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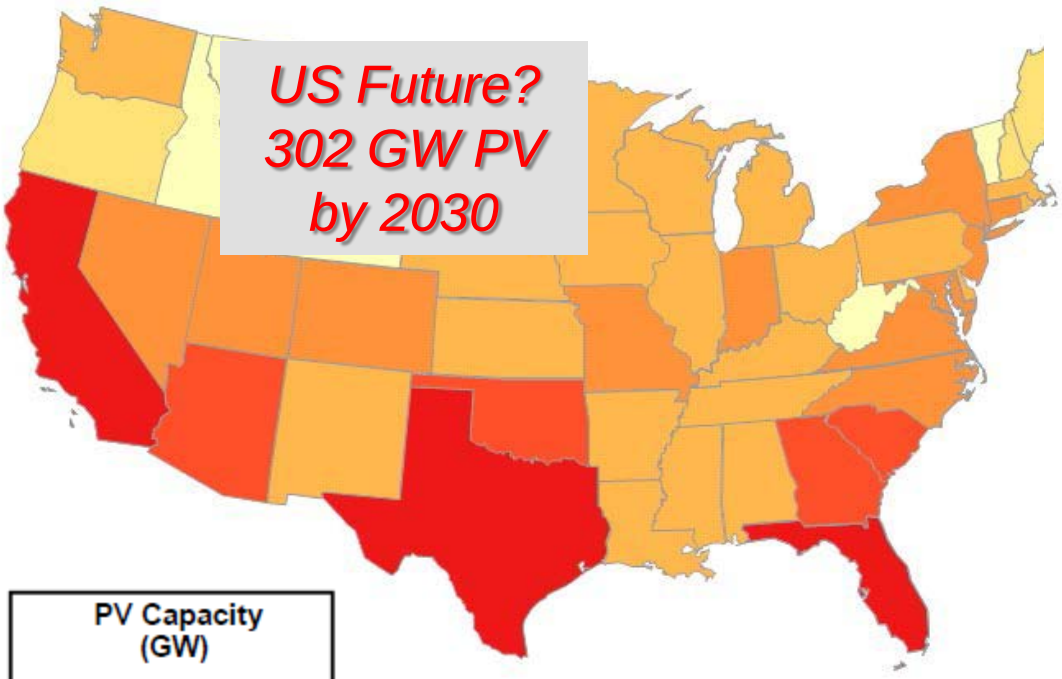
Smart Inverters

Smart Grid Information Sharing Webcast

Brian K. Seal

July 11th, 2013

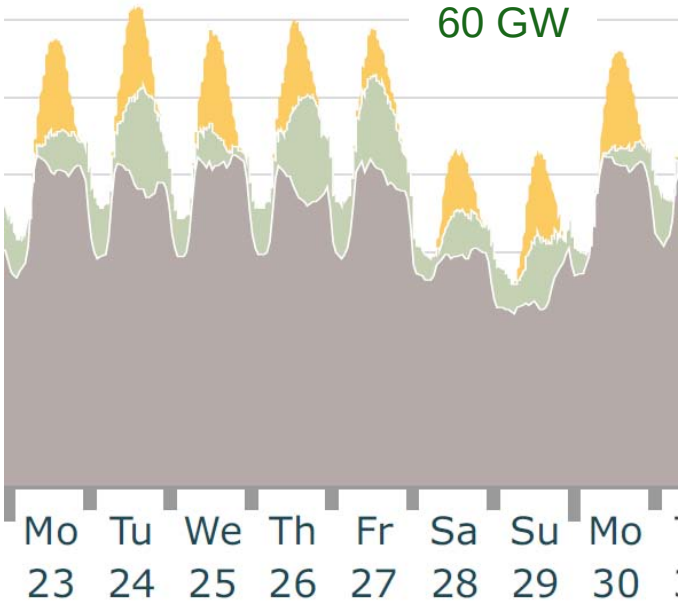
Inverter-Connected Solar is Coming



PV Capacity (GW)
< 0.5
0.5 - 1
1 - 5
5 - 10
10 - 30
30 - 50
> 50

DOE "SunShot" Vision Study, Released February 2012

Germany - Demand Late in May 2011



Is the grid ready for PV?

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Integration of Distributed Renewables Summary

- *Most near-term deployments of renewable generation affect the existing grid (~80% on distribution).*
- *EPRI Aims to:*
  - ➢*prepare members for these deployments,*
  - ➢*assist in determining hosting capacity without compromising safety, quality or reliability of the distribution system.*

Source: EPIA Global Market Outlook 2013

ROW: Rest of the World. MEA: Middle East and Africa. APAC: Asia Pacific.

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Inverter – Role in PV Plants

PV inverter converts DC energy from solar modules in to AC energy and interface the PV system with electricity grid

Inverter Functionality Today

- Harvesting maximum power from PV array
- Matching plant output with grid voltage and frequency
- Providing safety by providing unintentional islanding protection

What it Can Do Tomorrow ?

- Improving grid and PV system reliability
- Reduce PV Balance of Plant Cost

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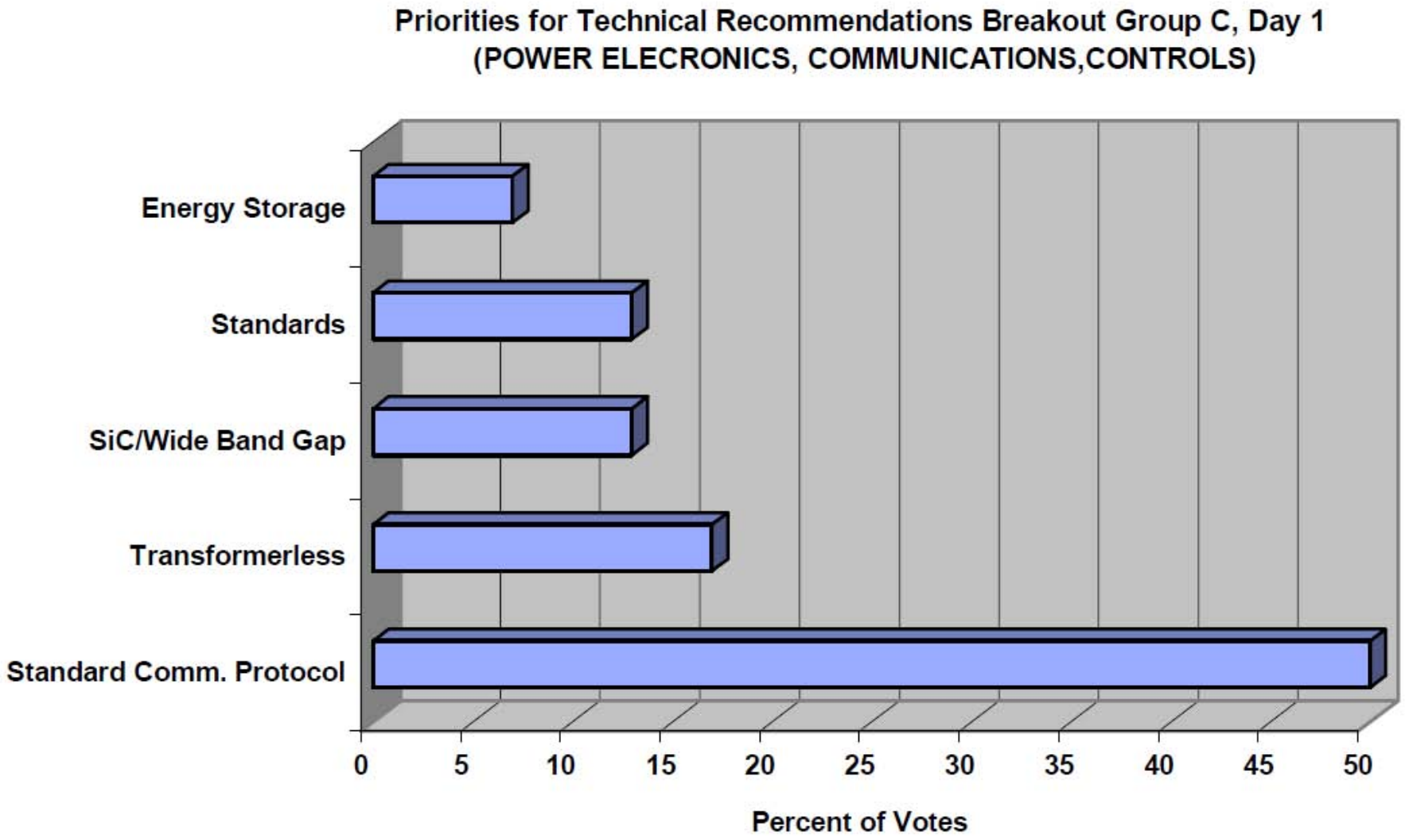
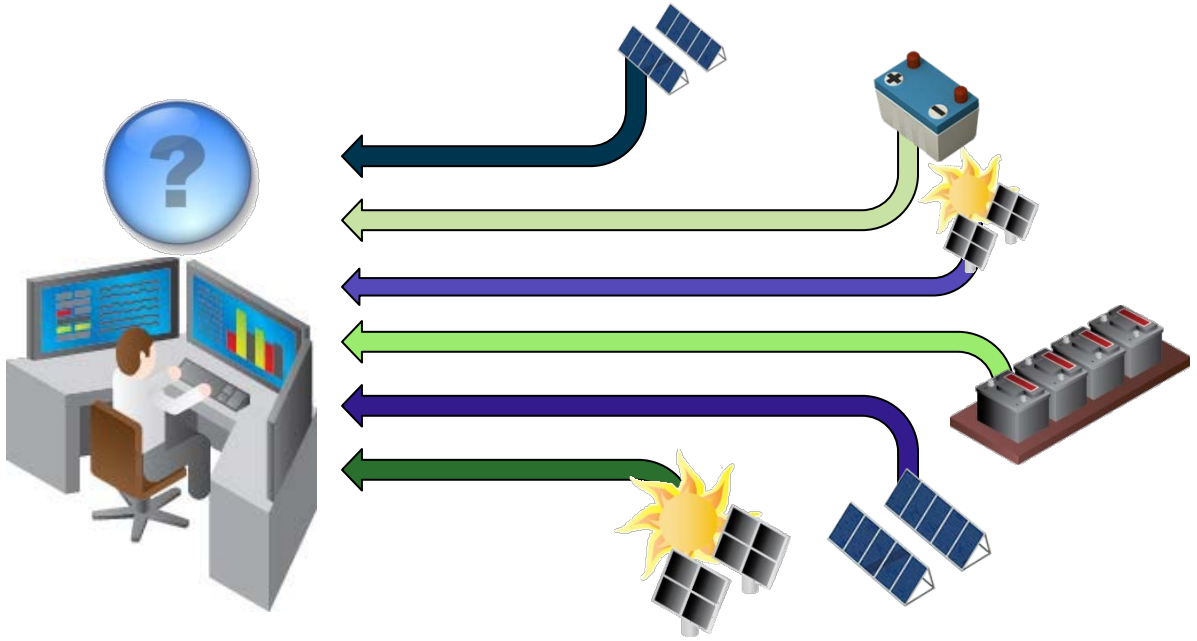
2004 DOE High-Tech Inverter Workshop



