NIST/DOE Workshop on Wide-Bandgap Power Electronics for Advanced Distribution Grids

Al Hefner (NIST)

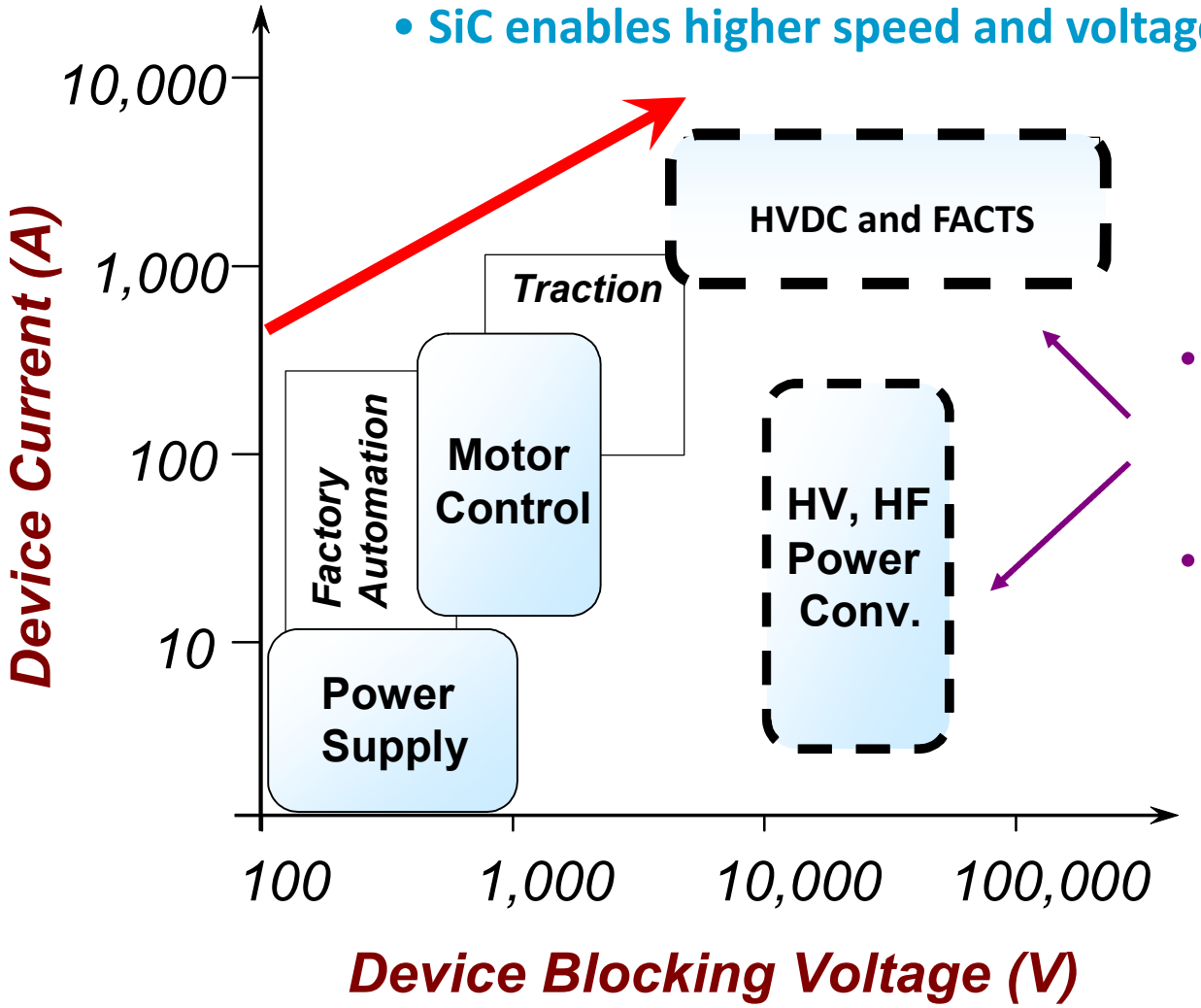
http://www.nist.gov/pml/high_megawatt/

NIST High-Megawatt PCS Workshops

- High-Megawatt Converter Workshop: January 24, 2007
- HMW PCS Industry Roadmap Workshop: April 8, 2008
- NSF Power Converters for Alternate Energy : May 15-16, 2008
- Future Large CO2 Compressors: March 30-31, 2009
- High Penetration of Electronic Generators: Dec. 11, 2009
- Plugin Vehicle Fleets as Grid Storage: June 13, 2011
- Grid Applications of Power Electronics: May 24, 2012
- High-Power Variable-Speed Motor Drives: April, 2014
- High-Power Direct-Drive Motor Systems: September, 2014
- Enabling Technology for Next Generation Electric Machines (NGEM): September, 2015

