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**SOLAR ENERGY  
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U.S. Department Of Energy

# Securing Solar for the Grid (S2G)

National Renewable Energy Laboratory

Award # 38445

October 2021–September 2024

Presented on: September 12, 2024

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**Principal Investigator:** Danish Saleem

**Team Members:** Ryan Cryar, Zoe Dormuth, Jordan Peterson, Chelsea Neely, Emily Waligoske

# Standards Development and Best Practices

*Moderated by:*



**Danish Saleem**

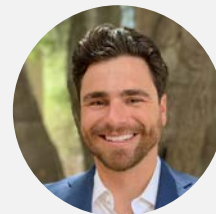
National Renewable Energy Laboratory

## Panelists



**Aung Thant**

NERC



**John Franzino**

Grid Security, Inc.



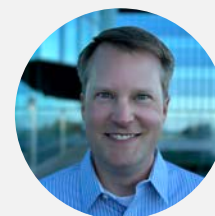
**Andre Ristaino**

ISA



**David Benton**

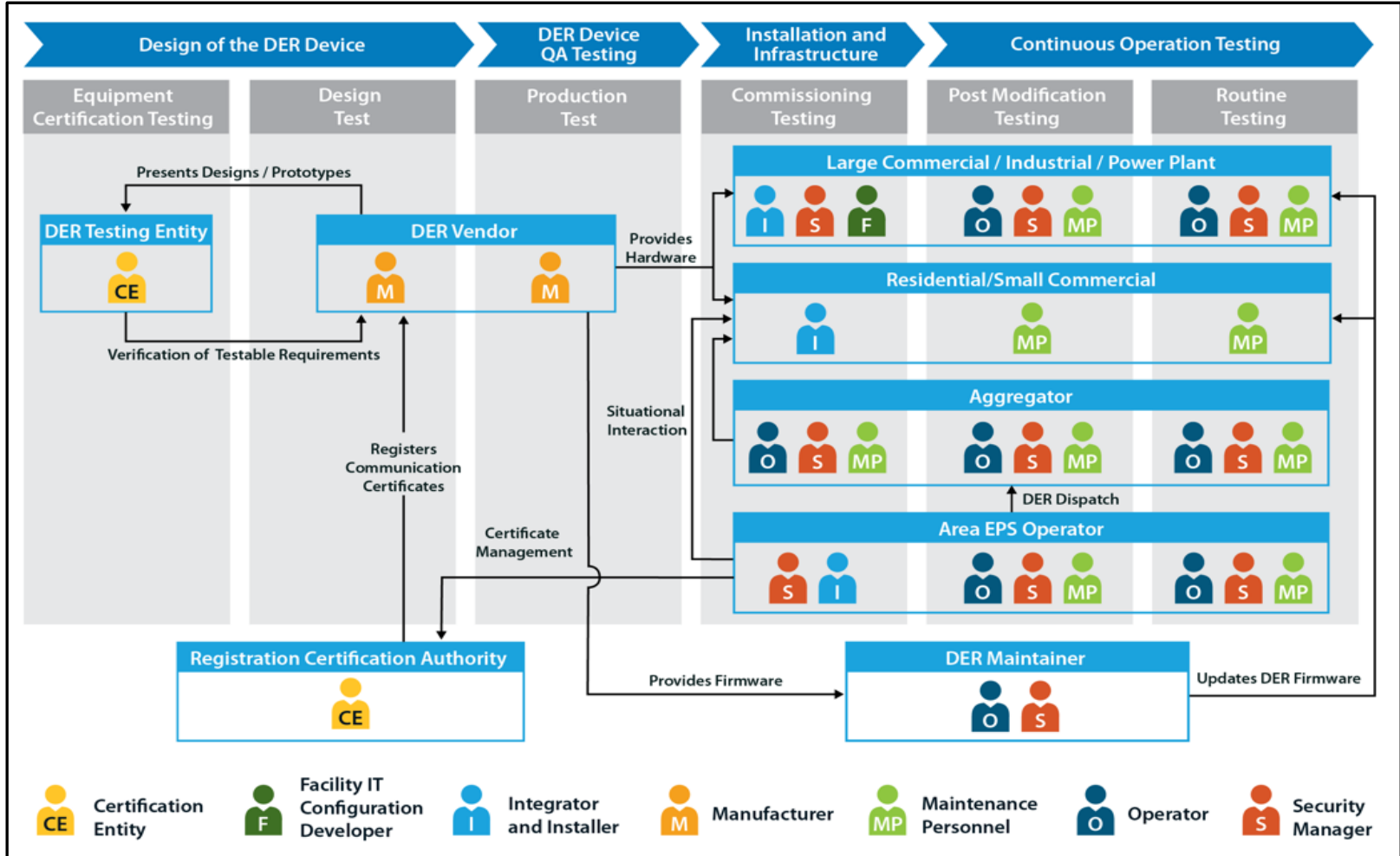
Berkshire Hathaway  
Energy



**Mike Slowinske**

Underwriters  
Laboratories

# How Recently Developed Standards Would Affect Product Lifecycle & Associated Stakeholders



# Key Milestones for NREL

## Cybersecurity Certification Standard

Lead the development of a cyber certification standard for solar PV industry

Develop test guidance to support UL 2941 certification standard

Support consensus development for UL 2941 among OEMs, utilities, installers, and aggregators