Grid Integration Requirement:
Uniform DER Services and Coordination

- All inverters have “grid supportive” capabilities
- All inverters have communication capability
- But all in different ways

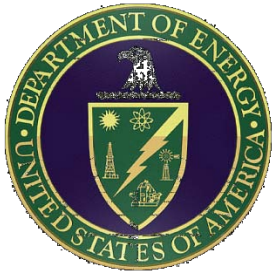


Collaborative Industry Project Formed in 2009

To identify a standards-based means for the fielding of inverters with a common set of advanced functions

More than 550 individuals engaged, representing:

- 50+ PV & Storage equipment providers
- 60+ utilities
- 12 National labs and research organizations



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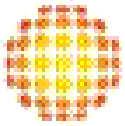
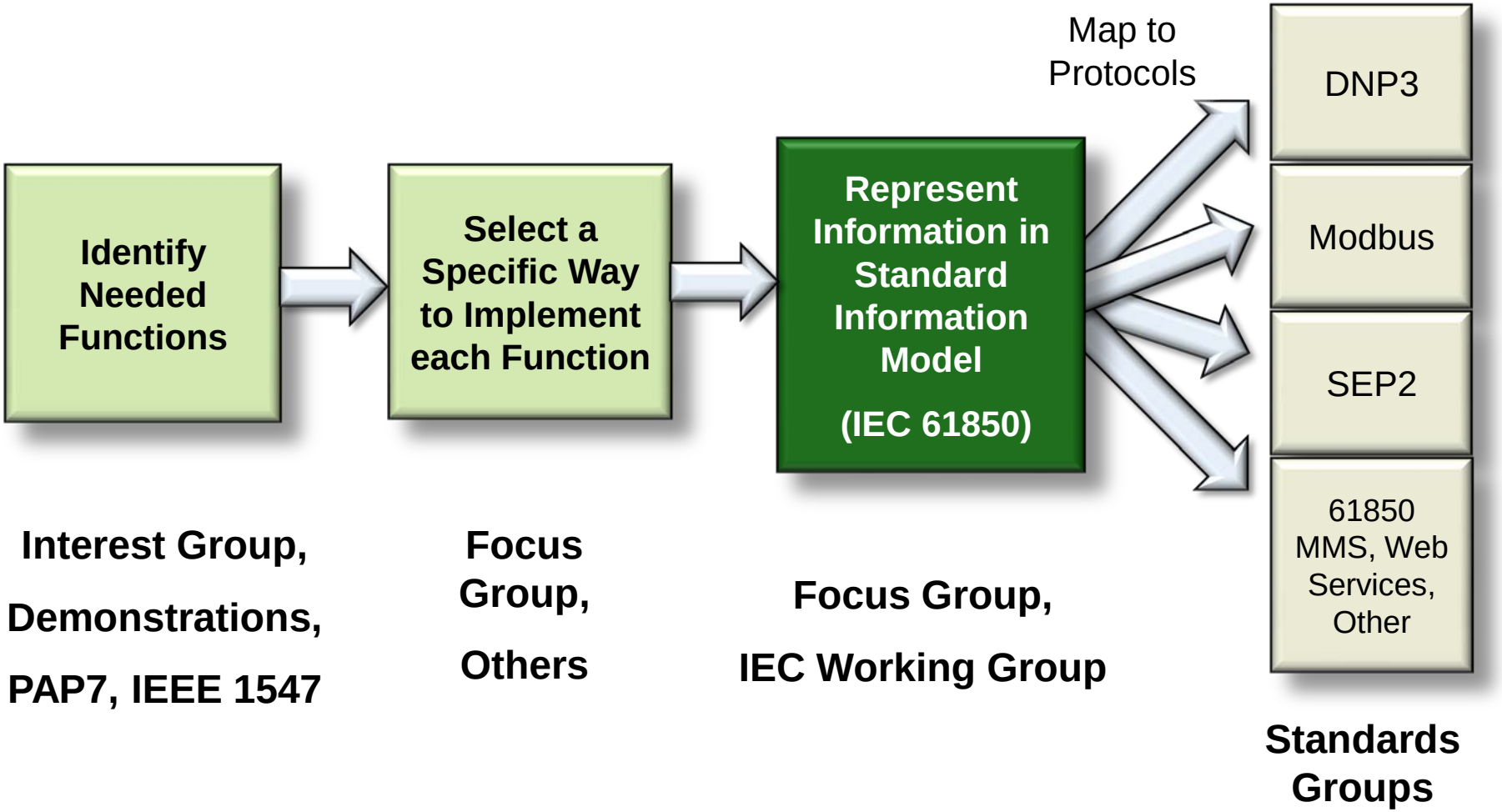


SEPA
solar electric power association

Sandia National Laboratories

Smart Inverter Initiative Activity Flow



Standardized Functions, IEC Object Models

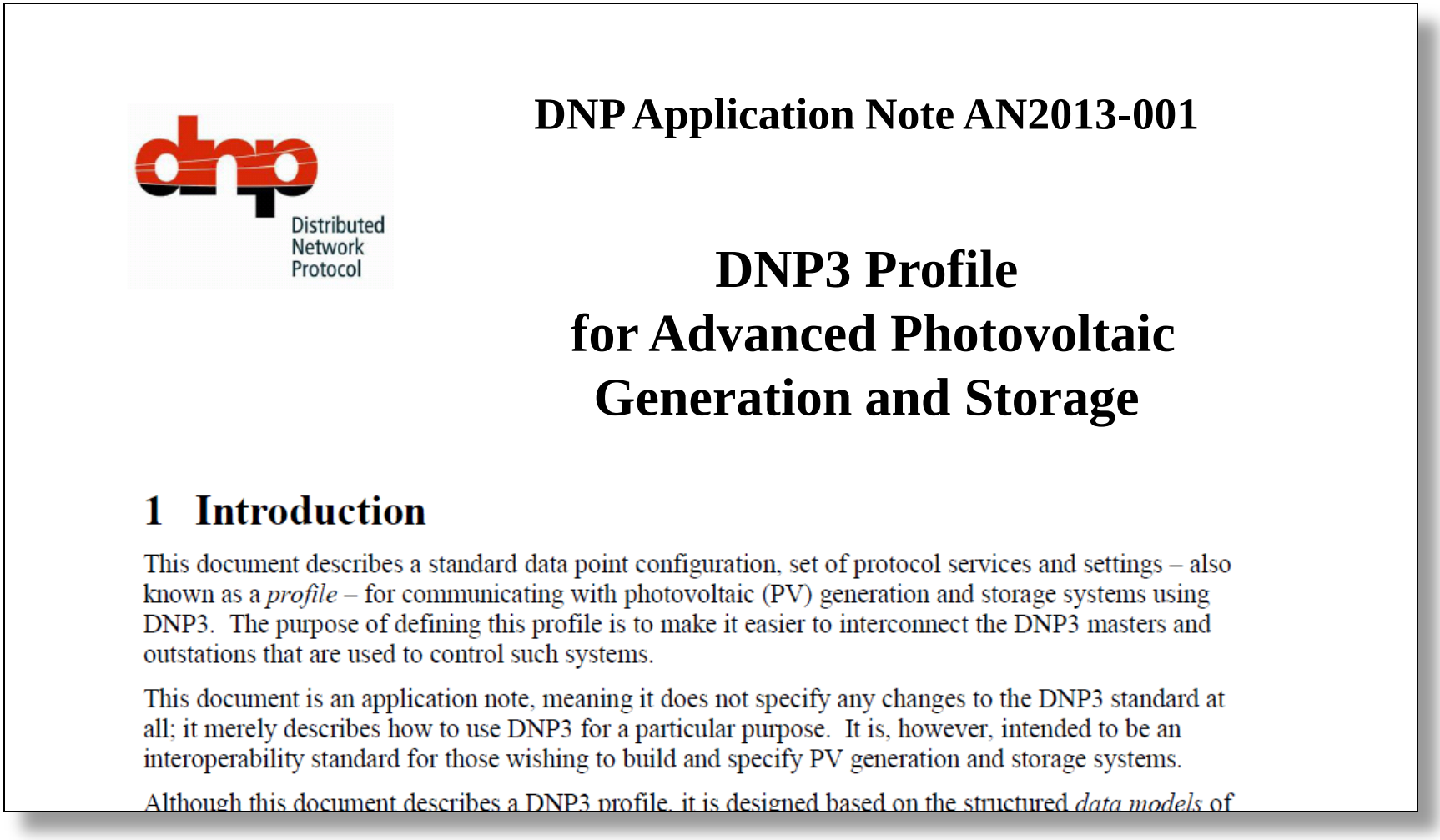
IEC 61850-90-7

IEC 61850 Object Models for Photovoltaic, Storage, and Other DER inverters

May be Mapped into Any Protocol

Standard Communication Protocol

DNP3 Mapping Example



dnp Distributed Network Protocol

DNP Application Note AN2013-001

DNP3 Profile for Advanced Photovoltaic Generation and Storage

1 Introduction

This document describes a standard data point configuration, set of protocol services and settings – also known as a *profile* – for communicating with photovoltaic (PV) generation and storage systems using DNP3. The purpose of defining this profile is to make it easier to interconnect the DNP3 masters and outstations that are used to control such systems.

This document is an application note, meaning it does not specify any changes to the DNP3 standard at all; it merely describes how to use DNP3 for a particular purpose. It is, however, intended to be an interoperability standard for those wishing to build and specify PV generation and storage systems.