HV-HF Power Device Applications

- Switching speed decreases with voltage
- SiC enables higher speed and voltage



- Power distribution, transmission and generation
- MV and High-Power Motors

DARPA/EPRI Megawatt Program

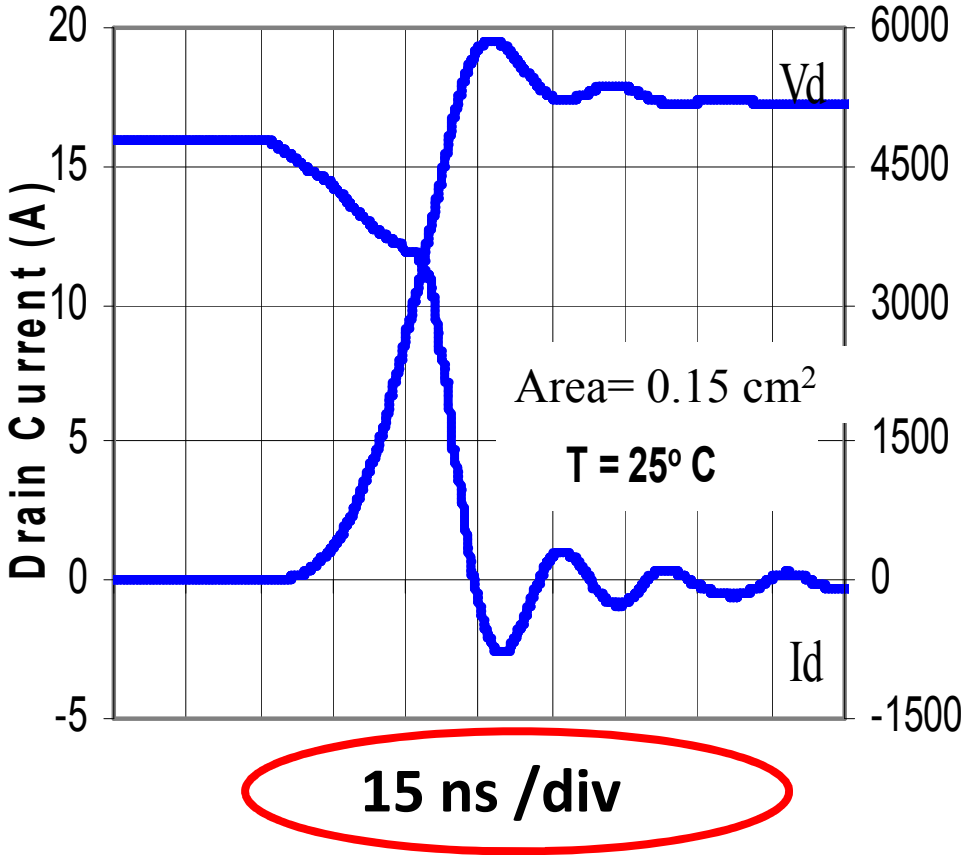
A. Hefner, et.al.; "SiC power diodes provide breakthrough performance for a wide range of applications" IEEE Transactions on Power Electronics, March 2001, Page(s):273 – 280.

DARPA/ONR/NAVSEA HPE Program

10 kV HV-HF MOSFET/JBS

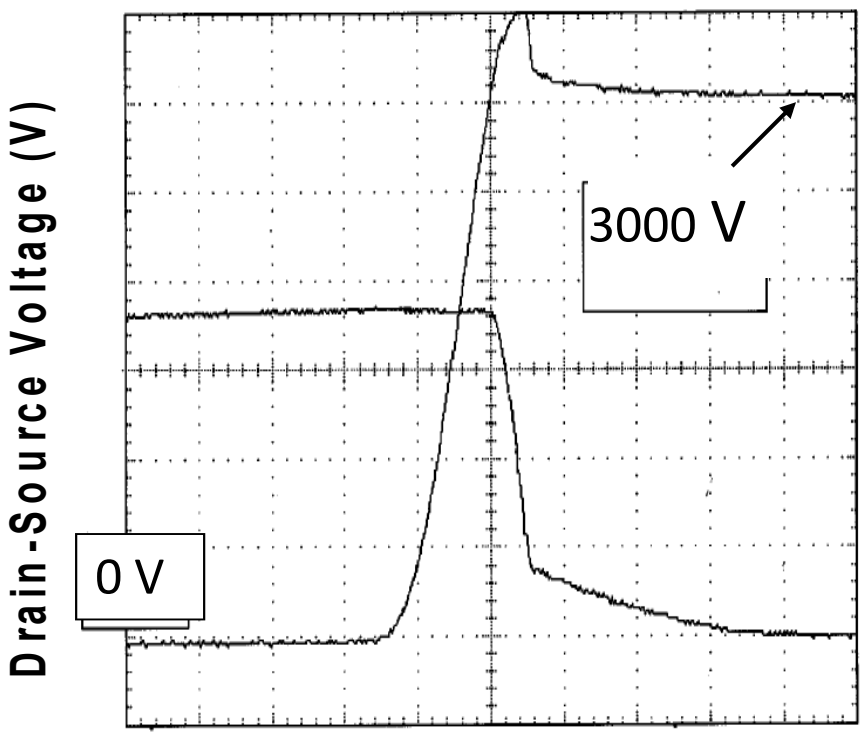
High Speed at High Voltage

SiC MOSFET: 10 kV, 30 ns



15 ns /div

Silicon IGBT: 4.5 kV, >2us



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A. Hefner, et.al. "Recent Advances in High-Voltage, High-Frequency Silicon-Carbide Power Devices," *IEEE IAS Annual Meeting,* October 2006, pp. 330-337.

