Converter Topologies Using High-Voltage High-Frequency SiC Devices

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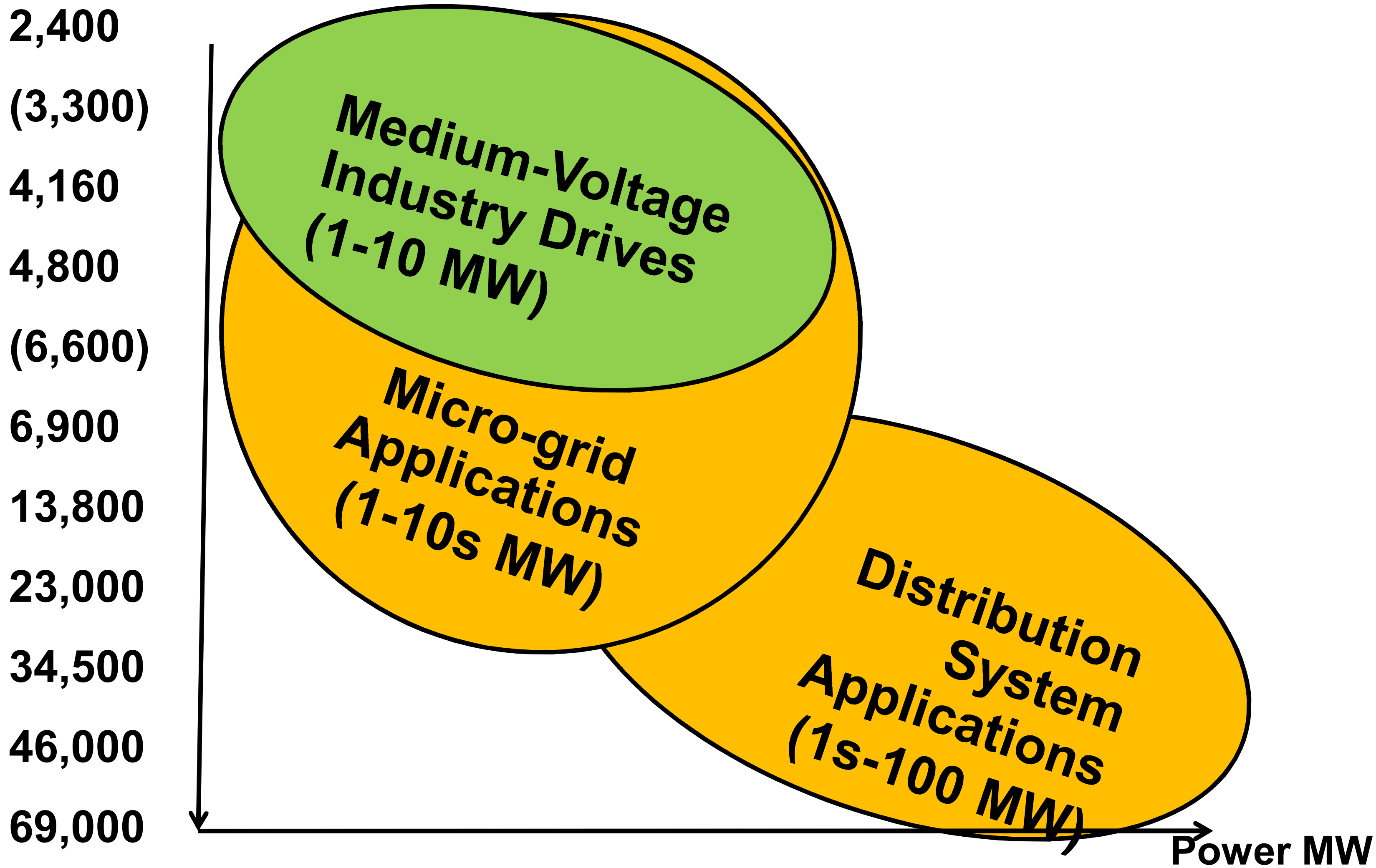
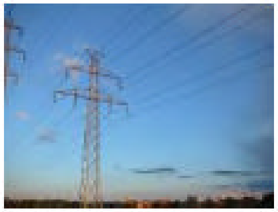
Medium-Voltage Levels and Applications

