U.S. DEPARTMENT OF ENERGY
Office of Electricity Delivery & Energy Reliability

Solid State Power Substation Roadmap and Request for Information

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Webinar Overview

Purpose: To provide an overview of the draft Solid State Power Substation (SSPS) Roadmap, the context for DOE's Request for Information (RFI), and an opportunity to answer clarifying questions.

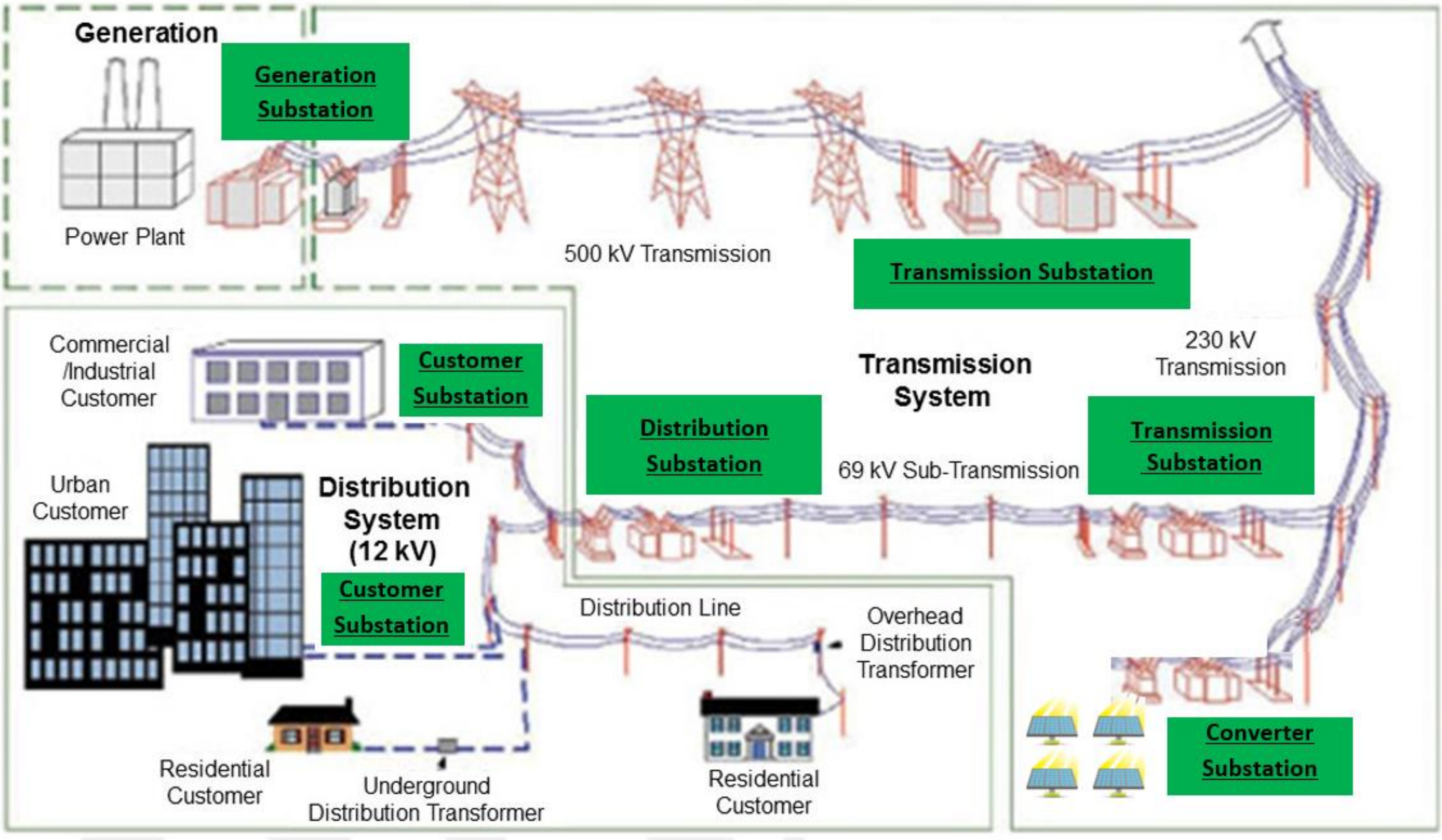
- **Overview of Roadmap and RFI Questions**
  - Roadmap objective
  - Substations, power system trends, and challenges
  - SSPS Converters and their benefits
  - SSPS technology development pathway
  - SSPS technology challenges, gaps, and goals
- **Q&A**

Roadmap Objective

Solid state power substation (SSPS): the strategic integration of high voltage power electronic converters in substations to provide enhanced capabilities and support the evolution of the grid.