Key Questions to Address During Workshop

1. What are early adoption opportunities for SiC power devices in medium-voltage distribution grid applications?

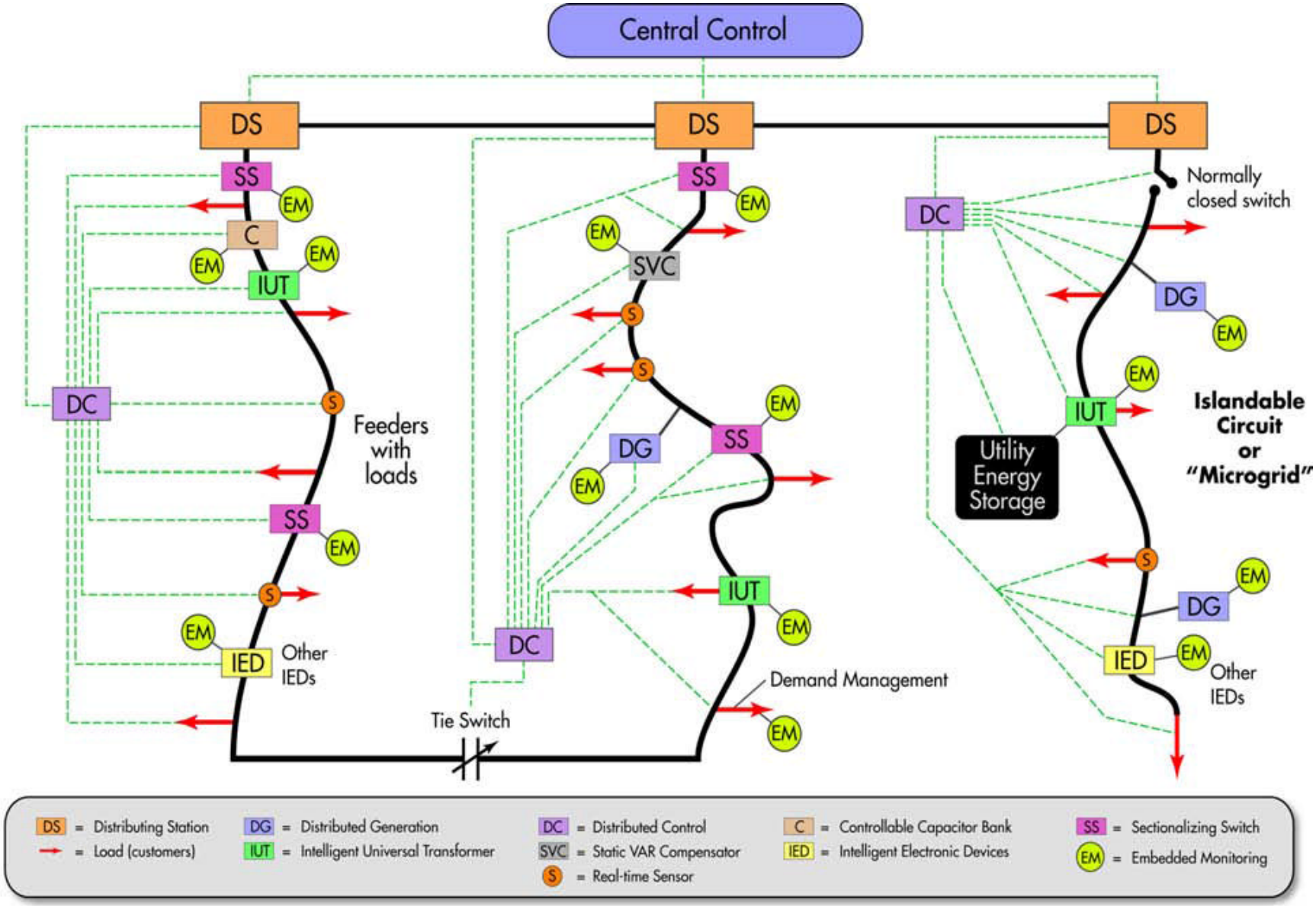
2. What transformative medium-voltage distribution grid paradigms might be enabled in the future by pervasive availability of low-cost HV-HF wide-bandgap semiconductors?

3. What near term prototype demonstrations might enable more rapid market adoption of wide-bandgap power electronics in medium-voltage distribution grid applications and more rapid advancement toward new grid paradigms?

4. What are specifications of wide-bandgap power semiconductor modules, passive components, and PCSs needed for these applications?

EPRI Advanced Distribution Automation

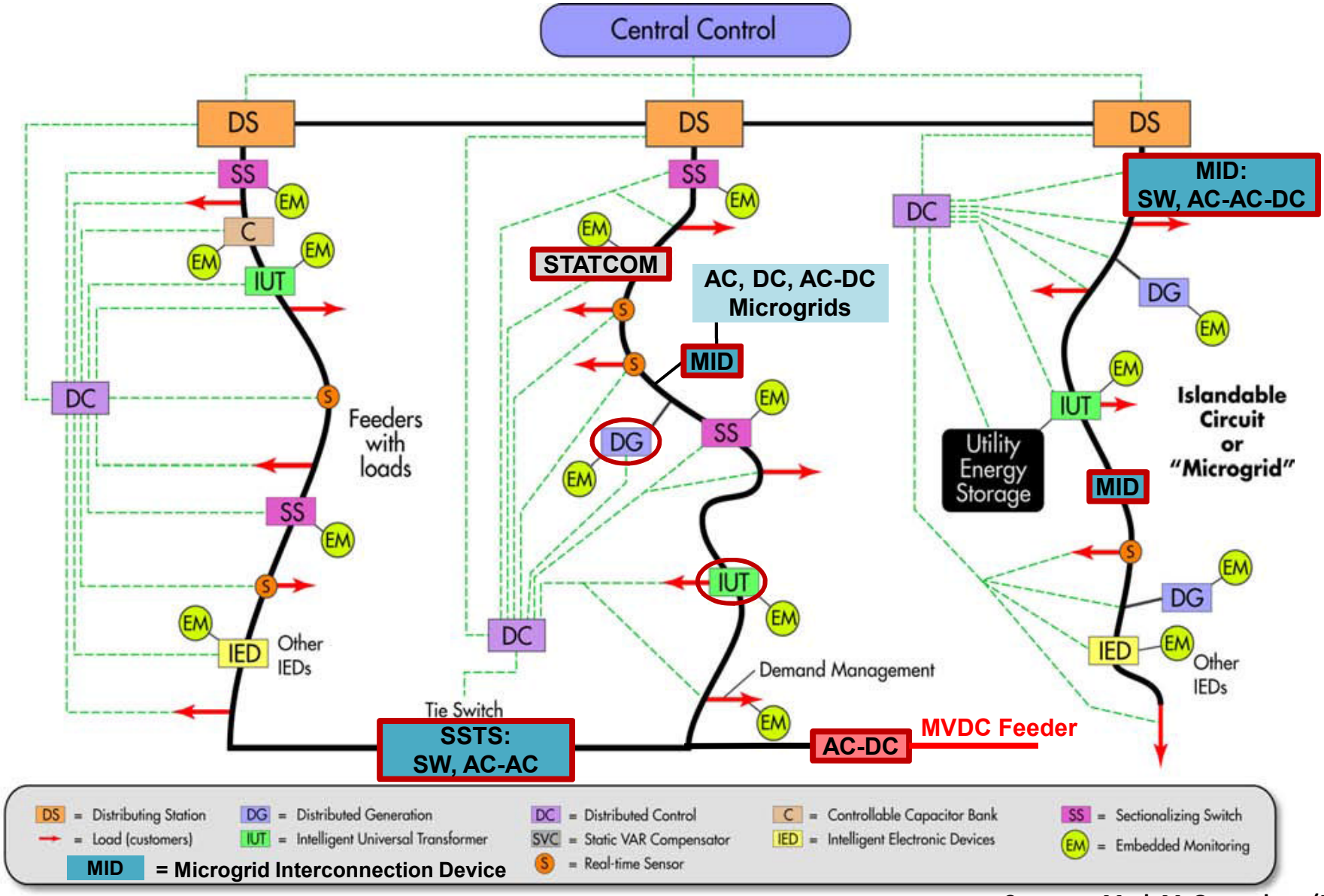
Advanced Distribution Automation – EPRI Report 1010915, June 2004



