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SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

Securing Solar for the Grid (S2G)

National Renewable Energy Laboratory

Award # 38445

Final Project Report

Period of Performance: October 2021 – September 2024

Principal Investigator: Danish Saleem

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

DOE/GO-102025-6677

S2G: Securing Solar for the Grid

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VISION

Achieving high cybersecurity maturity levels for solar technologies, equipment, supply chains, facilities, as well as the bulk and distribution electric power grids.

GOAL

Strengthen and standardize cybersecurity approaches for electric grids with high penetrations of solar PV and other DERs

APPROACH

Collaboration among multiple national labs, DOE offices, and industry to address gaps in requirement standards, best practices, testing, and analysis for solar PV and DERs cybersecurity

EXPECTED OUTCOMES

Development and dissemination of **standards' requirements, best practices, equipment testing procedures, assessment tools, as well as education and training materials** for cyber defense, posture and maturity tailored to solar technologies.

Overview of NREL's Contribution

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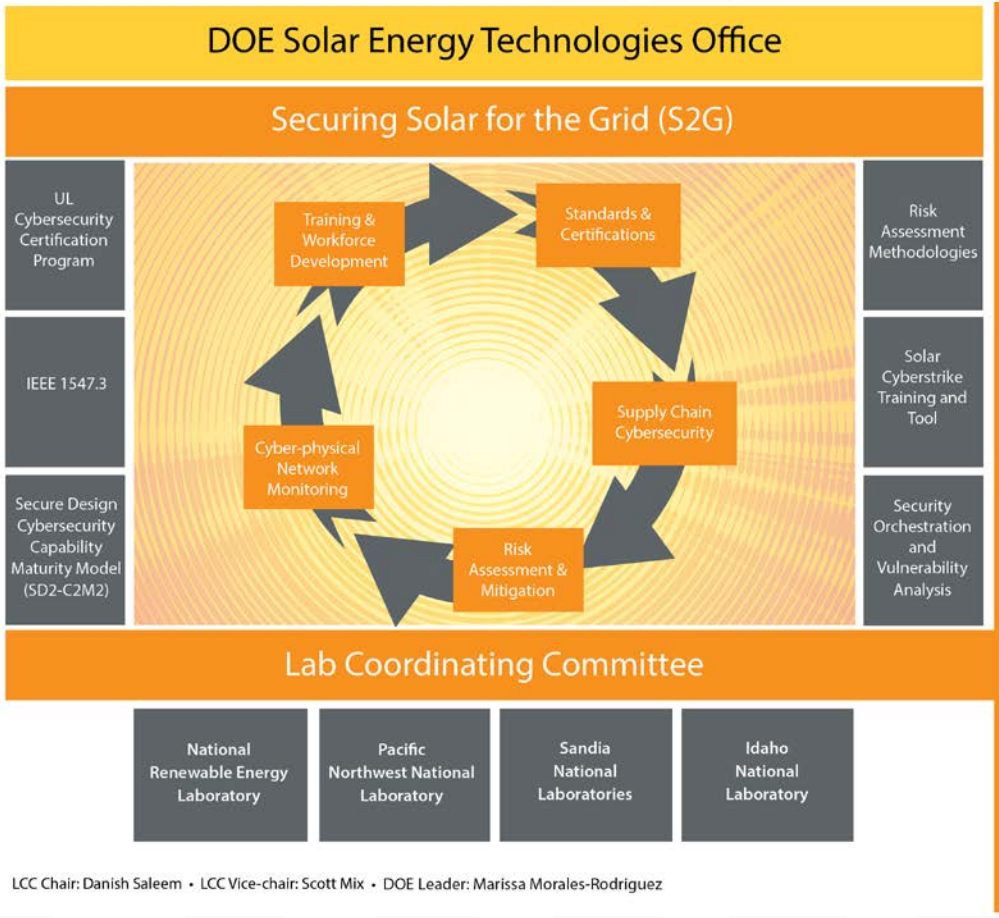
Outcome

Through S2G, NREL supported the development of standards & certification, help improved DER supply chain cybersecurity, and developed cybersecurity risk profiles to understand benefits or implications for leveraging distributed energy resource management systems (DERMS) in centralized utility DERMS deployments or decentralized aggregator DERMS