## Cybersecurity Guide for DERs

Develop a guide with recommendations for cybersecurity of DERs i.e., IEEE 1547.3

Integrate cybersecurity recommendations into IEEE 1547 standard

## Solar PV Supply Chain Cybersecurity

Analyze and document the gaps in the supply chain cybersecurity for DERs

Publish cybersecurity recommendations for solar PV industry

Lead a solar supply chain cybersecurity workshop

## DERMS Cybersecurity

Identify applicable cybersecurity standards and/or guidelines for DERMS

Identify cybersecurity considerations for DERMS

Develop cybersecurity risk profiles for DERMS

Through S2G, NREL co-led the development, coordination, and consensus development of 1) cyber certification standard, 2) cybersecurity guide, 3) cyber recommendations for supply chain and 4) DERMS cybersecurity for solar technologies to help secure the clean energy transition.

# Impact of NREL's Work Through S2G



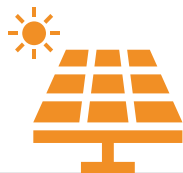
Led S2G proposal in  
FY 2018

Chaired the  
laboratory  
coordination  
committee (LCC) for  
last two years.  
Serving as vice chair  
this year.



Co-led the  
development of UL  
2941 OOI for solar  
cybersecurity  
certification standard

Co-led the  
development IEEE  
1547.3 cybersecurity  
guide for DERs



Gap analysis for DER  
supply chain  
cybersecurity

Supply chain  
cybersecurity  
recommendations  
  
DERMS cybersecurity  
risk profiles



Coordination of  
cybersecurity  
requirements from  
key industry  
stakeholders

Testing guidance for  
PV inverters



LCC structure such as  
charter, graphic,  
information page,  
invitation emails, etc.

