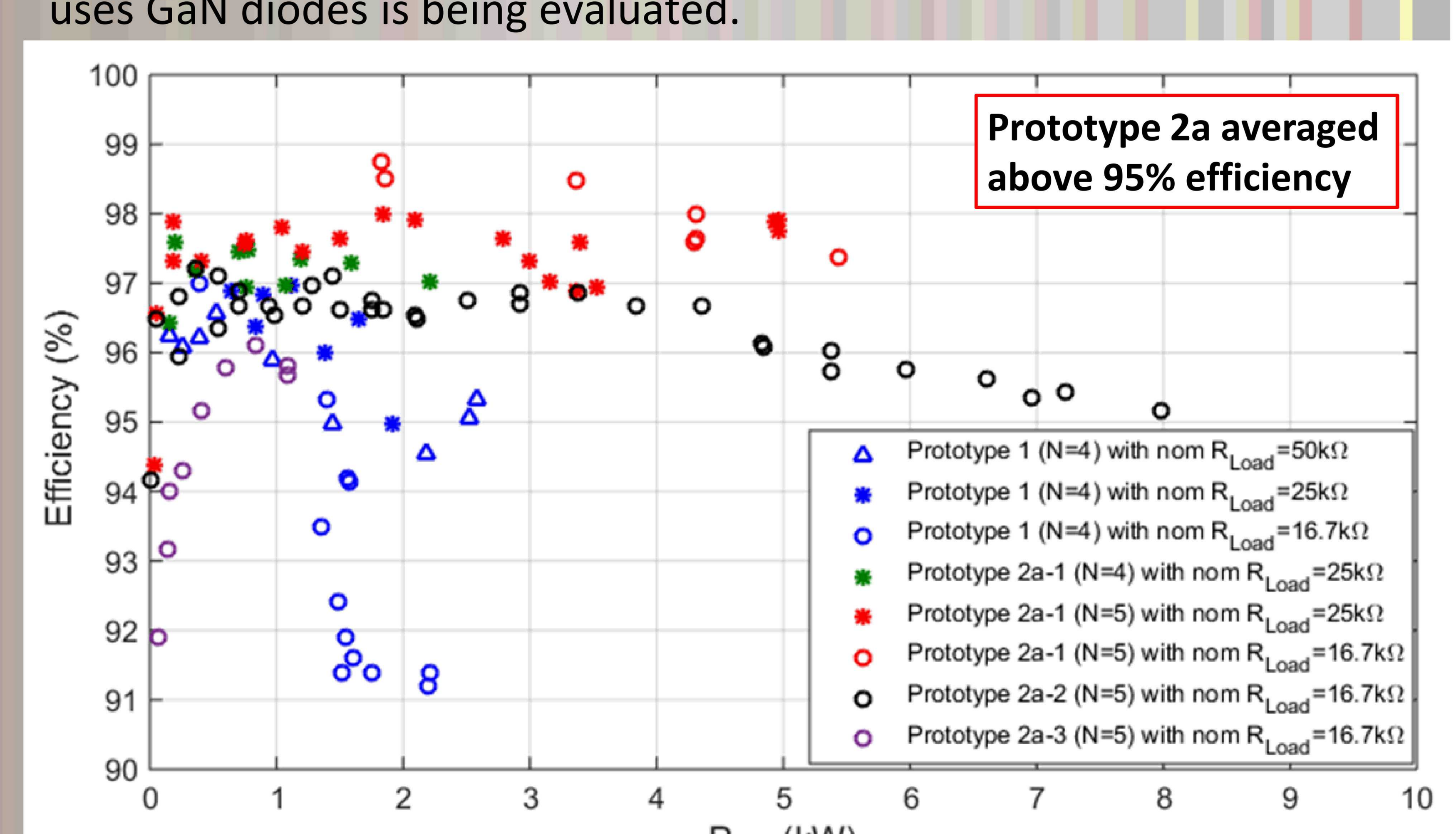


For the second prototype, the circuit parameters were revised, and a method to regulate the input power to the converter was developed while also mitigating switching loss. In this control scheme, the MOSFET switches on as the inductor current rises through the i_L=0 crossing and then switches off when a reference peak current is reached.



The bipolar HSCC prototypes were evaluated at many operating points. A peak power of 7.98 kW was achieved with V_s = 480V, a peak output voltage of V_{out} = 10.05 kV (gain of 20.9) was achieved, with 7.98 kW output power and a conversion efficiency of 95.1%. For V_{out} = 10.0 kV (gain of 20.8) at 4.96 kW output power, conversion efficiency reached 97.9%.

Converter prototypes used SiC MOSFETs and diodes. A prototype that uses GaN diodes is being evaluated.



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