Although this document describes a DNP3 profile, it is designed based on the structured *data models* of

Standard Communication Protocol

DNP3 Mapping Example

Table 12 – Analog Output Point List

Point Index	Name	Supported Control Operations			Transmitted Value		Scaling		Units	Reso-lution	Default Event Class		IEC 61850			
		Select/Operate	Direct Operate	Direct Operate – No Ack	Minimum	Maximum	Multi-plier	Off-set			Chg	Cmd	LN Class	LN Inst	Data Object	CDC
0	Time window for Connect/Disconnect	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	1	WinTms	ING
1	Timeout period for Connect/Disconnect	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	1	RevtTms	ING
2	Time window for limited Watts mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	2	WinTms	ING
3	Timeout period for limited Watts mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	2	RevtTms	ING
4	Ramp time for limited Watts mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	2	RmpTms	ING
5	Time window for fixed power factor mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	3	WinTms	ING
6	Timeout period for fixed power factor mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	3	RevtTms	ING
7	Ramp time for fixed power factor mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	3	RmpTms	ING
8	Time window for charge or discharge rate mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	4a	WinTms	ING
9	Timeout period for charge or discharge rate mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	4a	RevtTms	ING
10	Ramp time for charge or discharge rate mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	4a	RmpTms	ING
11	Time window for price mode	X	X	X	0	2147483647	1	0	Seconds	1	2	2	DOPM	4b	WinTms	ING

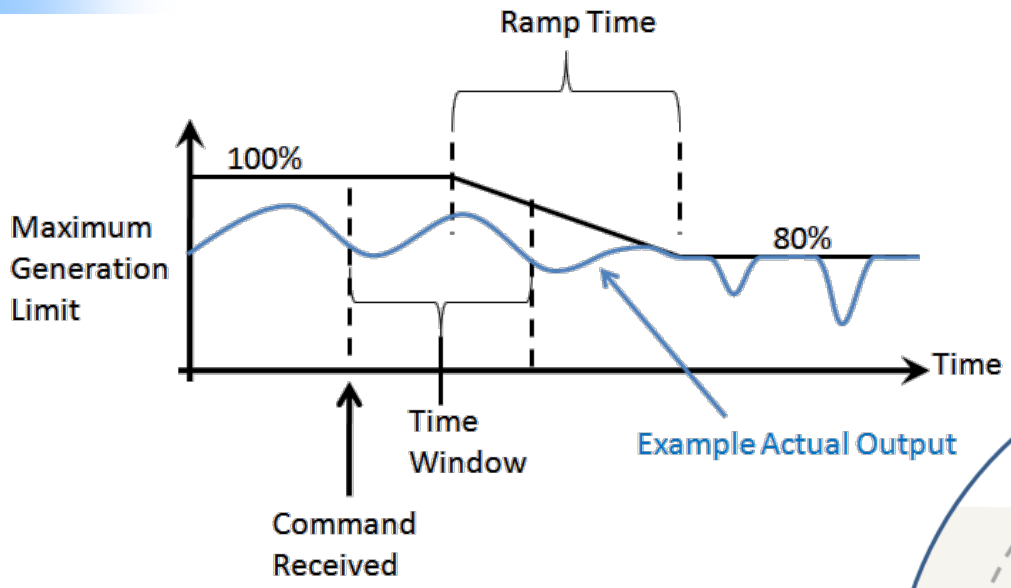
Standard Protocol Mappings Can Provide…

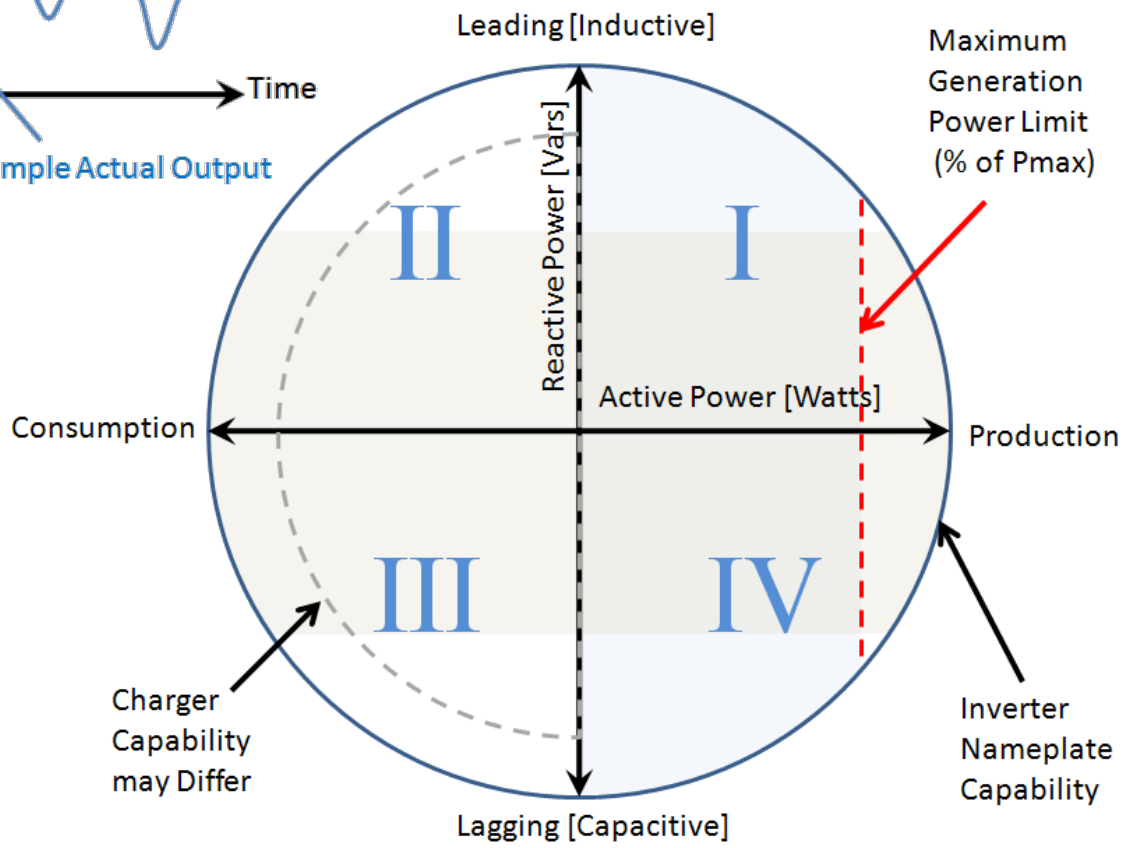
- An inverter provider could design to these standards and be compatible with multiple types of monitoring and management software/systems.
- A DER management software provider could design to these standards and be compatible with multiple types of resources and inverters.
- An interoperability testing or compliance certification facility could evaluate products of all kinds with one another and against the specification.

Flexible Architectures for Grid Support

Example Integration Architectures	Technique for Providing Grid Support: Fixed, Out of the Box	Locally Configured	Monitoring	Loosely Coupled, Autonomous Commands (local V & F)	Tightly Coupled, Immediate Commands
No Communication	✓				
Onsite Communication Only		✓			
One Way to Utility			✓		
One Way to DER				✓	
Two-Way Low Bandwidth			✓	✓	
Two-Way High Bandwidth			✓	✓	✓