Co-hosted LCC  
meetings, recruited  
members, and much  
more

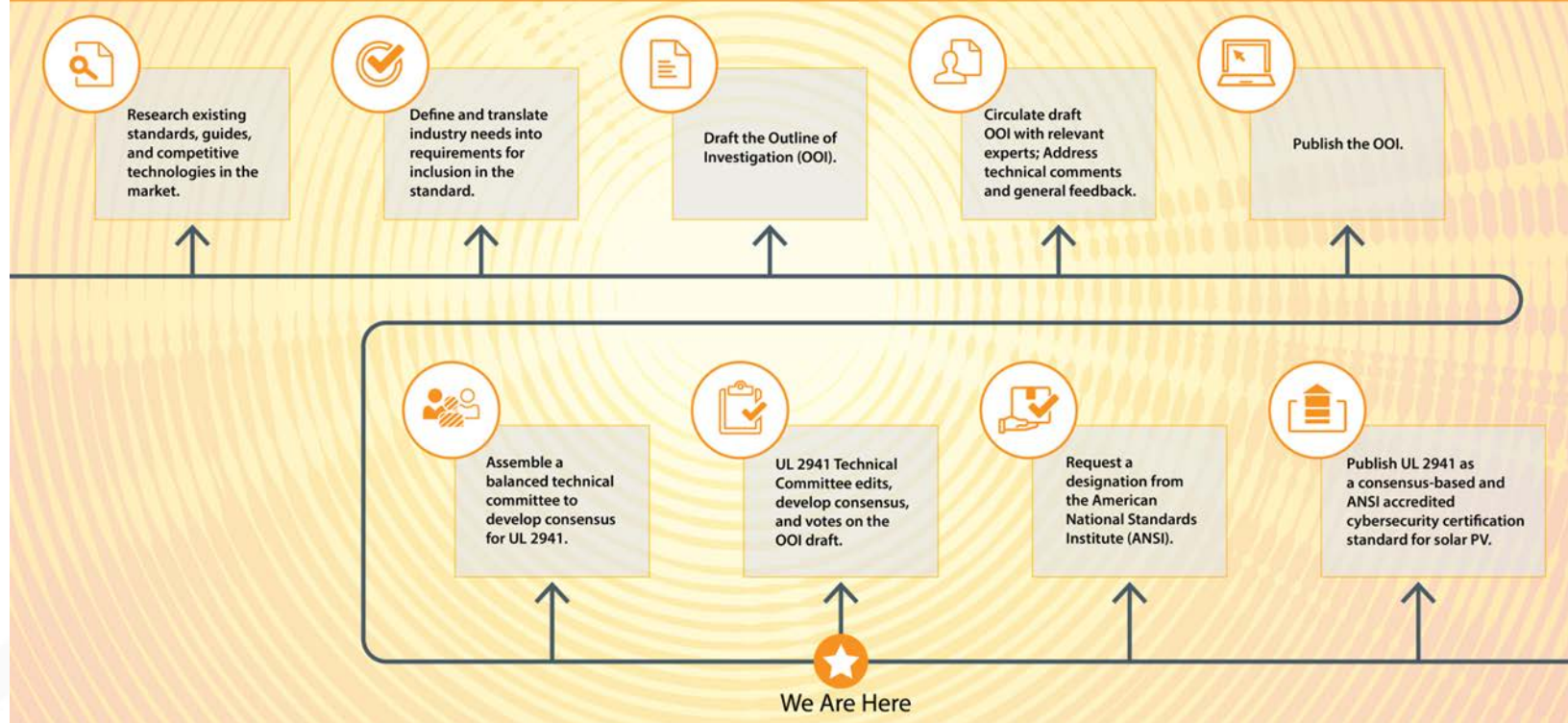


Impactful reports and  
papers to pave the  
way for new  
standards,  
certifications, tools,  
and recommended  
practices

The project supported a **first of its kind cybersecurity certification standard** that can be used to validate cybersecurity posture of solar PV inverters before deployment and while in the field.



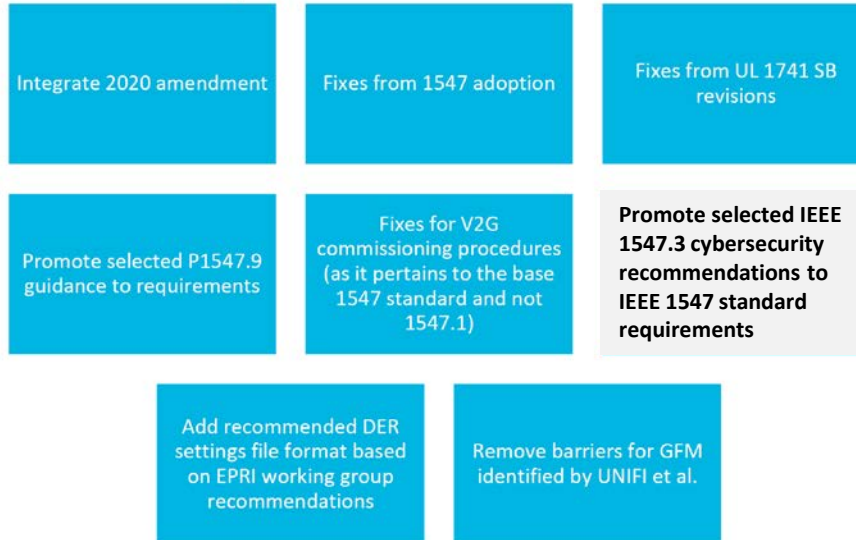
## Underwriter Laboratories 2941: Where are we in the process?



# IEEE 1547.3: Cybersecurity Guide for DERs

P1547 Revision Working Group: Expectations of SG Leads & Facilitator

## Proposed Focus of this Revision



- IEEE 1547.3 cybersecurity guide published in December 2023 after being approved by the working group and standards coordination committee
- It was added to the IEEE 1547 standard revision timeline

IEEE Std 1547.3™-2023  
(Revision of IEEE Std 1547.3-2007)

## IEEE Guide for Cybersecurity of Distributed Energy Resources Interconnected with Electric Power Systems

Developed by the  
Distributed Generation, Energy Storage, and Interoperability Standards Committee  
and the  
Power System Communications and Cybersecurity Committee  
of the  
IEEE Board of Governors  
and the  
IEEE Power and Energy Society

Approved 5 June 2023  
IEEE SA Standards Board

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# Publications



## Certification Procedures for Data and Communications Security of Distributed Energy Resources

Danish Saleem<sup>1</sup> and Cedric Carter<sup>2</sup>

<sup>1</sup> National Renewable Energy Laboratory  
<sup>2</sup> The MITRE Corporation



## Supply Chain Cybersecurity Recommendations for Solar Photovoltaics

Ryan Cryar, Vikash Rivers, Jennifer Guerra, Chelsea Quilling, Zoe Dormuth, and Danish Saleem

National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency & Renewable Energy Operated by the Alliance for Sustainable Energy, LLC

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Contract No. DE-AC35-09OR22038