Medium-Voltage Range [V] **Major Applications**

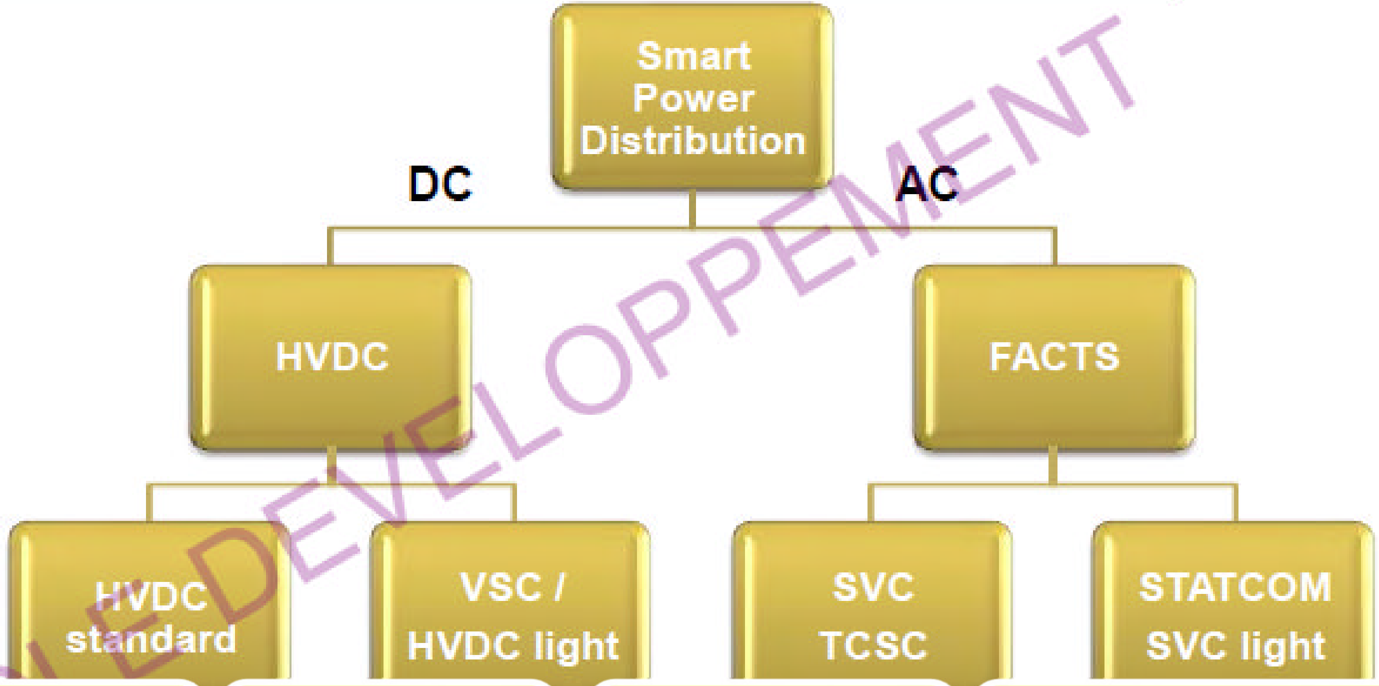


Architectures of Smart Power Distribution Sytems: HVDC & FACTS



Power systems technologies

Power



New Devices Needed in Microgrids

Phase Shifter | **Phase Balancer** | **Power Regulator** | **Impedance Compensator**

ge Direct Current

lternating Current Transmission System

urce Converters ("IGBT Light" is a brand of ABB)

SVC : Static VAR Compensator (VAR: Reactive Power)