Simple Max Generation Level Control





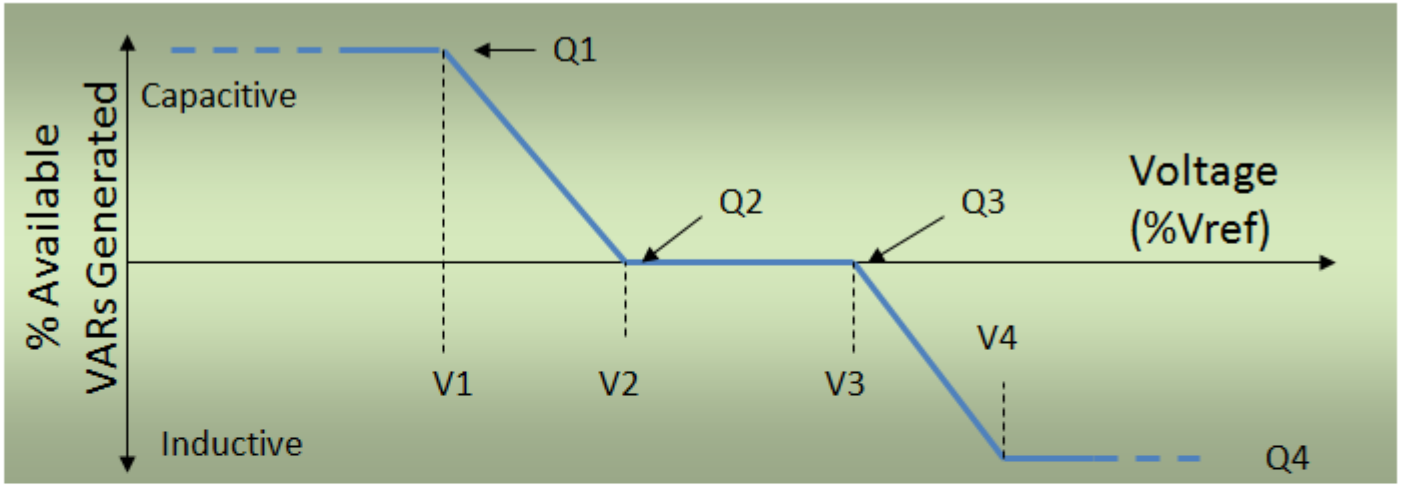
Volt-Var Function

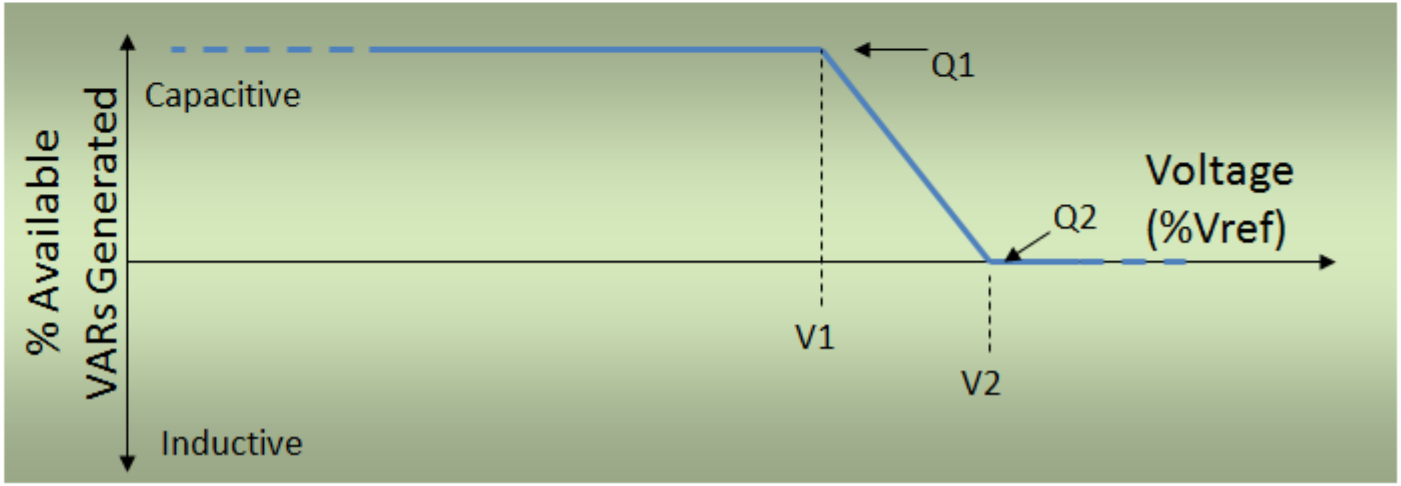
Volt/Var Mode 1 – Normal Regulation

Simple Broadcast

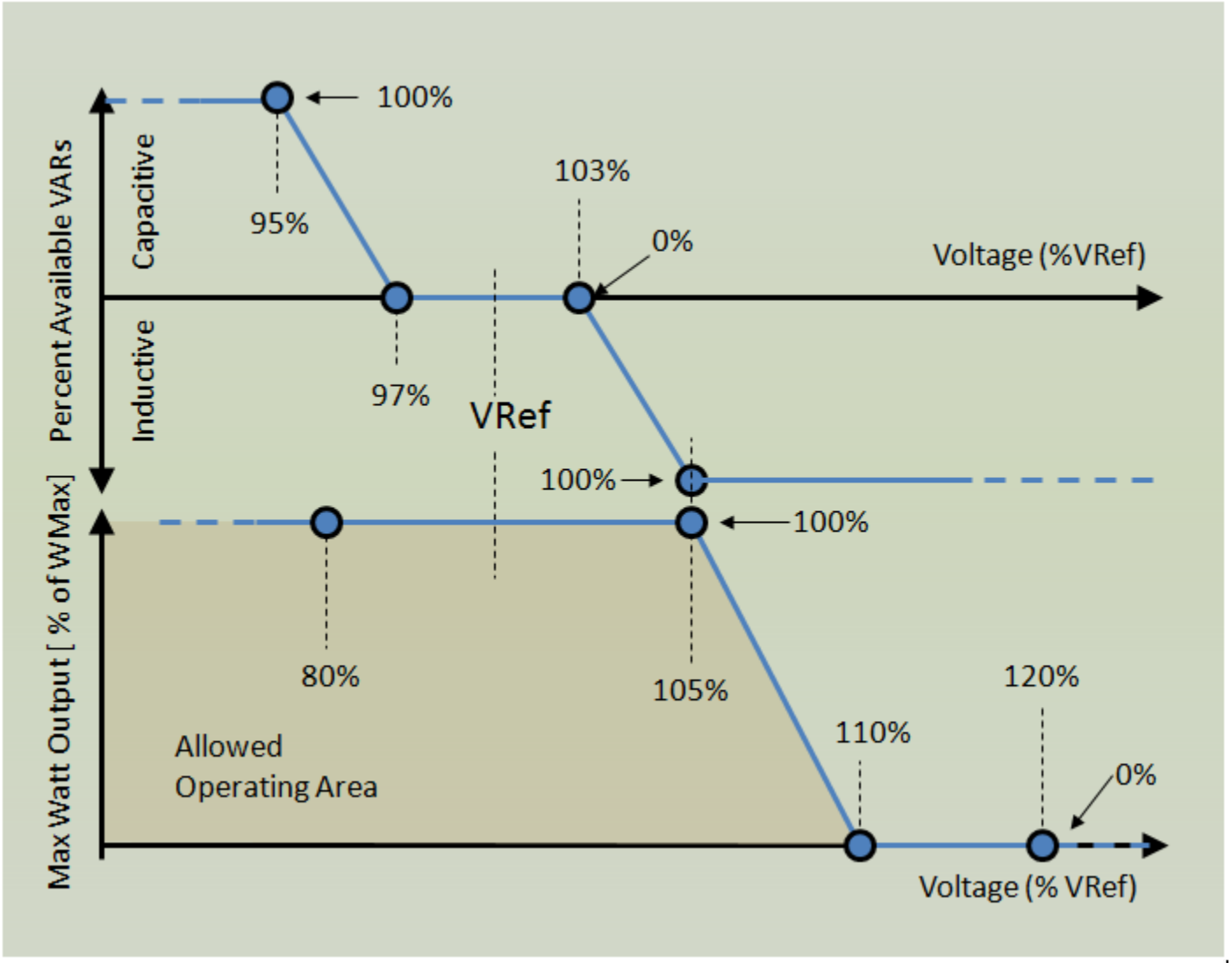
Volt/Var Mode 2 – Transmission VAR Support