Industry Advisory Board

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National Rural Electric Cooperative Association
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Operant Networks
San Diego Gas & Electric
Smart Electric Power Alliance
Solar Energy Industries Association
Solectria
Southern California Edison
SunSpec Alliance
UL

Key Milestones for NREL

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Cybersecurity Certification Standard	Cybersecurity Guide for DERs	Solar PV Supply Chain Cybersecurity	Cybersecurity Guide for DERs
Lead the development of a cyber certification standard for solar PV industry	Develop a guide with recommendations for cybersecurity of DERs i.e., IEEE 1547.3	Analyze and document the gaps in the supply chain cybersecurity for DERs	Identify applicable cybersecurity standards and/or guidelines for DERMS
Develop test guidance to support UL 2941 certification standard	Integrate cybersecurity recommendations into IEEE 1547 standard	Publish cybersecurity recommendations for solar PV industry	Identify cybersecurity considerations for DERMS
Support consensus development for UL 2941 among OEMs, utilities, installers, and aggregators		Lead a solar supply chain cybersecurity workshop	Develop cybersecurity risk profiles for DERMS

Impact of NREL's Work Through S2G

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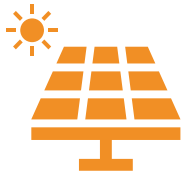
Led S2G proposal in FY 2018

Led the laboratory coordination committee (LCC) as chair in FY22 and FY23, and as vice chair in FY24

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

Co-led the development IEEE 1547.3 cybersecurity guide for DERs



Conducted gap analysis for DER supply chain cybersecurity

Compiled supply chain cybersecurity recommendations

Defined DERMS cybersecurity risk profiles

Coordination of cybersecurity requirements from key industry stakeholders

Developed testing guidance for cyber certification of PV inverters

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

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

Developed impactful reports and research papers to pave the way for new cybersecurity standards, certifications, tools, and recommended practices for DERs

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.