Courtesy: Mark McGranaghan (EPRI)

EPRI Advanced Distribution Automation + WBG PCS

Advanced Distribution Automation – EPRI Report 1010915, June 2004



Courtesy: Mark McGranaghan (EPRI)

Advanced Distribution Automation PCS Applications (MV benefits of WBG)

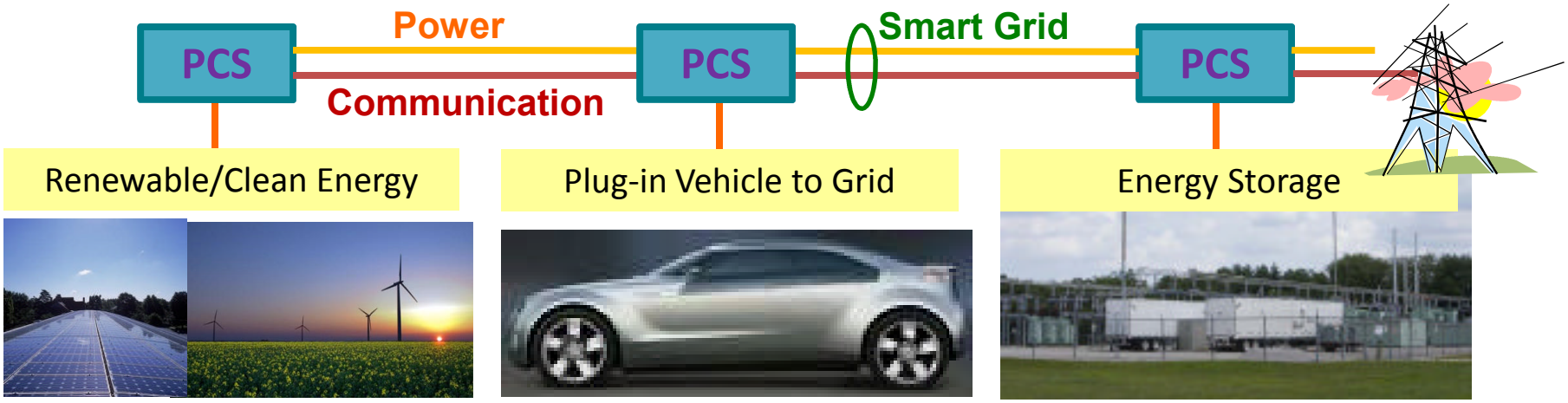
ADA Device	Power	Voltage	Benefits
STATCOM, SSCB, SSFCL		MV	Automation, grid-utilization
DER Inverters	0.01 - 10 MW	LV or MV	MV: efficiency, cost, size ^
IUT = SST	0.05 - 3 MW	LV & MV	load support, multiport ^
MID	2 - 10 MW	MV	u-grid support, transitions ^
SSTS	1 - 10 MW	MV	Flexible power flow ^
MVDC	1 - 10 MW	MV	efficiency, stability ^

"Feasibility Assessment for Intelligent Universal Transformer," EPRI Technical Report 1001698, December 2002.

"Feasibility Study for the Development of High-Voltage, Low-Current Power Semiconductor Devices" EPRI Technical Report 1009516, March 2004

"Advanced Distribution Automation," EPRI Report 1010915, June 2004

High Penetration of Distributed Energy Resources



- Power Conditioning Systems (PCS) convert to/from 60 Hz AC for interconnection of renewable energy, electric storage, and PEVs

- "Smart Grid Interconnection Standards" required for devices to be utility-controlled operational asset and enable high penetration:
  - **Dispatchable real and reactive power**
  - **Acceptable ramp-rates to mitigate renewable intermittency**
  - **Accommodate faults without cascading/common-mode events**
  - **Voltage regulation and utility-coordinated islanding**

http://www.nist.gov/pml/high_megawatt/2008_workshop.cfm

PAP 7: Smart Grid ES-DER Standards

Task 0: Scoping Document

Prioritized timeline for ES-DER standards

Task 1: Use Cases, *EPRI Smart Inverter

Define requirements for different scenarios

Task 2: IEEE 1547.4 for island applications and IEEE 1547.6 for secondary networks

Task 3: Unified interconnection method with multifunctional operational interface for range of storage and generation/storage.

IEEE 1547.8

(a) Operational interface
(b) Storage without gen
(c) PV with storage
(d) Wind with storage
(e) PEV as storage