Utility-Defined Curve Shapes

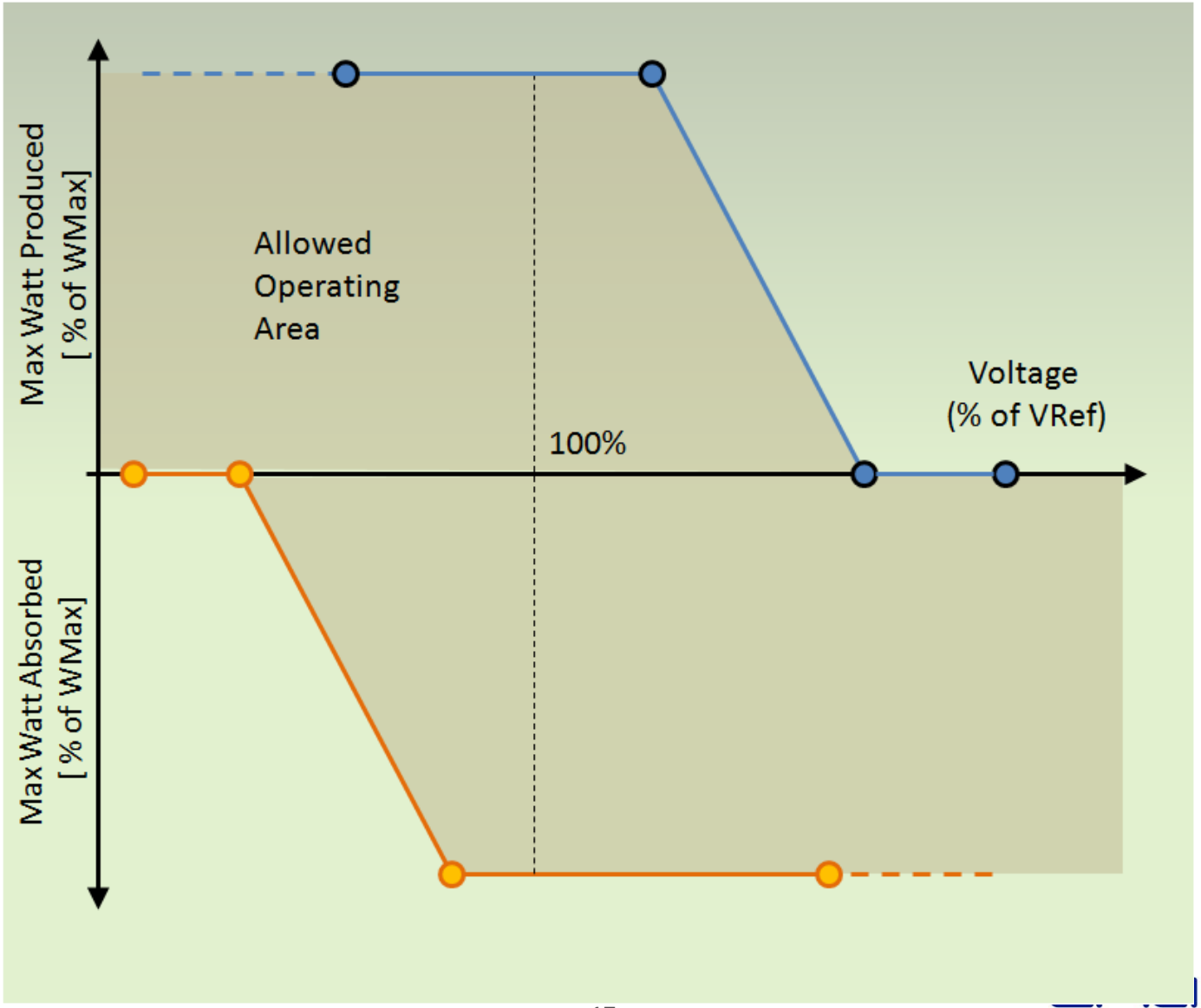




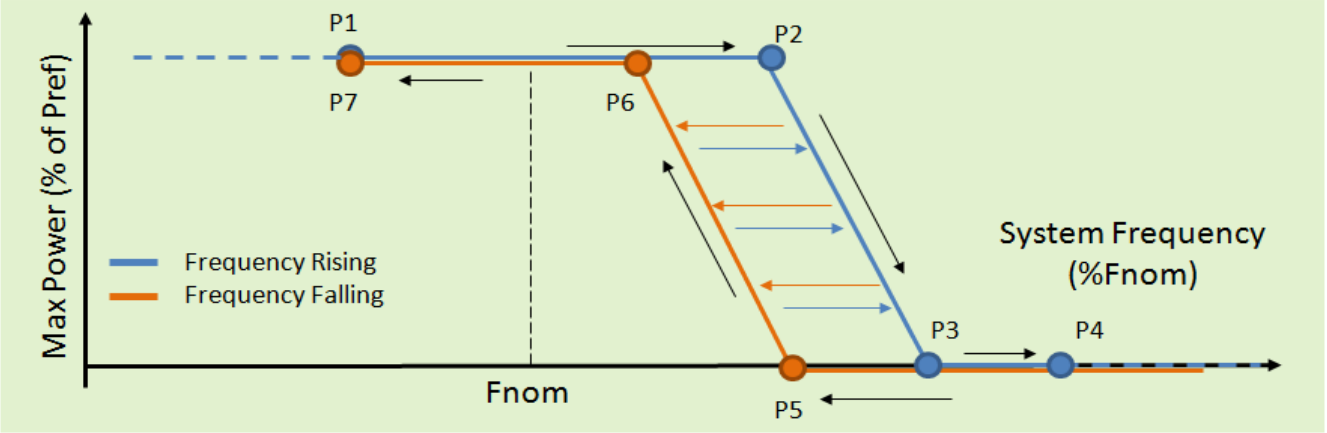
Volt-Watt Function

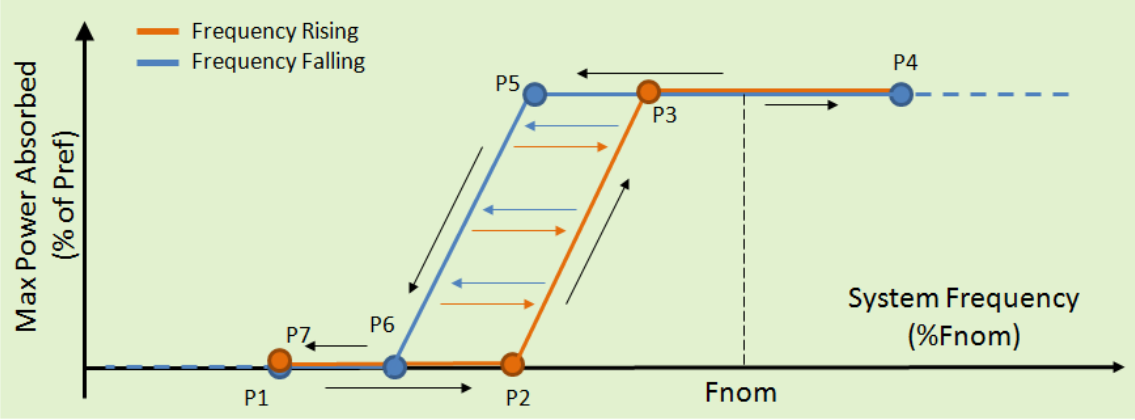


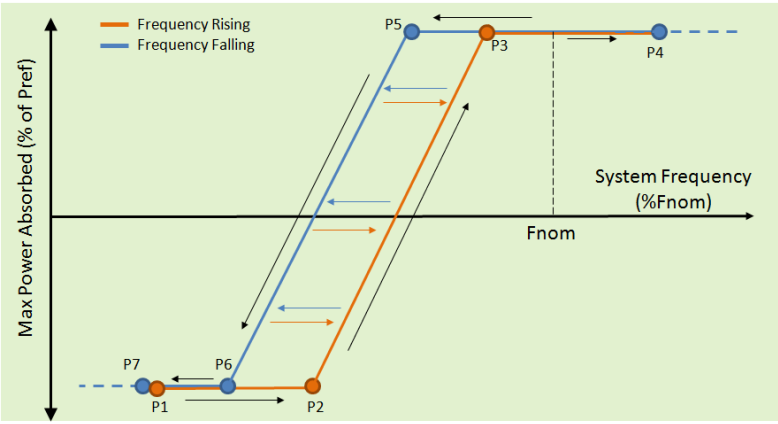
Volt-Watt Function (Produced and Absorbed)



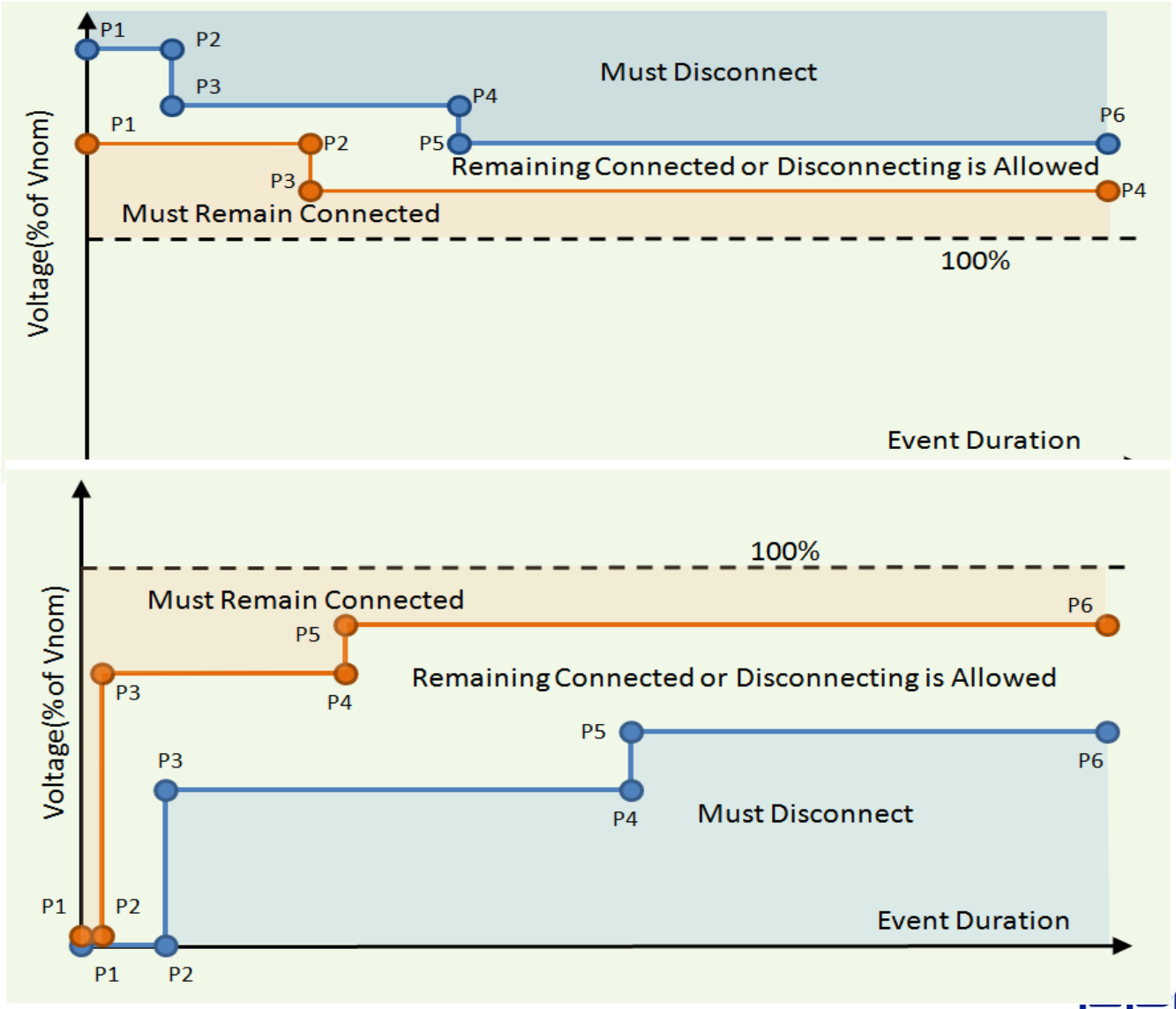
Frequency-Watt Function







Configurable Voltage Event Ride-through



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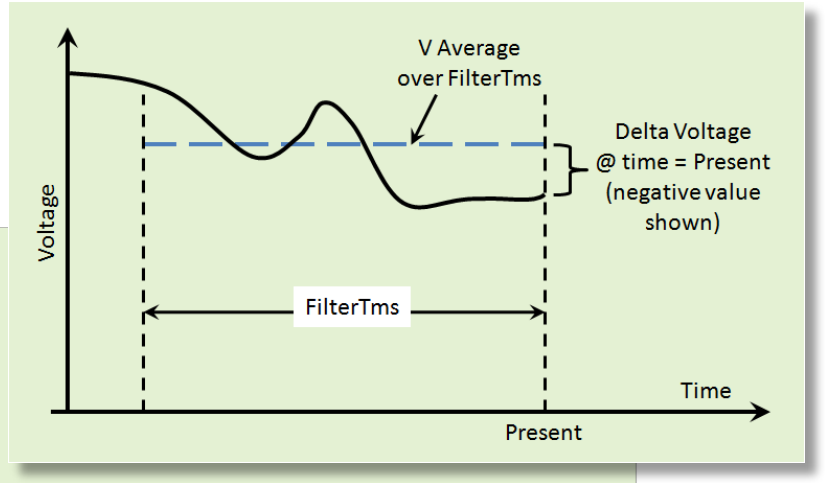
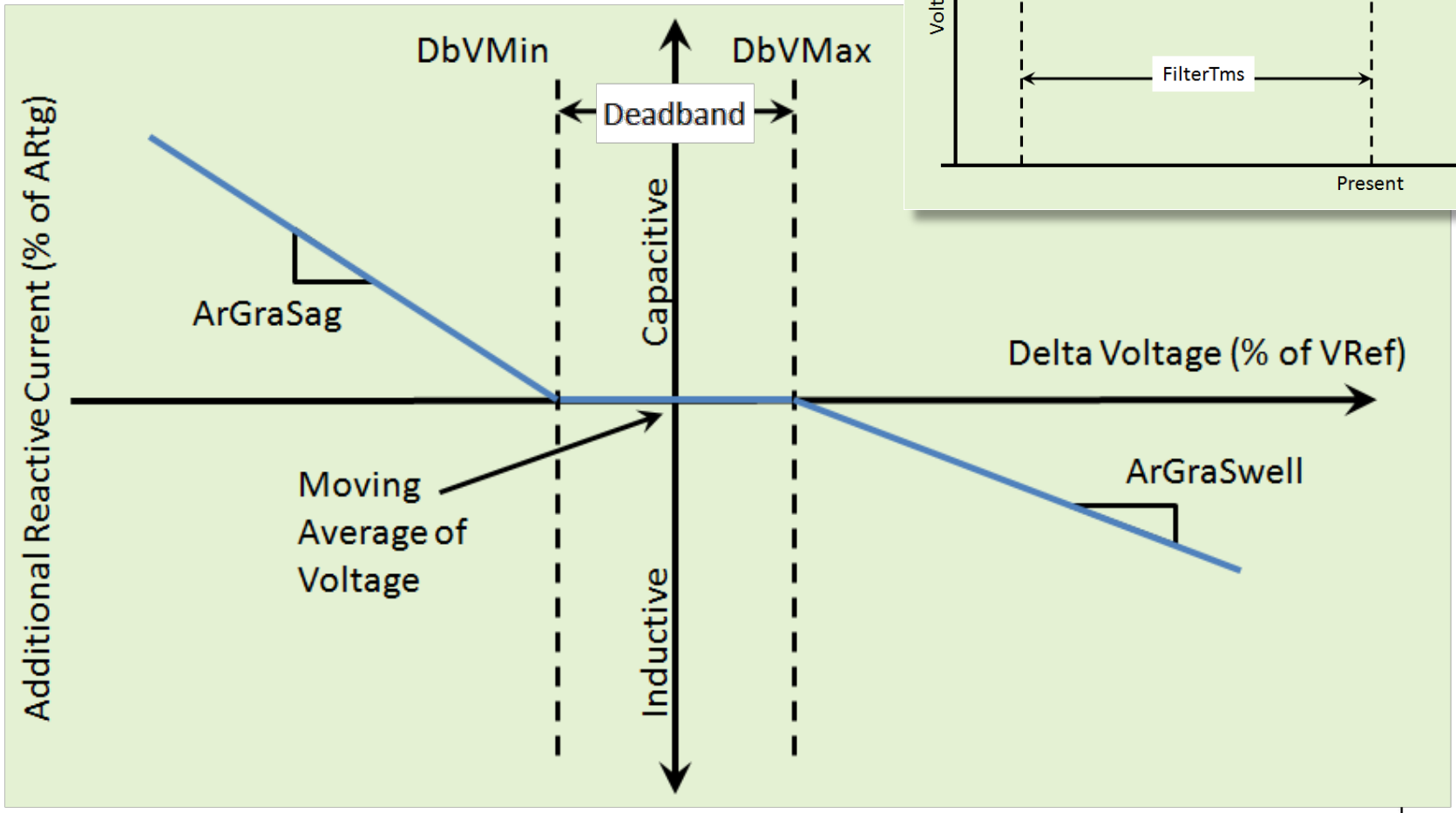
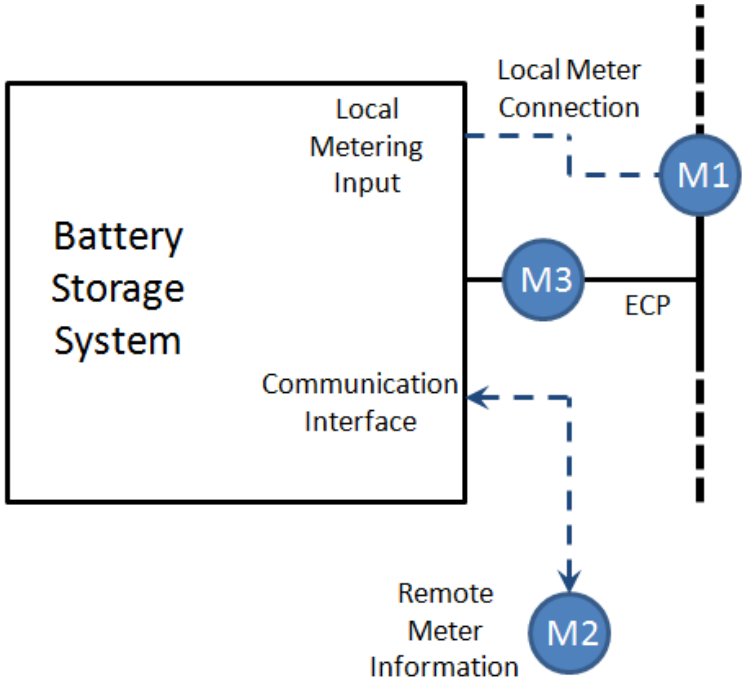
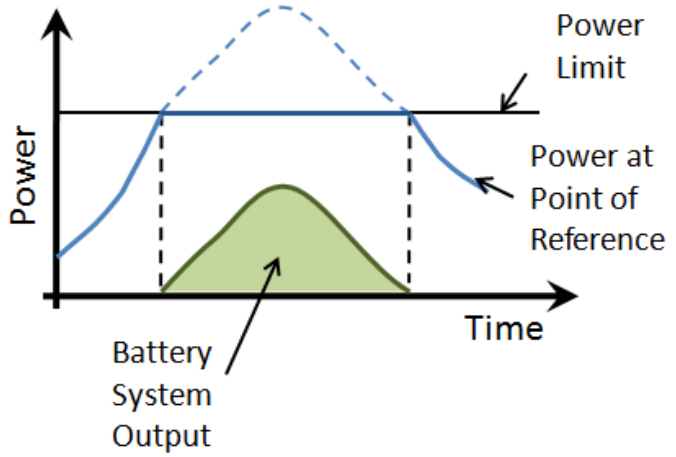
Dynamic Reactive Current