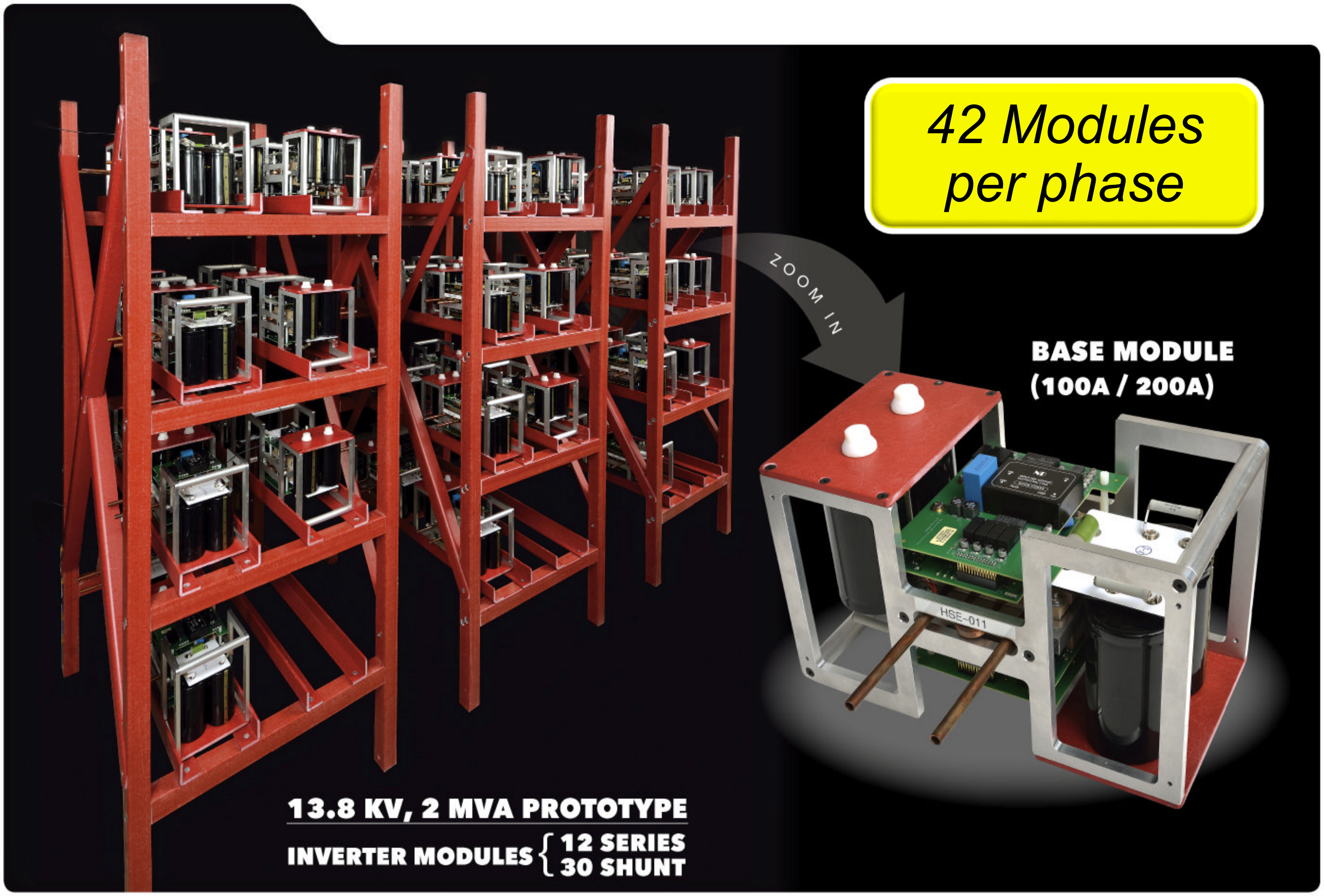
STATCOM (SVC light) : Static Synchronous Compensator

Major Converter Topologies

1. Cascade Multilevel Converters (Both Star- and Delta-CMI): STATCOM, ESS, UPFC, …
2. Modular Multilevel Converter (MMC): HVDC
3. Emerging Multilevel Converters (2-Port CMI, nX Converter, …)

Example 1: Power Flow Controller at 13.8 kV

2 MVA **DEMONSTRATION**



Example 2: HVDC at 13.8 kV

Si IGBT based VSC for HVDC and FACTS:

- **Consider the case of Trans-Bay Cable, CA for example**
- **Built on modular multi-level converter topology**

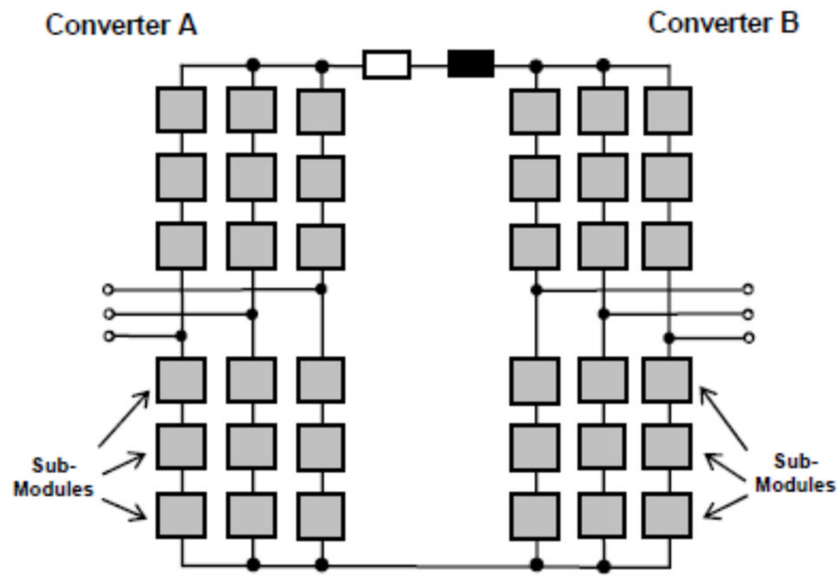
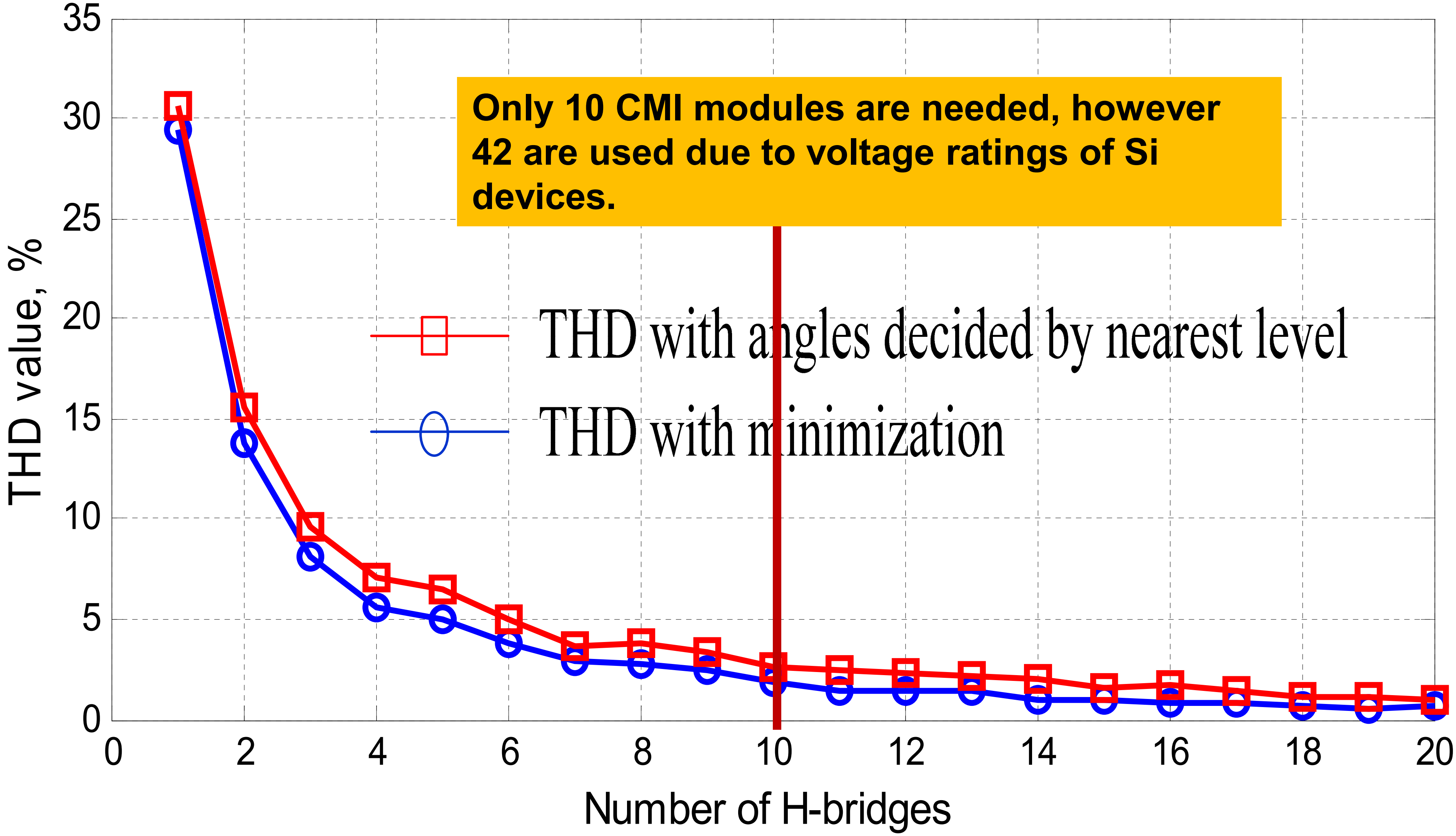