Info exchanges

MIC

PAPs

Task 4: DER Object Models and Mappings

IEC 61850-7-420, -90-7: Expanded to include

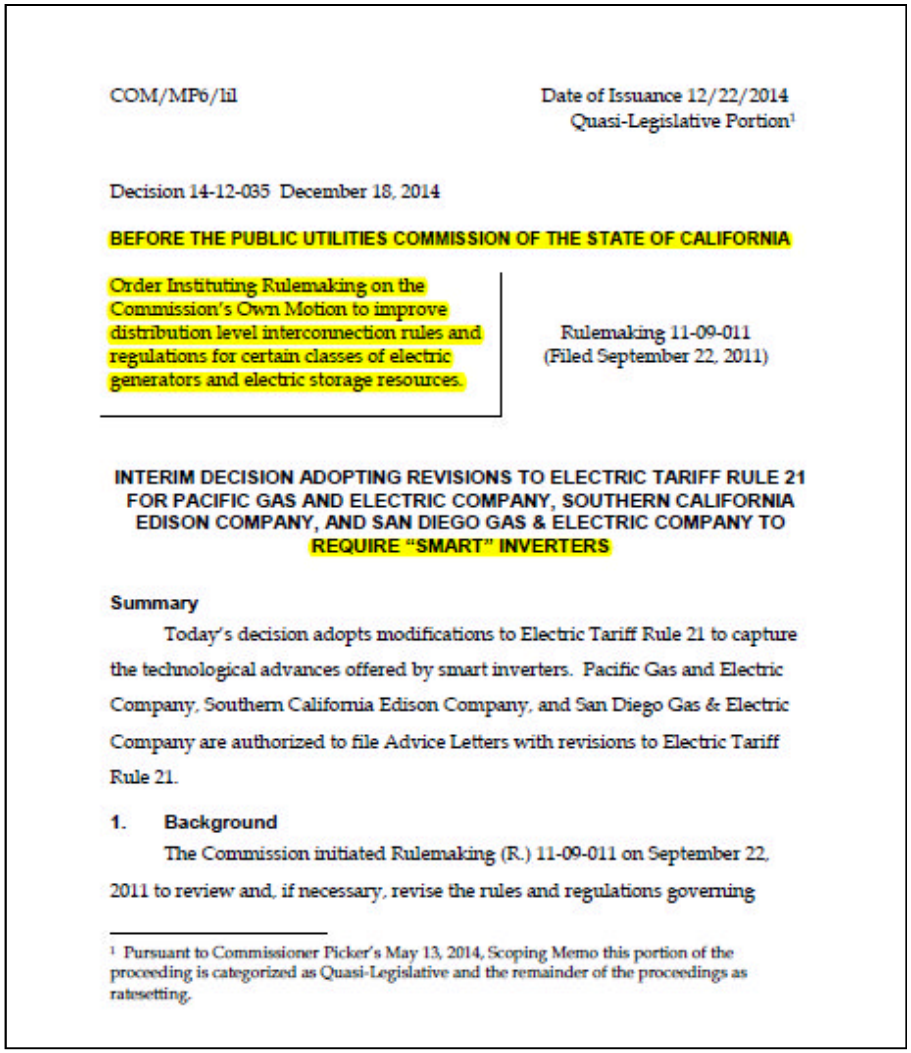
- Multifunctional ES-DER operational interface
- Harmonized with CIM & MultiSpeak
- Map to MMS, DNP3, web services, & SEP 2

Task 5: Test, Safe and Reliable Implementation

UL 1741, NEC-NFPA70, SAE, CSA and IEC

http://www.sgip.org/About-PAPs

CPUC Rule 21: Rules and Regulations for Interconnecting DER to Distribution Systems



COM/MP6/lil

Date of Issuance 12/22/2014
Quasi-Legislative Portion[1]

Decision 14-12-035 December 18, 2014

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking on the Commission's Own Motion to improve distribution level interconnection rules and regulations for certain classes of electric generators and electric storage resources.

Rulemaking 11-09-011
(Filed September 22, 2011)

INTERIM DECISION ADOPTING REVISIONS TO ELECTRIC TARIFF RULE 21 FOR PACIFIC GAS AND ELECTRIC COMPANY, SOUTHERN CALIFORNIA EDISON COMPANY, AND SAN DIEGO GAS & ELECTRIC COMPANY TO REQUIRE "SMART" INVERTERS

Summary

Today's decision adopts modifications to Electric Tariff Rule 21 to capture the technological advances offered by smart inverters. Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company are authorized to file Advice Letters with revisions to Electric Tariff Rule 21.

1. Background

The Commission initiated Rulemaking (R.) 11-09-011 on September 22, 2011 to review and, if necessary, revise the rules and regulations governing

[1] Pursuant to Commissioner Picker's May 13, 2014, Scoping Memo this portion of the proceeding is categorized as Quasi-Legislative and the remainder of the proceedings as ratesetting.

CPUC Rule 21 - Based on IEEE 1547 Std

Phase 1: Rule 21 Amendment (Dec. '14) Requires Smart Inverter Functions from SIWG after UL 1741 update is complete:

a. Revised Anti-Islanding Protection - consistent with support functions
b. Low/High Voltage Ride Through
c. Low /High Frequency Ride Through
d. Dynamic Volt-Var Operation
e. Ramp Rate requirements
f. Fixed Power Factor function
g. Soft Start Reconnection

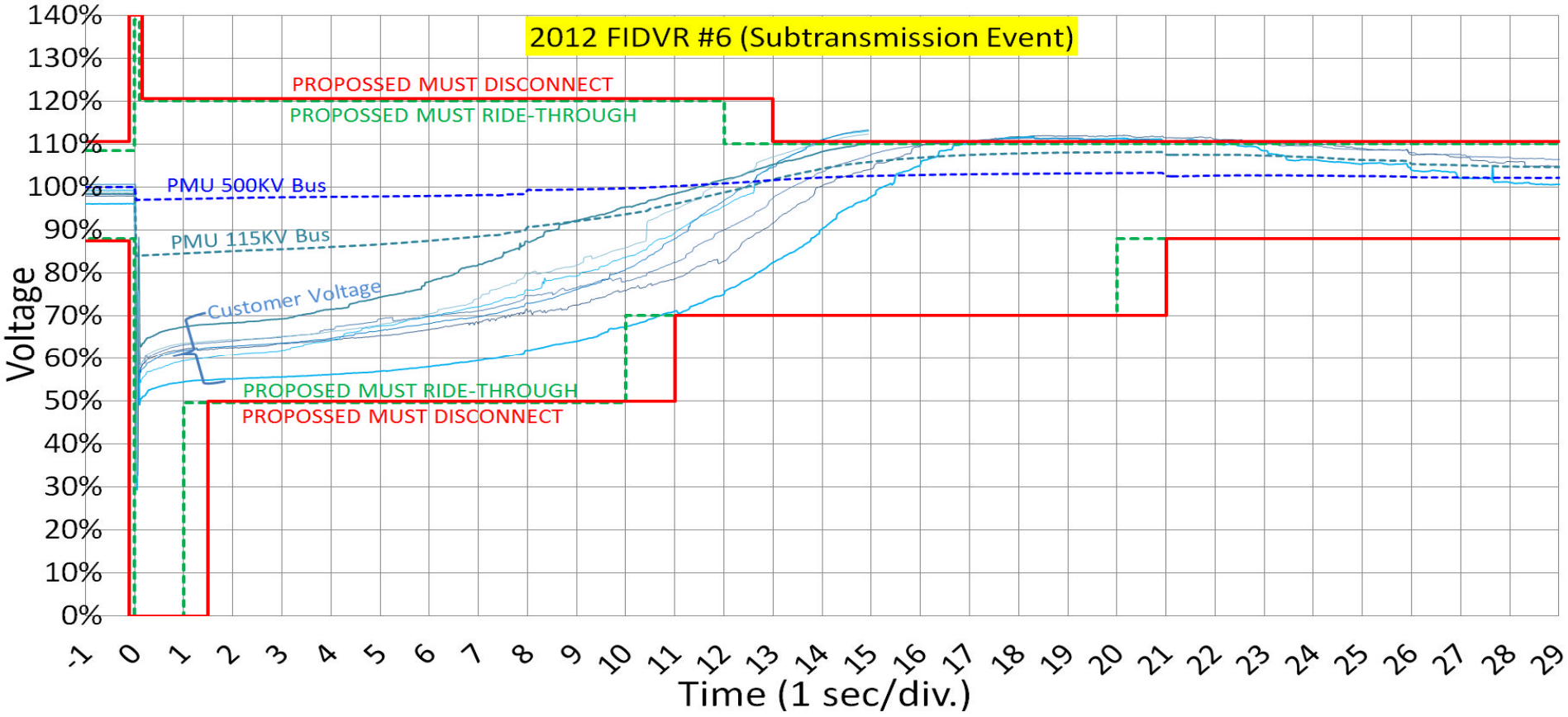
Phase 2&3: Communication requirements and communication-based functions.