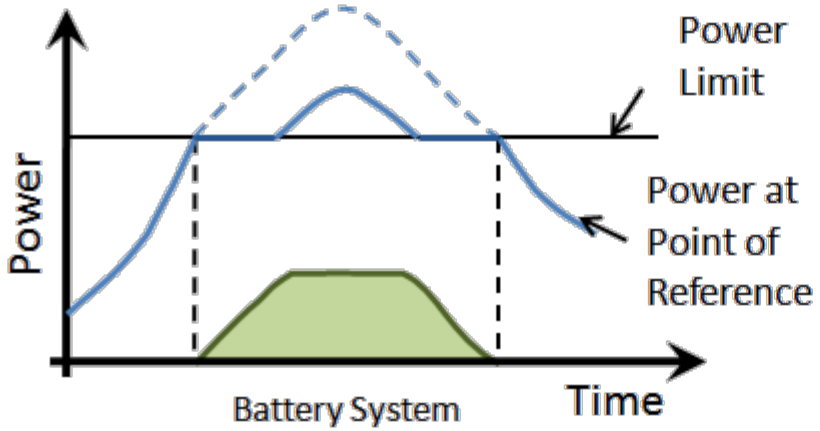


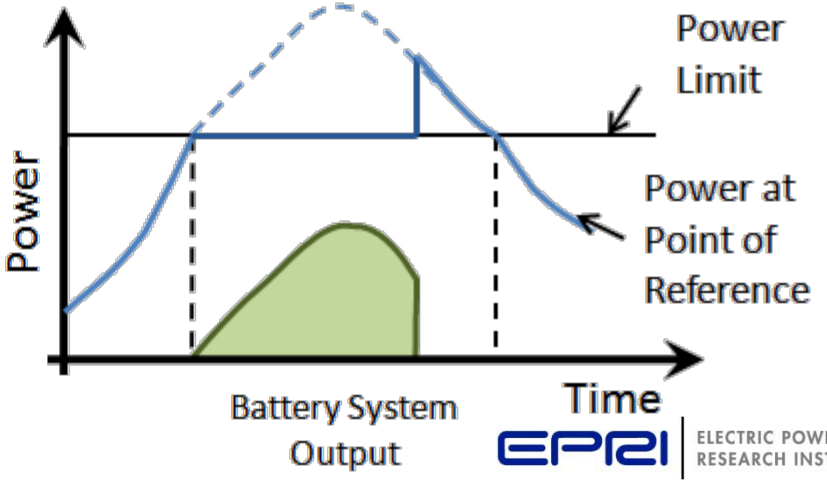


Peak Power Limiting (at point of reference)