Technical Report  
NREL/TP-5500-47135  
August 2023



## Cybersecurity Recommendations for Distributed Energy Resource Management Systems

Chelsea Quilling, Ryan Cryar, Danish Saleem, and Jennifer Guerra

National Renewable Energy Laboratory



## Gap Analysis of Supply Chain Cybersecurity for Distributed Energy Resources

Ryan Cryar, Danish Saleem, Jordan Peterson, and William Hupp

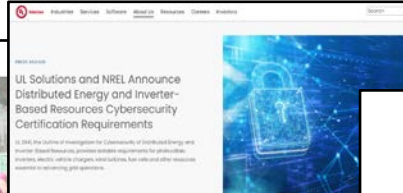
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Contract No. DE-AC35-09OR22038

Technical Report  
NREL/TP-5500-47135  
August 2023



## UL Solutions and NREL Announce Distributed Energy and Inverter-Based Resources Cybersecurity Certification Requirements

UL Solutions and NREL announce the release of the Cybersecurity Certification Requirements for Distributed Energy and Inverter-Based Resources, providing a path for manufacturers to demonstrate their products meet the requirements for cybersecurity.



## IEEE Guide for Cybersecurity of Distributed Energy Resources Interconnected with Electric Power Systems

IEEE Std 1647.3™-2023  
(Revision of IEEE Std 1647.3-2013)

Developed by the Distributed Generation, Energy Storage, and Interoperability Standards Committee and the Power System Communications and Cybersecurity Committee of the IEEE Board of Governors IEEE Power and Energy Society

Approved 3 June 2023  
IEEE SA Standards Board



## Cybersecurity in Photovoltaic Plant Operations

Andy Walker,<sup>1</sup> Jal Desai,<sup>1</sup> Danish Saleem,<sup>1</sup> and Thrushara Gunda<sup>2</sup>

<sup>1</sup> National Renewable Energy Laboratory  
<sup>2</sup> Sandia National Laboratories

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Contract No. DE-AC35-09OR22038

Technical Report  
NREL/TP-5500-57155  
March 2021



## Distributed Energy Resource Cybersecurity Standards Development – Final Project Report

Jay Johnson, Neoma Onunkwo, Danish Saleem, William Hupp, Jordan Peterson, Ryan Cryar



Prepared by Sandia National Laboratories, Operated by the Alliance for Sustainable Energy, LLC

Technical Report  
SAND2022-1116  
Printed January 2022



## Cyber Security for Distributed Energy Resources and DER Aggregators

NERC Security Integration and Technology Enablement Subcommittee (SITES) White Paper  
December 2022

**Purpose**  
This report provides industry with information regarding activities underway to further secure the electricity ecosystem under rapid grid transformation, specifically in the area of cyber security efforts for distributed energy resources (DER) and DER aggregators. NERC is working with utility stakeholders to advance cyber security efforts for DER as the penetration of these resources continue to grow in many areas across North America. This paper is informational and seeks to help provide clarity and guidance to industry stakeholders in the area.

**Defining DER and DER Aggregator**  
The NERC Cyber Planning Project Team (CCTP) Working Group (DPERWG) defines DER as "any source of electric power located on the distribution system." This definition specifically focuses on these resources in the distribution system that can produce or store energy, i.e., a generating resource and does not include end-use loads or demand response as part of the DER definition. Conversely, the Federal Energy Regulatory Commission (FERC) DER definition outlined in FERC Order 2222<sup>1</sup> does consider load resources, including demand response, energy efficiency, and storage, whether the expanded FERC definition includes all DER types able to participate in regional organized wholesale electricity markets through aggregation (DER aggregators).

This document will generally refer to DERs with the NERC definition but acknowledging that DER aggregators may include DER (with the FERC definition) that are load resources and not generating elements where used. This language does not critically impact the key points being made in this paper.

**Understanding Security of the Electricity Ecosystem**  
The full power system (EPS) includes many interconnected power plants with power flowing across the transmission system, down through the distribution networks, and then to end-use consumers. A significant portion of this system area operated either with analog controls or analog-digital connectivity. However, the great return of today's underlying a rapid transformation, the generation base is moving toward clean energy innovation and connected through modern technology. Large synchronous generators and related power plants are being retired and replaced with smaller wind and solar resources, battery energy storage, and hybrid power plants. DER connected resources are also being added with DERs that connect to the distribution system, some of which are behind-the-meter and owned and operated by end-use consumers or third parties. Many of these systems are now connected directly to the Internet as digitalization and its associated connectivity continue to expand exponentially. Grid planners, designers, and operators are faced with managing a grid with a significant portion of the resources base connected by



## Cybersecurity Certification Recommendations for Interconnected Grid Edge Devices and Inverter Based Resources

William Hupp, Danish Saleem, and Jordan T. Peterson  
National Renewable Energy Laboratory

Kenneth Boyce  
Underwriters Laboratories

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November 2021

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U.S. Department Of Energy

# Thank You

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NREL/PR-5T00-91112

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