http://www.cpuc.ca.gov/PUC/energy/rule21.htm/

http://www.energy.ca.gov/electricity_analysis/rule21/

CPUC Rule 21: Voltage Ride Through (VRT)

- VRT adopted parameters are based on actual field event data captured in Southern California with instrumentation provided by LBNL (DOE).



courtesy: Richard Bravo (SCE)

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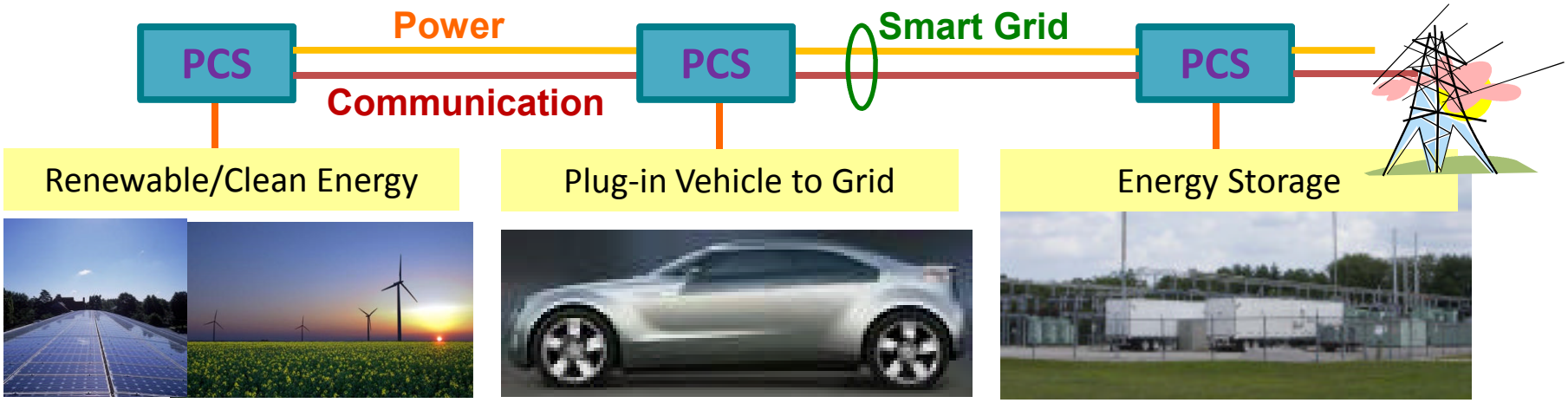