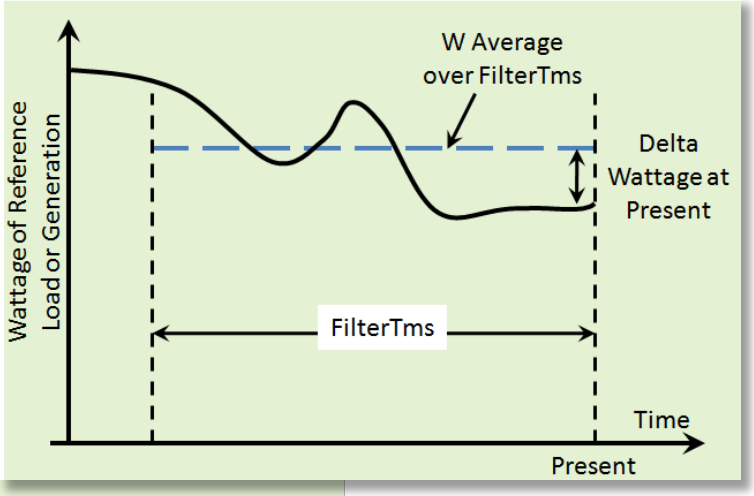


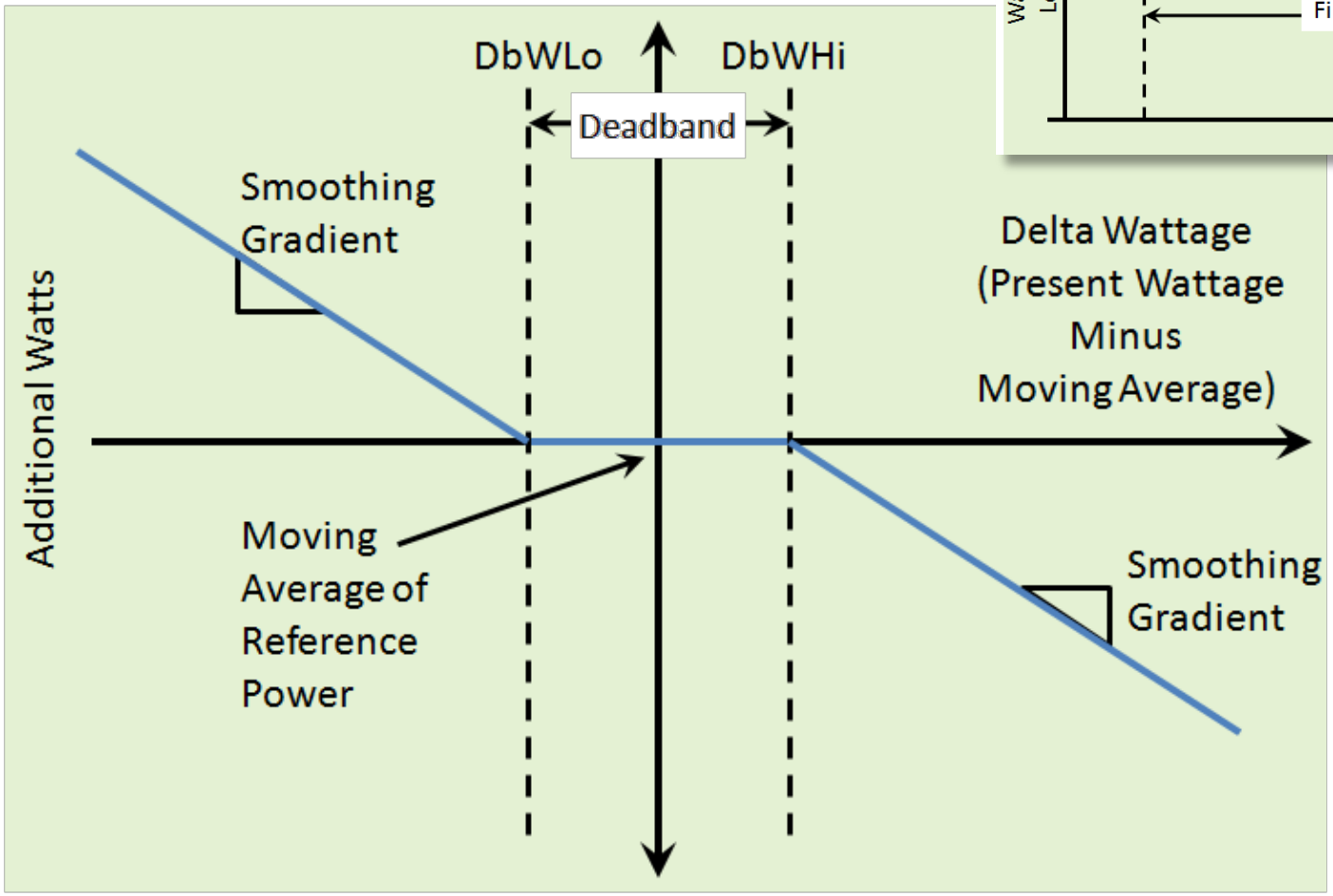




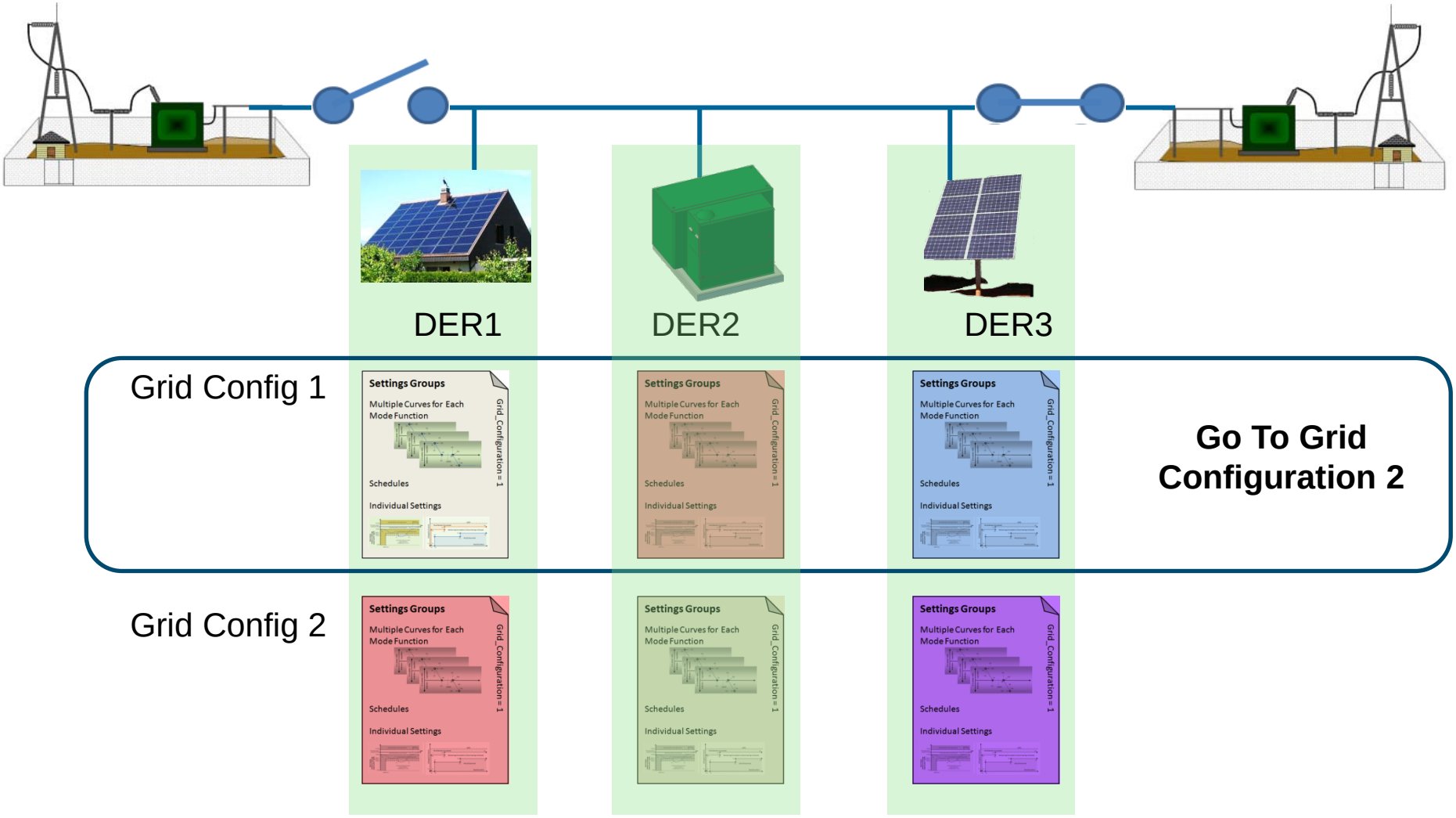


Power Smoothing





Multiple Grid Configurations



Monitoring & Logging

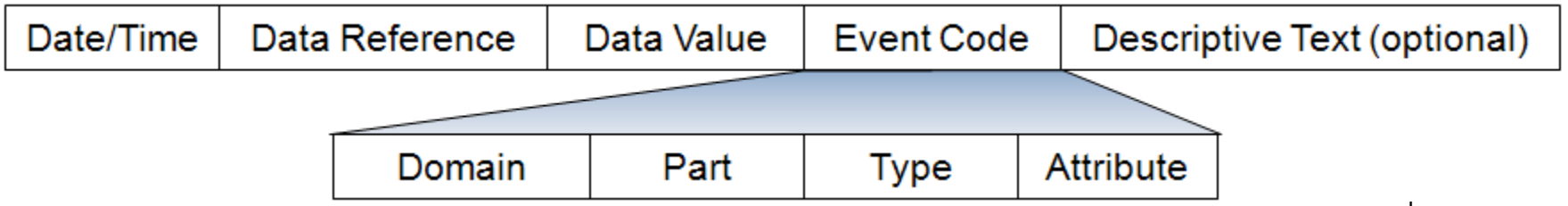
Monitoring

39 specific status items covered, touching the following areas:

- General Status Information
- Power Measurements
- Battery Storage Status
- Nameplate and Settings

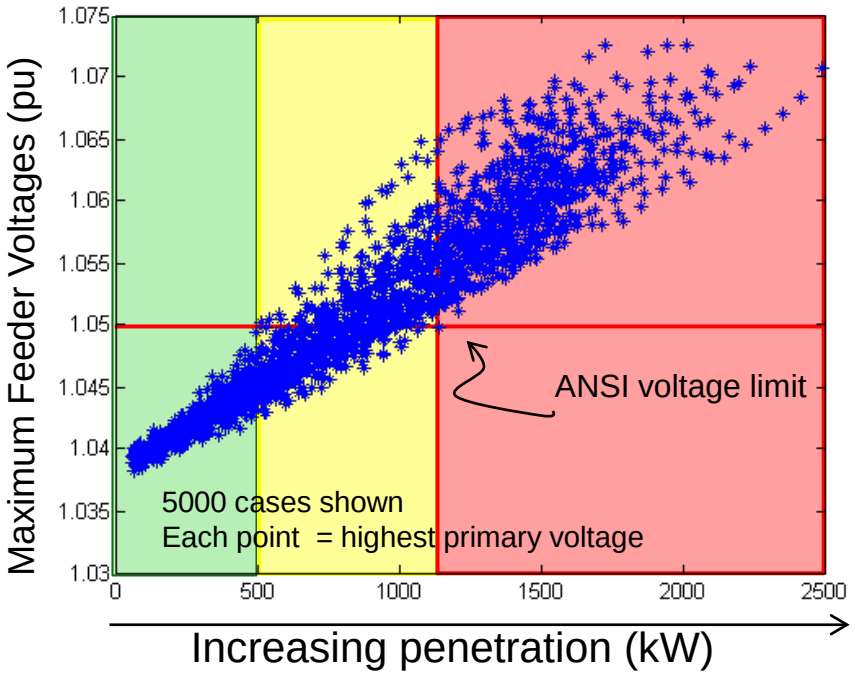
Logging

- Starting list of 39 event codes identified
- Circular buffers

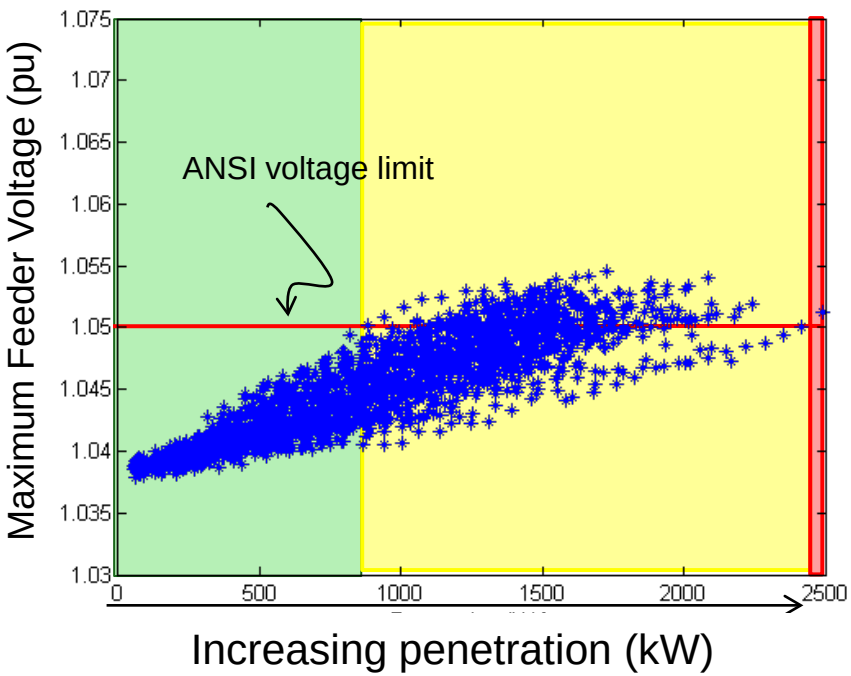


Increasing Hosting Capacity with Smart Inverters

Without Volt/var Control



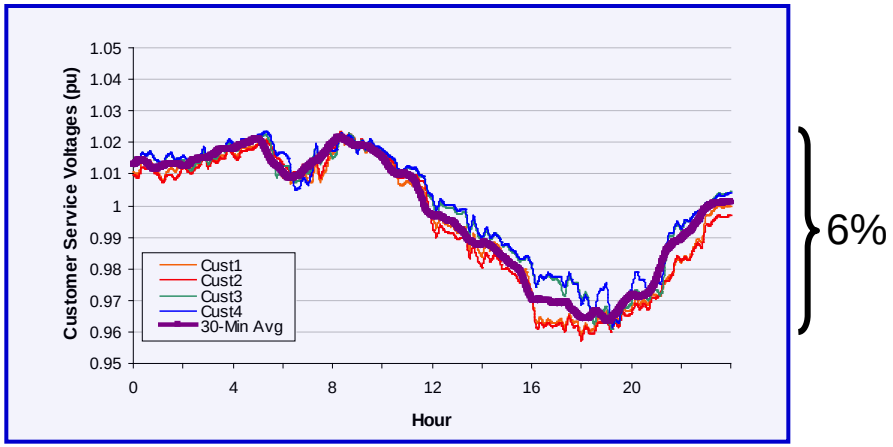
Volt/var Control



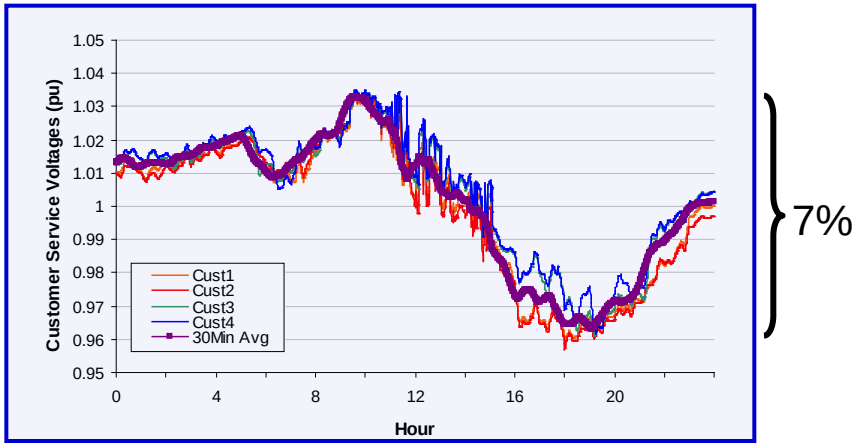
		PV Hosting Capacity (kW)		
		Without Volt/var	With Volt/var	
Primary Voltage Deviation	1st violation	938	>2500	**160%** increase in hosting capacity
	50% scenarios with violation	1323	>2500	
	All scenarios with violation	1673	>2500	
Primary Over Voltage	1st violation	540	880	**60%** increase in hosting capacity
	50% scenarios with violation	871	1464	
	All scenarios with violation	1173	2418	