- **Provide context, rationale, and potential benefits of utilizing SSPS technology**
- **Articulate a research and development pathway to accelerate maturation of SSPS**
- **Capture the state-of-the-art in critical enabling technologies**
- **Highlight research gaps and opportunities**
- **Align disparate activities across stakeholder communities**

Electric Power System with Substation Types



Trends and Challenges in a Modernizing Grid

Trends:

- Greater deployment of variable and distributed energy resources
- Potential mass-market adoption of electric vehicles
- Broader customer engagement
- Increasing use of information and communication technology
- Aging infrastructure
- Growing risks

Challenges:

- Accommodating distributed generation
- Enhancing security and resilience
- Ensuring reliable operations
- Making prudent investments

RFI Questions: What issues and concerns not captured in the roadmap most deeply impact the ability of substations to meet the demands of an evolving grid? What are additional challenges faced by utilities that would necessitate power electronic converters in substations?

Solid State Power Substations

- **Grid-scale power electronic systems:**
  - Flexible AC Transmission System
  - High Voltage Direct Current
  - Grid-tied inverters
  - Solid state transformers

- **SSPS converters:**

  Ultimately envisioned as a modular, scalable, flexible, and adaptable power block that can be used within all substations, SSPS converters will serve as power routers or hubs that have the capability to electrically isolate system components and provide bidirectional AC or DC power flow control from one or more sources to one or more loads - indifferent to magnitude and frequency

RFI Questions: Is there evidence of a growing need for power electronic converters in substations? If so, in what capacity? What specific challenges would the use of power electronic converters address?

SSPS Classification and Defining Functions and Features

	Defining Functions and Features
SSPS 1.0 25 kVA – 1 MVA Up to 34.5 kV	• Provides reactive power compensation • Provides voltage and frequency control • Capable of bi-directional power flow • Allows for multi-frequency systems (i.e., AC and DC) • Capable of riding through faults and disruptions (e.g., HVRT, LVRT)
SSPS 2.0 25 kVA – 100 MVA Up to 230 kV	+ Capable of serving as a communications hub + Enables system coordination of fault current and protection + Provides bidirectional power flow control between transmission and distribution + Enables distribution feeder islanding and resynchronization
SSPS 3.0 All Power Levels All Voltage Levels	+ Distributed control of multiple SSPS for global optimization + Autonomous control for plug-and-play features + Provides black start support and recovery coordination + Enables fully decoupled, asynchronous systems

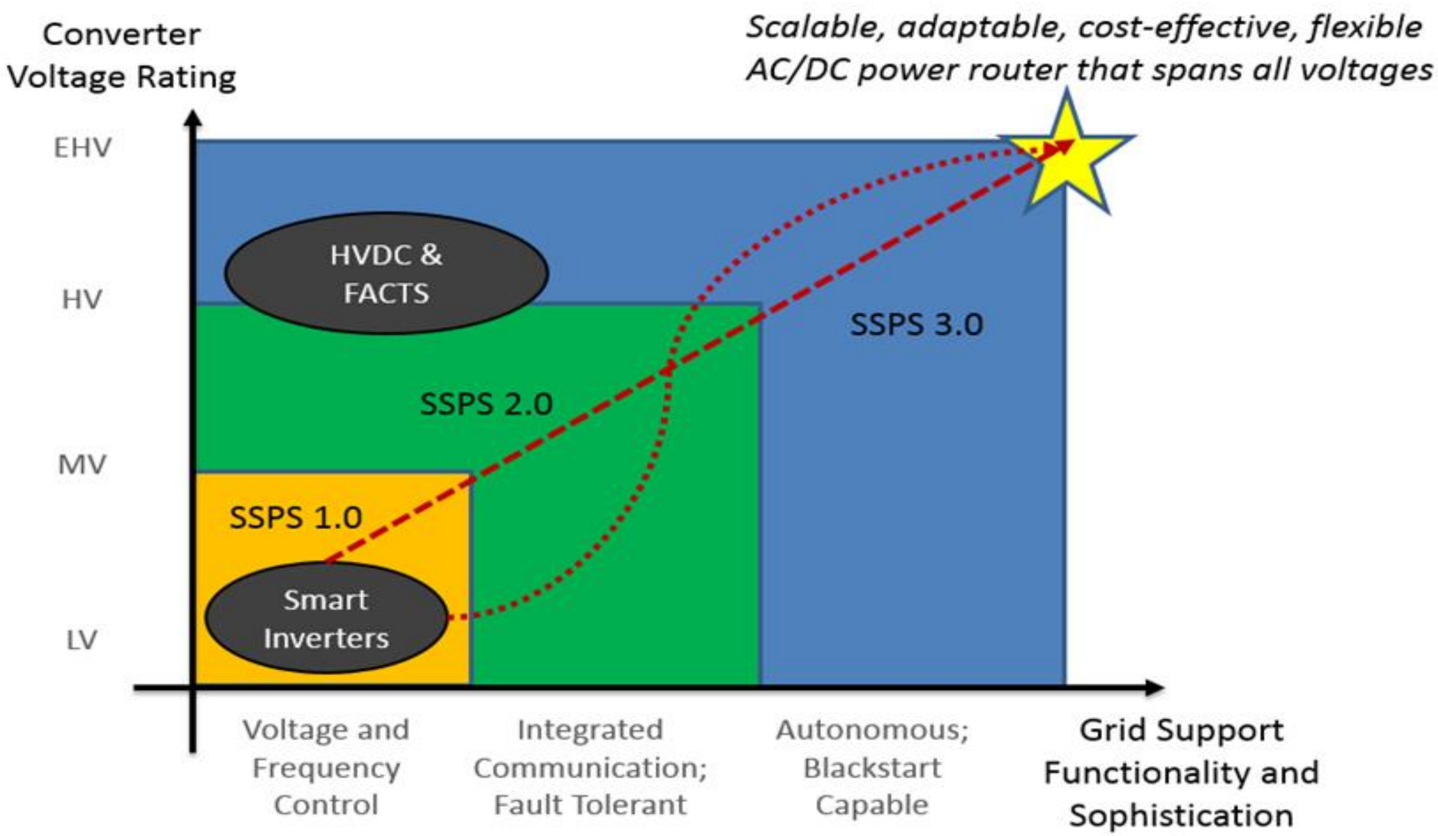
RFI Question: Comments are requested on the SSPS vision and the three classification of SSPS converters articulated in the roadmap, as well as on the defining feature and functions and the voltage and power ratings.