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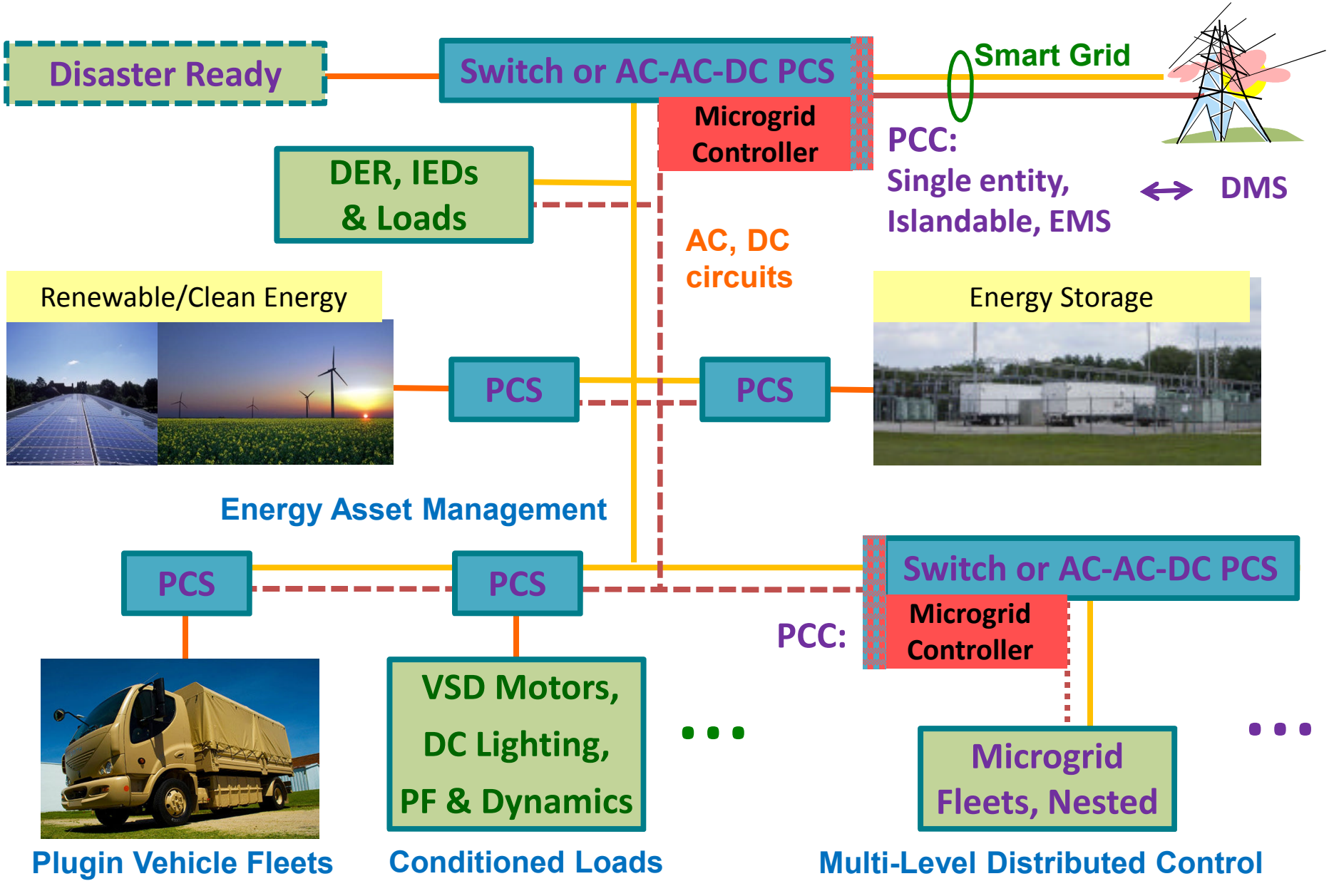
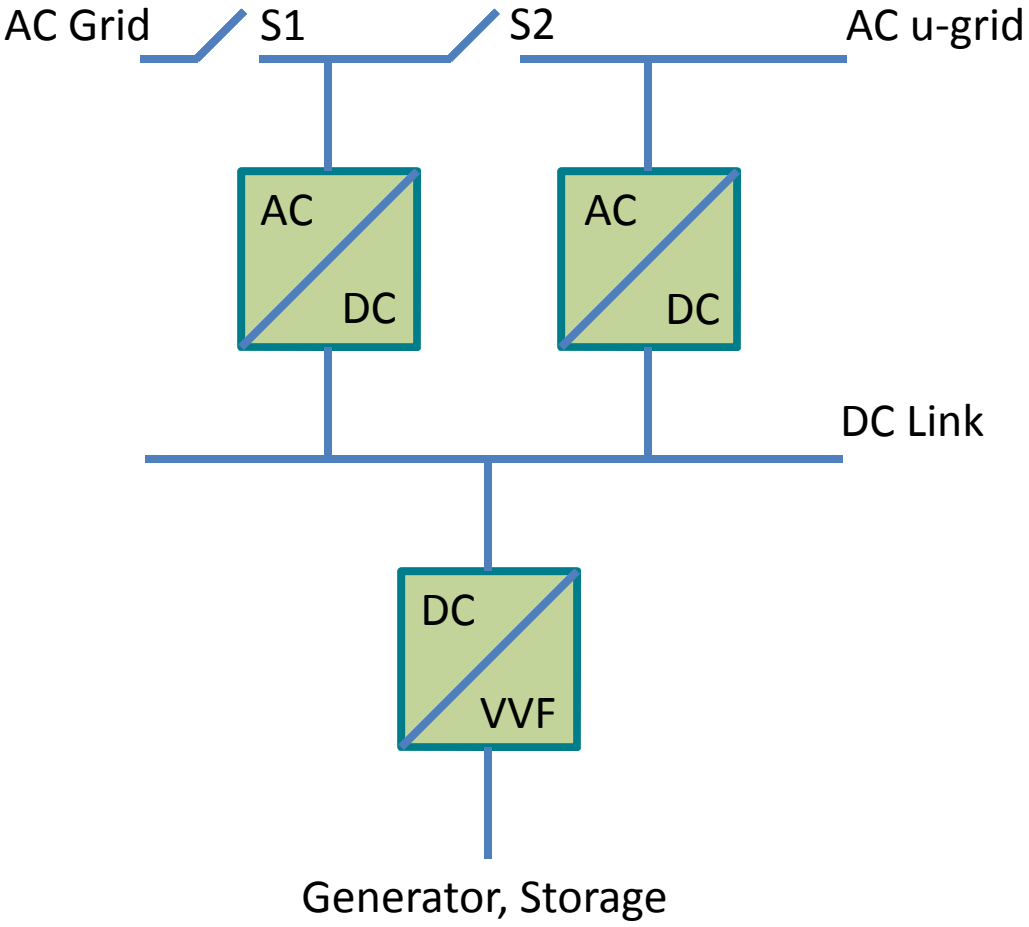
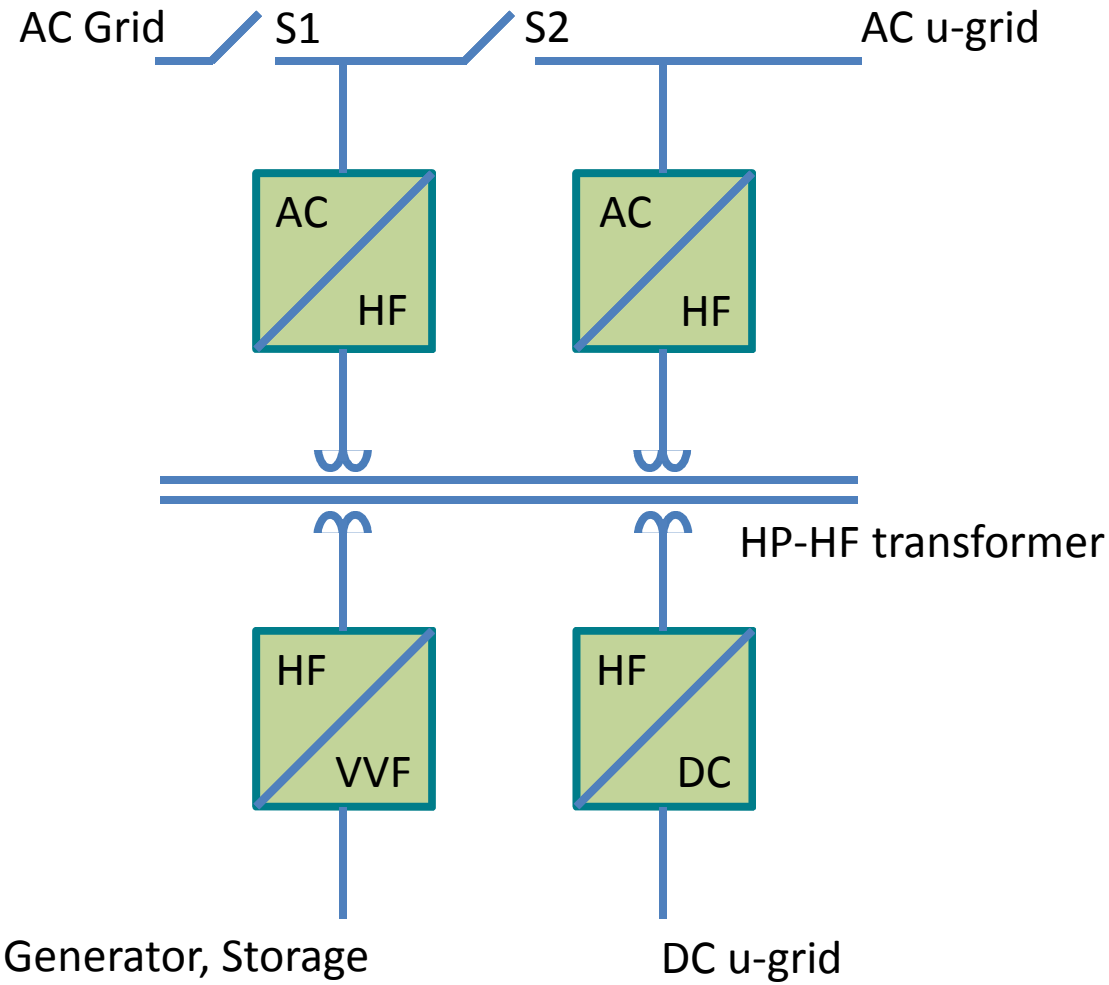
Microgrids Enable Pervasive DER and Resiliency