Volt/Var Control for CVR – Sample Results

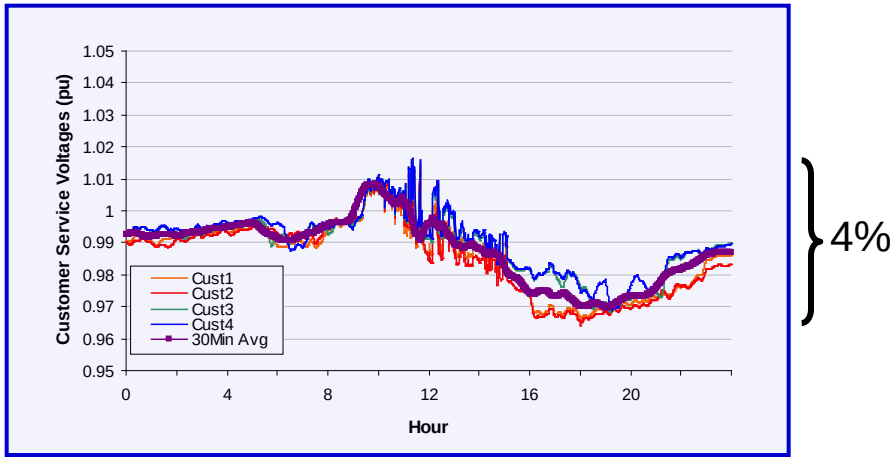
Baseline - No PV



With PV



PV with Volt/Var Control



- Energy Consumption
  - + 0.2% with PV
  - - 0.4% with PV and volt/var control
- Illustrates PV with volt/var control can coordinate with CVR

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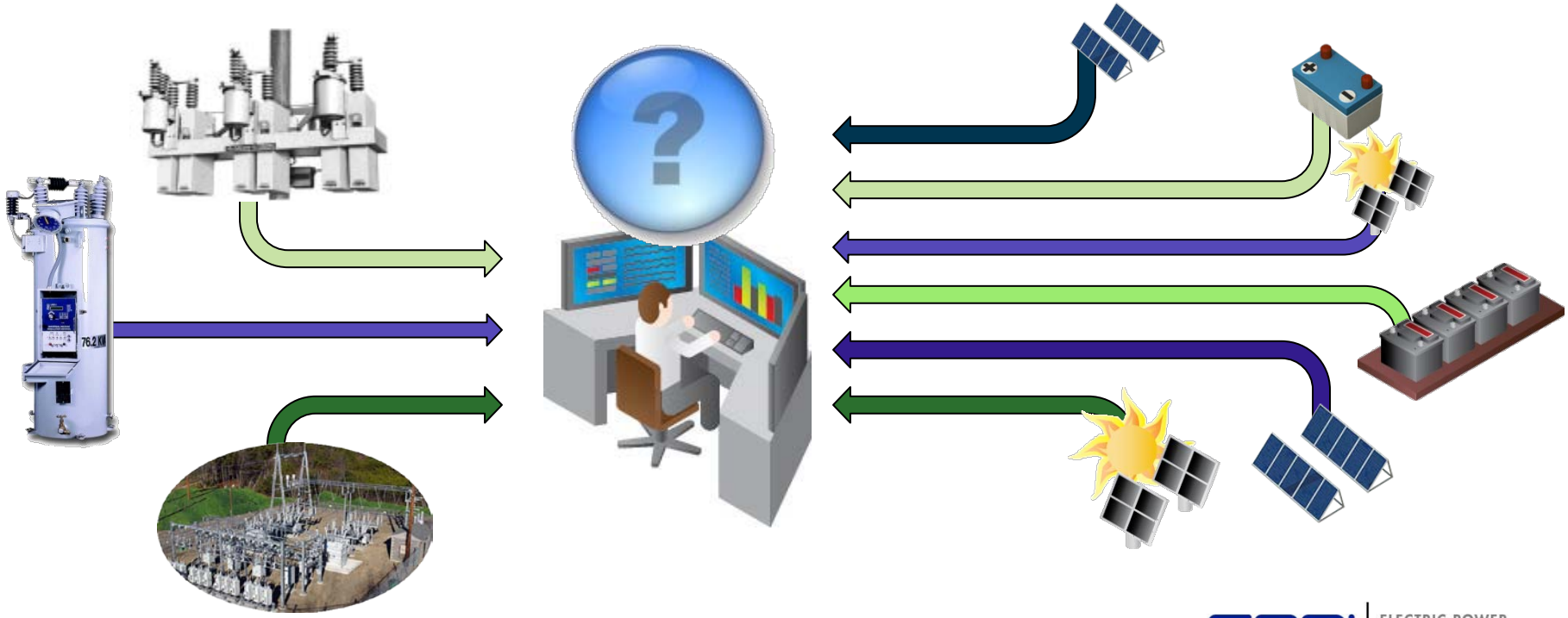
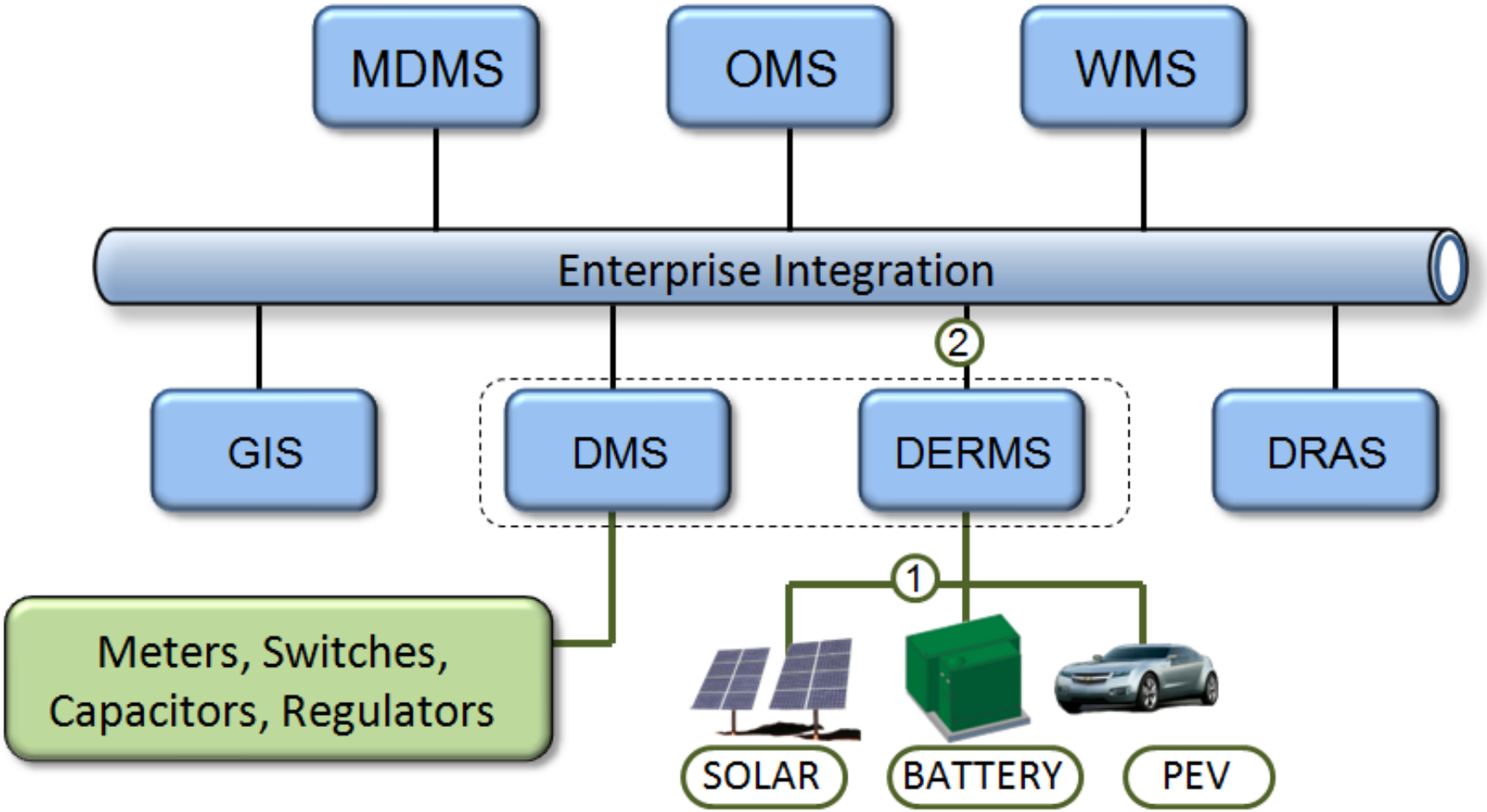


DER Enterprise Integration



Contrasting Enterprise-Level vs. Individual DER Functions

Individual DER Functions

- Configure a volt-var curve
- Island a device or tell it that it is now islanded
- Instruct a unit to charge or discharge at a particular rate
- Read real-time status from an individual device
- Change the volt-watt limits curve of a device or devices

Device-Capability Oriented

Example Enterprise Services

- Identify resources by feeder and segment
- Identify real-time variable generation by feeder and segment
- Request var support by feeder or segment
- Set power factor target at the feeder head
- Shift target voltage profile for CVR support

System-Need Oriented

Reference Documents

Whitepaper Describing Smart Inverter Initiative 1020906

Functions Defined and 61850-7-420 Mapped

NIST PAP7 Twiki http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP07Storage

EPRI Website 1026809

Standard Functions Codified by the IEC IEC 61850-90-7

Standard DNP3 Mapping of Functions AN2013-001 DNP3 Profile for Advanced Photovoltaic Generation and Storage

Standard SEP2.0 Mapping of a subset of Functions Part of the SEP2.0 Release

Standard Modbus Mapping SunSpec.org

Enterprise Integration Whitepaper 1024360

Enterprise Integration Workshop Results 1026789

Q&A / Discussion