SSPS Benefits

- **Increase energy efficiency**
- **Improve power quality and system operations**
- **Increase asset utilization and system optimization**
- **Enhance protection and system reliability**
- **Simplify and reduce the costs of capacity expansion and upgrades**
- **Increase security and resilience**
- **Enable new grid paradigms and novel business models**

RFI Question: What are additional benefits of using SSPS converters that should be captured?

SSPS Technology Development Pathway



RFI Questions: Comments are requested on the SSPS technology development pathway presented in the roadmap. For each classification of SSPS converters, are there other potential applications that have not been captured?

SSPS Technology Challenges, Gaps, and Goals

		SSPS 1.0	SSPS 2.0	SSPS 3.0
Category	**R&D Challenges**	**Goals**		
Substation Application	Power Converter Architecture	Modular, flexible, and scalable for various applications with high reliability		
	Converter Controller and Communications	Local Controls; Basic Plug-and-Play	Grid Forming & Synchronization; Wide Area Connectivity	Autonomous/AI & Distributed Controls; Peer-to-Peer
	Converter Protection and Reliability	Fault and Over-Voltage Tolerant; Withstand EMI and meets BIL; Manages Inrush/Fault Currents		Adaptive/Dynamic; Self-Healing
	System Costs and Performance	< \$150/kVA > 96% 5 MW/m^3 10 Year MTTF	< \$125/kVA > 96.5% 10 MW/m^3 20 Year MTTF	< \$100/kVA > 97% 20 MW/m^3 40 Year MTTF
Converter Building Block	Module Costs and Performance	< \$20/kVA > 97% 2.5 W/cm^3 2 Year MTTF	< \$15/kVA > 98% 5 W/cm^3 4 Year MTTF	< \$10/kVA > 99% 10 W/cm^3 8 Year MTTF
	Drivers and Power Semiconductors	1.7 kV \$0.1/kW	3.3 kV \$0.1/kW	10 kV \$0.1/kW
	Dielectric, Magnetic, and Passive Components	160 kV/mm 0.1 H/m 6.0×10^7 S/m	600 kV/mm 1.0 H/m 1×10^8 S/m	2000 kV/mm 2.0 H/m 1.5×10^8 S/m
	Packaging and Thermal Management	> 500 $W/(m^2 °C)$	> 1000 $W/(m^2 °C)$	> 10,000 $W/(m^2 °C)$
Grid Integration	Grid Architecture	Distribution Platform Paradigm	Asynchronous, Fractal, and Multi-frequency Paradigm	
	Grid Control and Protection Systems	Coordinates with Existing Protection	Dynamic Fault Detection and Adaptive Protection	Graceful Degradation & Blackstart
	System Modeling and Simulation	Tools and models capable of analyzing advanced controls, power flows, short circuit, faults, power quality, dynamics, and transient stability		

SSPS Technology Challenges, Gaps, and Goals

RFI Questions:

- Comments are requested on the R&D challenges identified in the roadmap and their associated goals.
- What R&D challenges not yet identified would prevent SSPS technologies from being realized, as envisioned?
- Comments are requested on the state-of-the-art and the research gaps identified in the roadmap for each of the R&D challenges.
- What additional gaps needs to be highlighted to address the R&D challenges identified?
- What specific actions will need to be taken in the near-, mid-, and long-term to sufficiently address the gaps identified?

Industry Acceptance

- **Cost benefit analysis**
- **Industry standards**
- **Markets and regulations**
- **Testing, education, and workforce**

RFI Questions: What additional non-technical challenges are there that would prevent SSPS converters from being accepted by industry? What additional standards would be relevant to SSPS technology, as envisioned? What are potential market or regulatory barriers that will need to be addressed?

General RFI Questions:

- Comments are requested on the technology topic described in the roadmap,
- What is the appropriate Federal role in advancing this technology area?
- What are some organizational roles in helping to advance this technology concept?
- What amount of resources would be required to fully implement the roadmap?

Questions?

Request for Information:

- Submit comments using Excel spreadsheet by **May 7, 2018**
- Submit comments to: DOE.SSPS.Roadmap@hq.doe.gov
- Submit any questions to: kerry.cheung@hq.doe.gov