UL 2941: Cybersecurity Certification Standard

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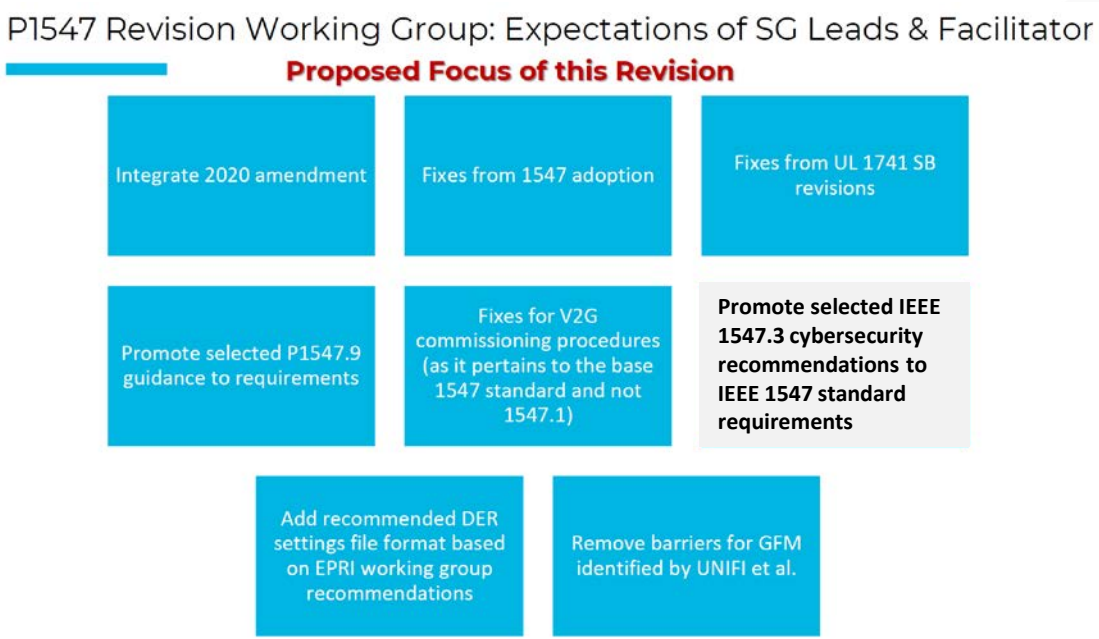
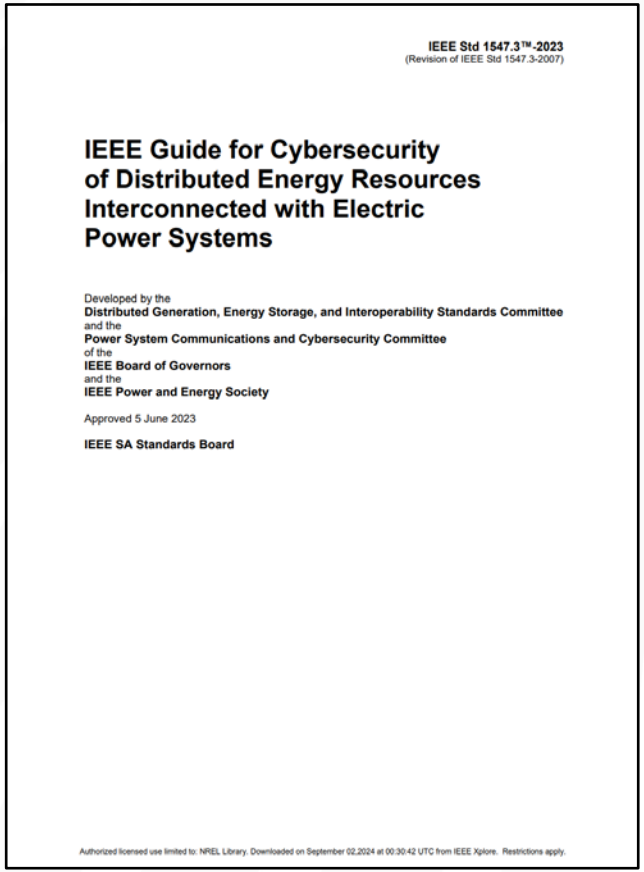
https://www.ul.com/news/ul-and-nrel-announce-cybersecurity-testing-recommendations-distributed-energy-resources-and
https://www.ul.com/news/ul-solutions-and-nrel-announce-distributed-energy-and-inverter-based-resources-cybersecurity

IEEE 1547.3: Cybersecurity Guide for DERs



- 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

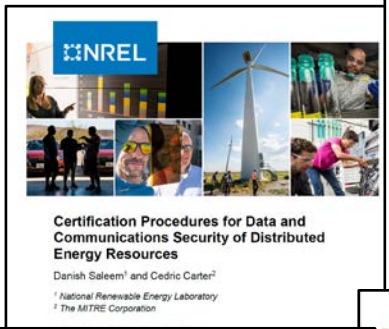
Developed by the
Distributed Generation, Energy Storage, and Interoperability Standards Committee
and the
Power System Communications and Cybersecurity Committee
of the
IEEE Board of Governors
and the
IEEE Power and Energy Society