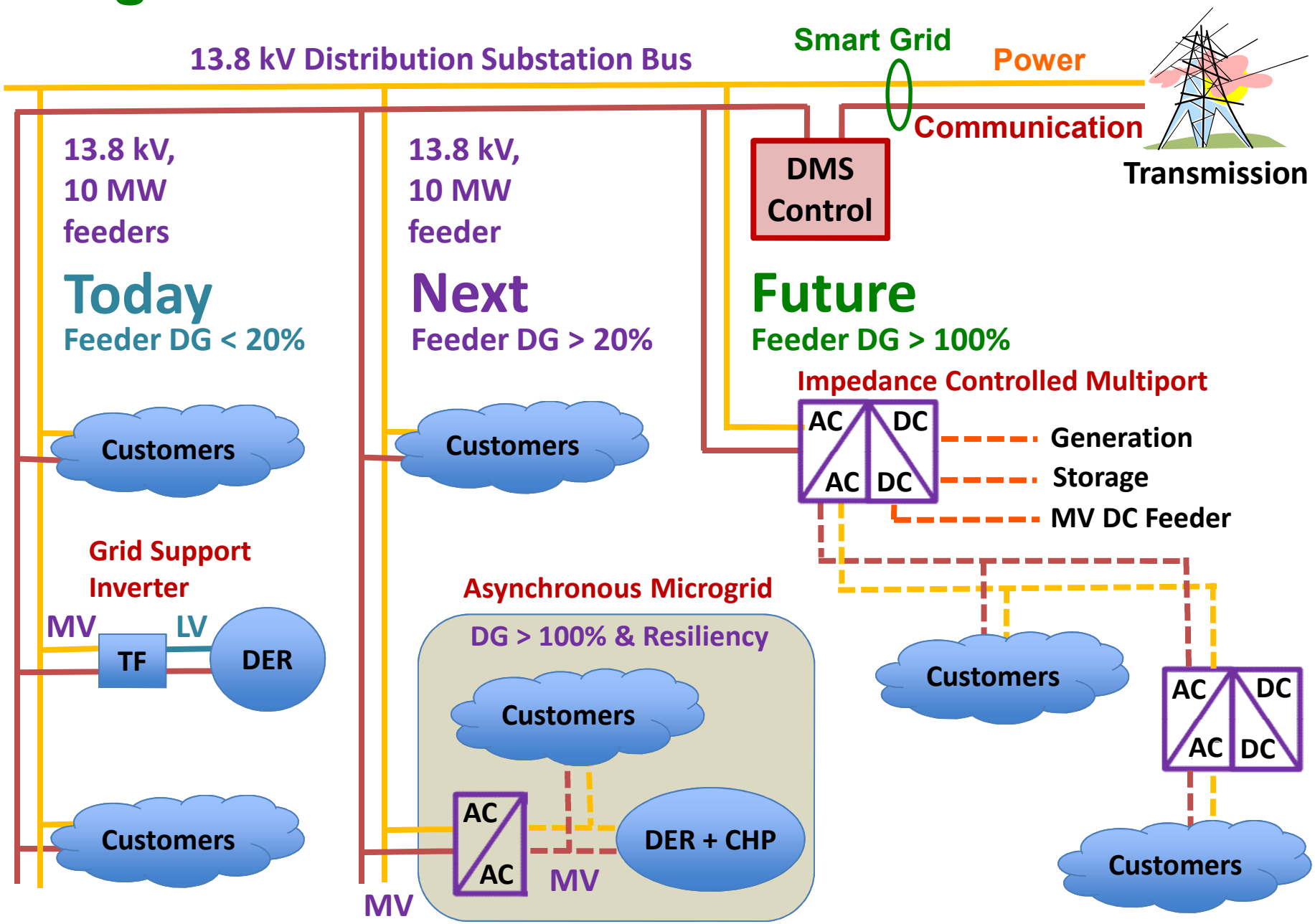
Hybrid Contactor / HV-HF B2B Inverter



Hybrid Contactor / HV-HF Inverter with HP-HF Transformer



High Penetration Distributed Generation



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