Fig. 1. Topology of a Modular Multilevel Converter based Scheme

- **Two Converters**
- **Each converter consists of 6 legs**
- **Each leg consists of ~200 modules***

*Teeuwsen, S.P., "Modeling the Trans Bay Cable Project as Voltage-Sourced Converter with Modular Multilevel Converter design," Power and Energy Society General Meeting, 2011 IEEE , vol., no., pp.1,8, 24-29 July 2011

Example 1: How many modules are required to achieve the needed performance?



Example 2: Today's Si-based HVDC MMC converter

- **Typical Service life of an overall system is 30 years*.**
- **All modules in a leg are in series.**
- **Without redundancy for 200 modules in series, each module has to be designed for an impossible lifetime of 200 X 30 = 6,000 years!**
- **Redundant modules are needed to make 30-year service time possible and to improve reliability.**
- **Large redundancy is needed to achieve 30-year lifetime.**

*Peter Kohnstam, Siemens High Voltage DC Conversion Systems- 22 April 2013, United States Department of Energy

Benefits Of SiC Power Devices

Today's Si IGBT voltage ratings*:

- **1700 V/ 3600 A to 6500 V/ 750 A**

With wide band gap devices, high current, high voltage devices are possible.

- **20-kV device are possible, which leads to reduction in the number of series modules for the same CMI or MMC rating.**
- **Low redundancy is needed to achieve 30-year lifetime, thus the number of total modules becomes significantly lower.**
- **Higher efficiency, simpler system, longer lifetime.**

*Ultra High Voltage Semiconductor Power Devices for Grid Applications –

M. T. Rahimo IEDM, December 2010, San Franscisco, USA

Benefits Of SiC Power Devices -cont

SiC power device

- Improves reliability of operation due to lesser number of redundant sub-modules.
- Reduces component costs.
- Increases efficiency of CMI and MMC converters.
- Reduces cooling requirement, potentially making natural convection air cool possible –A utility company's dream!