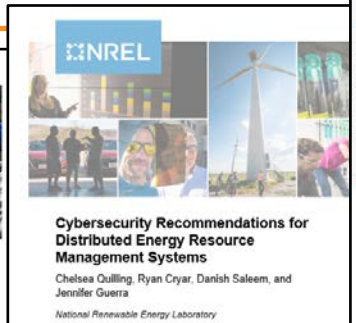
Approved 5 June 2023

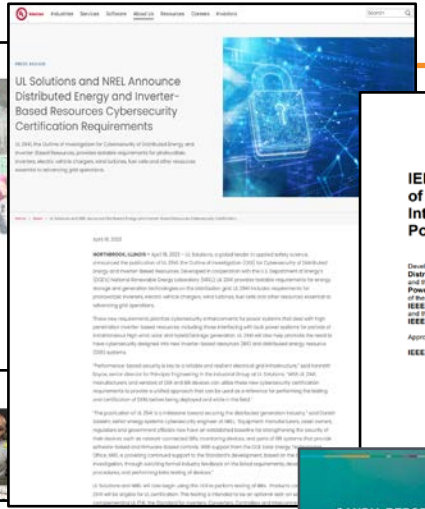
IEEE SA Standards Board

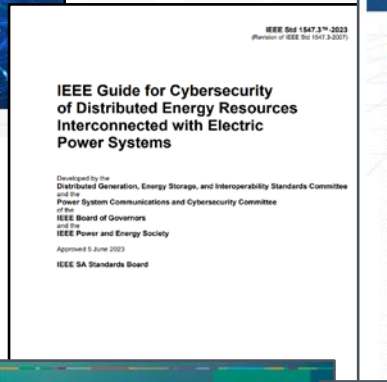
https://ieeexplore.ieee.org/document/10352402/keywords#keywords

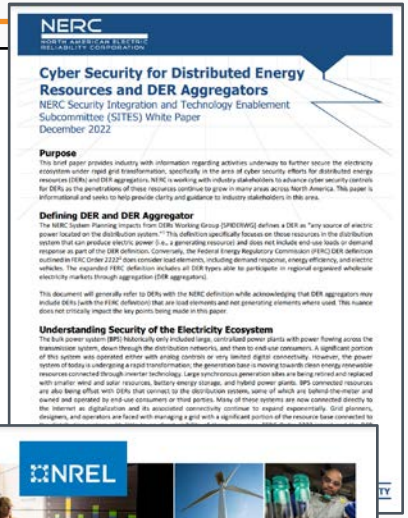
Publications

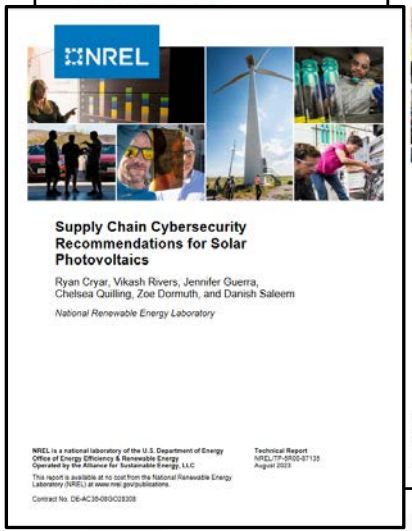


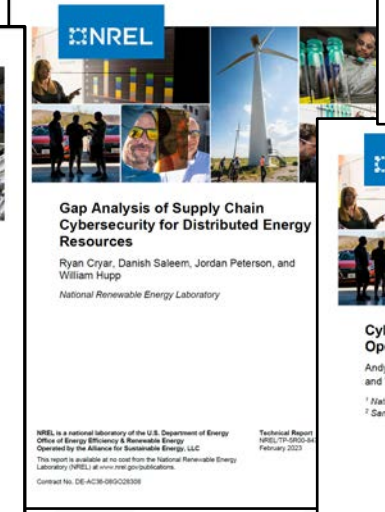


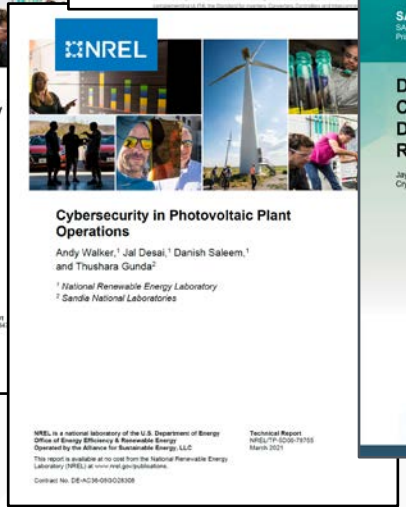


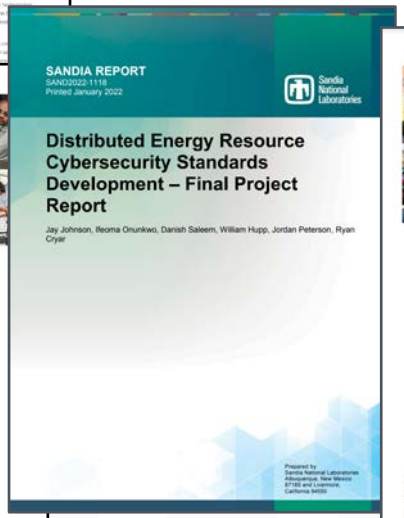












Industry Engagement: Publications

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- Cybersecurity Guidance for DERMS (Link to be added)
- UL 2941 Testing Guidance (Link to be added)
- S2G Final Report (Link to be added)
- Privacy and Security Impacts of DER and DER Aggregators
  - https://www.nerc.com/comm/RSTC_Reliability_Guidelines/JointWhitePaper_PrivacyAndSecurityImpactsOfDERAggregators.pdf
- Supply Chain Cybersecurity Recommendations For Solar Photovoltaics
  - https://www.nrel.gov/docs/fy23osti/87135.pdf
- Gap Analysis of Supply Chain Cybersecurity for Distributed Energy Resources
  - https://www.nrel.gov/docs/fy23osti/84752.pdf
- Design of Distributed Energy Resource Cybersecurity Certification Programs
  - https://www.researchgate.net/publication/371904823_Design_of_Distributed_Energy_Resource_Cybersecurity_Certification_Programs
- Cyber Security for Distributed Energy Resources and DER Aggregators
  - https://www.nerc.com/comm/RSTC_Reliability_Guidelines/White_Paper_Cybersecurity_for%20DERs_and_DER_Aggregators.pdf
- Cybersecurity Certification Recommendations for Interconnected Grid Edge Devices and Inverter-Based Resources
  - https://www.nrel.gov/docs/fy22osti/80581.pdf
- Distributed Energy Resource Cybersecurity Standards Development
  - https://www.osti.gov/servlets/purl/1843109/
- A Multidimensional Holistic Framework for the Security of Distributed Energy and Control Systems (*not S2G funded*)
  - https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8755282
- Cybersecurity in Photovoltaic Plant Operations
  - https://www.nrel.gov/docs/fy21osti/78755.pdf
- Certification Procedures for Data and Communications Security of Distributed Energy Resources
  - https://www.nrel.gov/docs/fy19osti/73628.pdf
- Recommended Functionalities for Improving Cybersecurity of Distributed Energy Resources
  - https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8972000

Industry Engagement: Presentations

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- Standards and Certification Panel at S2G annual workshop at hosted by RE+ in Anaheim (9/12/2024)
- Supply chain cybersecurity workshop, hosted by NREL (8/01/2024)
- S2G Panel at IEEE PES GM, hosted by IEEE in Seattle (7/24/2024)
- Cybersecurity training for FERC hosted virtually by FERC (04/25/2024)
- SETO peer review 2024_hosted by DOE SETO in Washington DC (03/27/2024)
- S2G Industry Advisory Board Meeting hosted virtually by NREL and INL (03/14/2024)
- RE+ 2023 Securing Solar for the Grid (S2G) Workshop in Las Vegas (09/14/2023)
- IEEE PES General Meeting_hosted by IEEE PES in Orlando (07/19/2023)
- IEEE 1547 Interoperability and Cybersecurity Working Group presentation delivered by NREL (05/31/2023)
- NERC RSTC meeting in Clearwater, Florida (03/24/2023)
- FY2023 Industry Advisory Board Meeting_hosted by NREL (02/27/2023)
- NERC DER workshop_hosted virtually by NERC and the SPIDERWG (12/14/2022)
- Wind Cybersecurity Workshop_hosted by NREL in Washington DC (09/27/2022)
- Re+ (Previously SPI)_Panel session with UL (09/22/2022)
- Cybersecurity training for state commissioners _hosted by NARUC (09/08/2022)
- Security Integration and Technology Enablement committee_ hosted by NERC (08/10/2022)
- King Abdullah City for Atomic and Renewable Energy_Delegation from Saudi Arabia (07/25/2022)
- Securing Solar for the Grid Workshop_hosted by NREL (07/20/2022)
- Cybersecurity and Technology Innovation Conference_hosted by DOE CIO (06/15/2022)
- Cybersecurity Advisory Team for State Solar (CATSS) _hosted by NASEO (01/24/2022)

Past Workshops/Meetings

July 2022

September 2024

September 2023