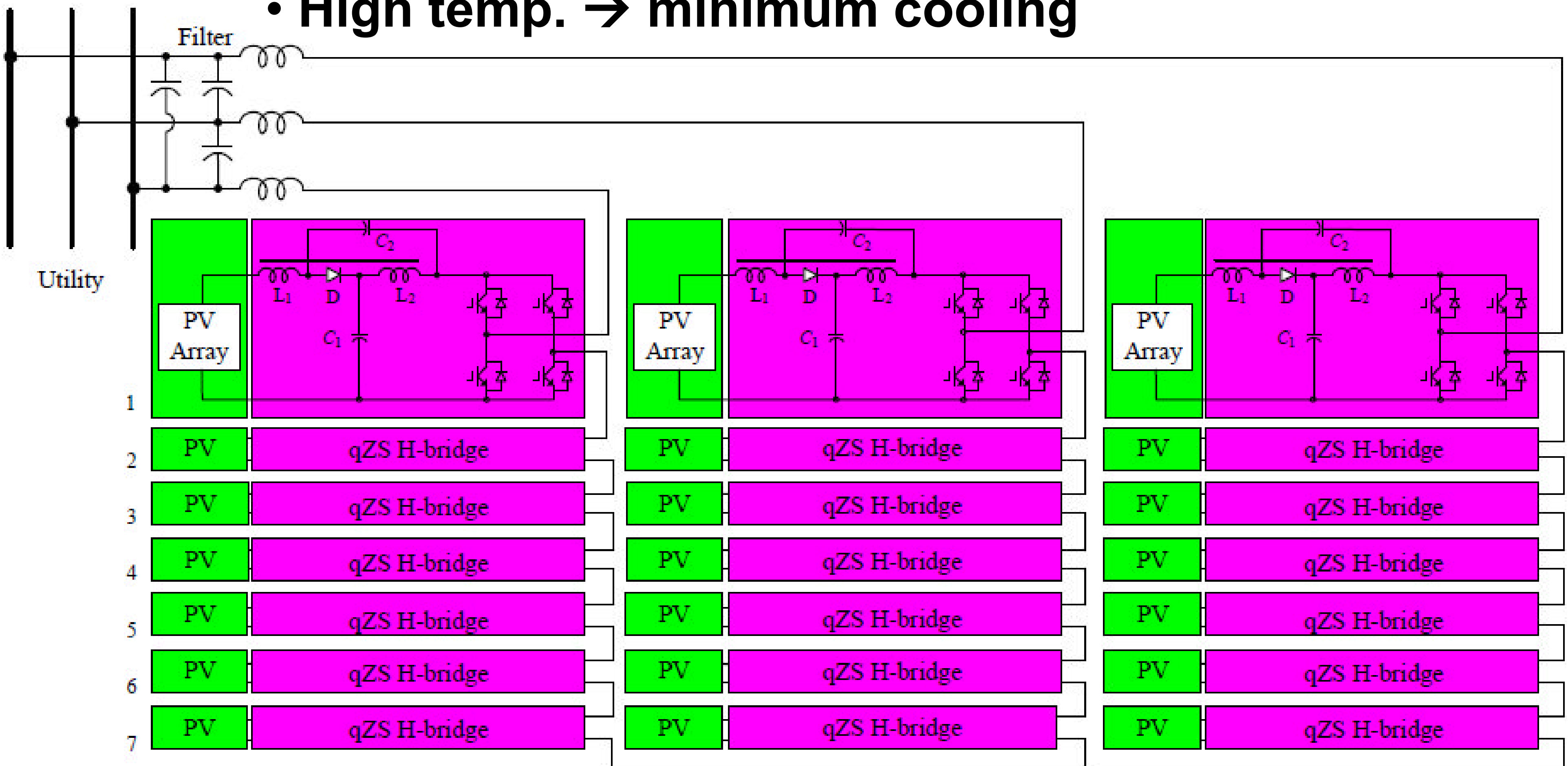
New Converter Topologies and Applications Become Feasible Because of SiC's High-Frequency Switching

- Solid-State Variable Inductor
- Solid-State Variable Capacitor
- Solid-State Variable Transformer
- DC Transformer, nX DC-DC Converter
- DC Capacitor-less Inverters
- Z-Source Converters

For Solar Power Generation

For example: MW MV solar power based on cascade multilevel and quasi-Z-Source Inverter

- **High switching frequency → small inductors**
- **High temp. → minimum cooling**



Ideal Grid Converters/Inverters

Grid Needs for Converters to be:

- **Scalable to any grid voltage levels without excessive # of modules**
- **DC capacitor-less or minimized L & C**
- **Highly efficient (>99%)**
- **Reliable and maintenance-free**
- **Natural-convection air-cooled**

SiC Attributes: