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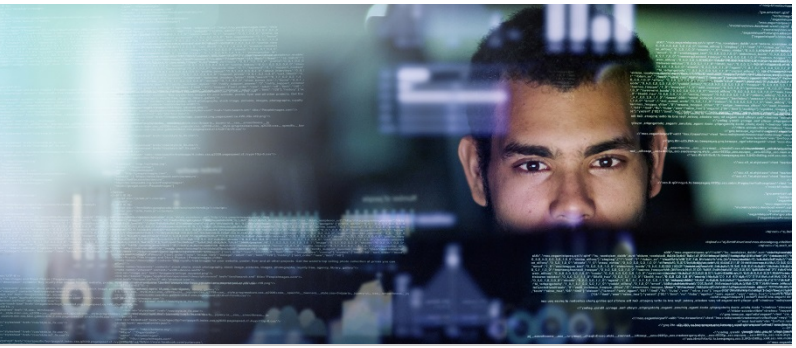

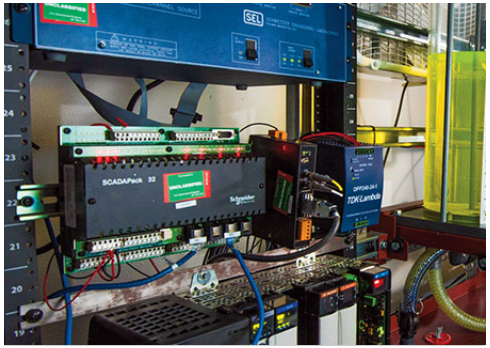

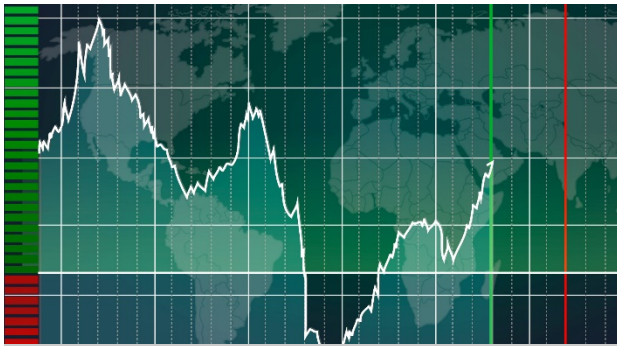

Cyber Security Assessments of DER

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Sandia's DER Cyber Team

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Outline

- Cyber Assessment Motivation
- Ideology, Methodology, and Sources
- Targeted Devices
- Cyber Assessment
  - Test Plan Overview
  - Test Cases
- Conclusions
- Q&A

Motivation for DER Cyber Assessments: DER Interoperability

- Distributed Energy Resource (DER) interconnection standards are being re-written to include communication requirements:
  - CA Rule 21 Phase 2 and 3 address communications and advanced grid functions requiring communications
  - IEEE 1547 full revision will require interoperability for DER equipment
- Many DER already include communications for monitoring and reporting
- New advanced grid function requirements require DER to adjust active and reactive power levels
- Control of an aggregation of DER is equivalent to controlling a large centralized power plant
- **It is critical to secure DER communications**

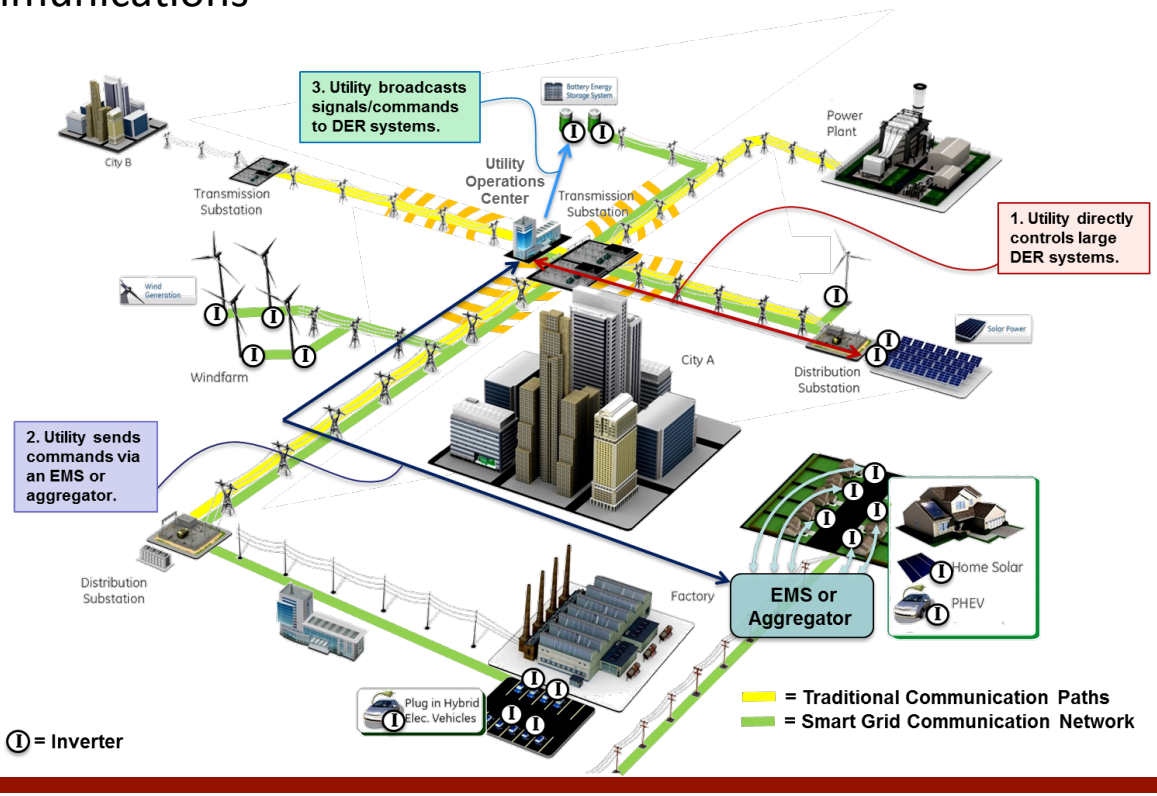

Image: Forbes India

Goals for DER Cyber Assessments

- Goal: **understand weaknesses** in the current state-of-the-art to assist solar industry with **good cyber-secure designs**
  - Partner with multiple vendors to address potential DER cyber security issues
    - Assessment to act as starting place for new SunSpec Alliance DER Cyber Security Working Group - ***starting soon***
- Scope: Target multiple Photovoltaic (PV) inverters and gateway devices to study and identify the **feasibility** and **ease** of cyber attacks on DER devices
- Outcome: Generalized recommendations for securing DER communications
  - Recommend communication protocols which provide the greatest security.

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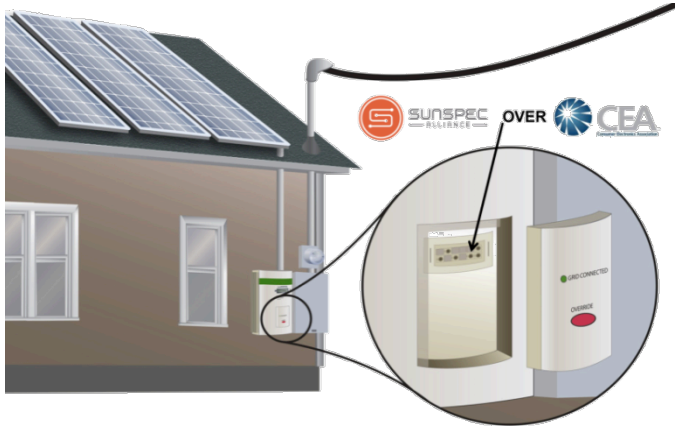

Possible Translation Idea: SEP 2.0 to Modbus

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Who are we?

An ethical red team that identifies and defines security vulnerabilities in a system

source: WittySparks.com

Advantage

Performing methodical assessment of a network or system to reveal vulnerabilities and mitigate them, thereby resulting in stronger security

Disadvantage

Performing any fraudulent activity on someone else's network without approval is a crime

Ideology, Methodology and Sources – Part I

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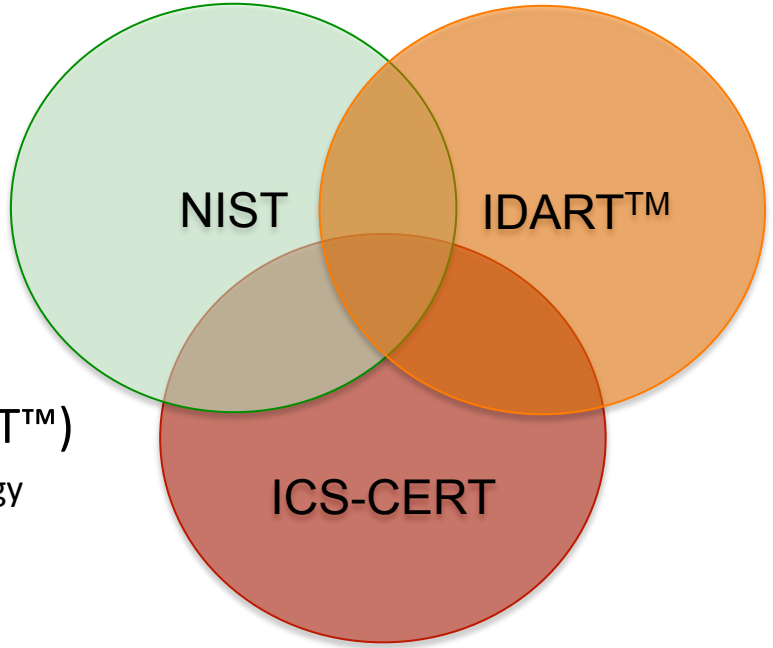
- Our team combined practices from multiple sources in creating our cyber assessment test plan for DER devices at Sandia's Distributed Energy Technologies Lab (DETL)
- We identified gaps and correlations between multiple methodologies and best practices to form a practical test plan that would be utilized for a range of DER devices
- Sources include:
  - NIST
    - Guide to ICS Security
      - » (800-82, rev 1)
  - SNL/Information Design Assurance Red Team (IDART™)
    - Sandia's Red Teaming Methodology
  - DHS/ICS-CERT
    - Cyber Security Assessments of ICS
      - » Practice Guide



Ideology, Methodology and Sources - Part II

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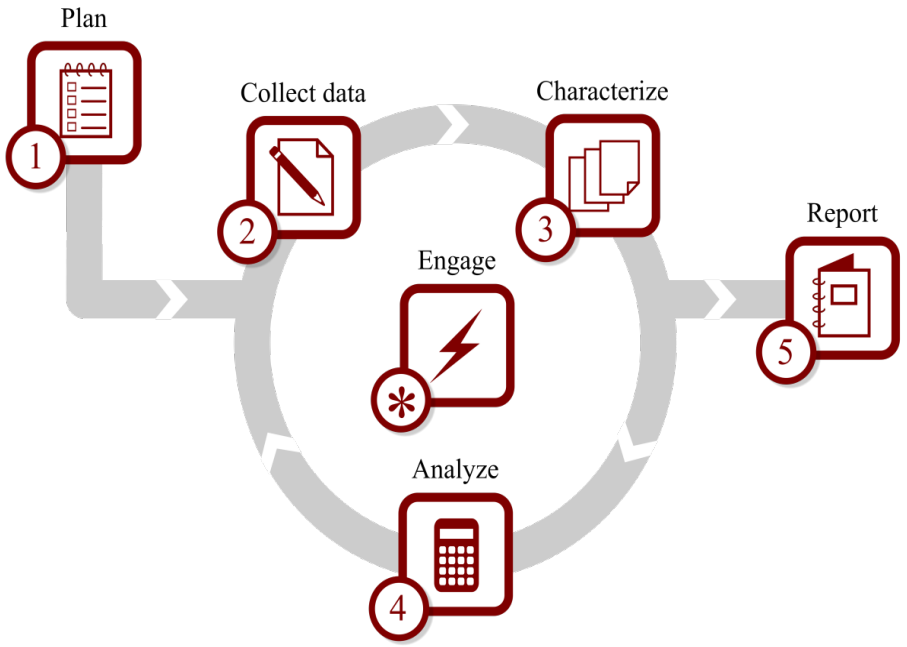
Information Design Assurance Red Team (IDART™)

- Authorized, adversary-based assessment for defensive purposes
- Understand adversaries and operational environments, assess threats



IDART™ Methodology Overview Framework, 2014

Targeted Devices

- *Completed DER Assessments*
  - **Inverter**
    - NRTL-listed inverter with a user-friendly graphic display
    - Equipped with serial and Internet Protocol (IP) interfaces for communication
  - **Two PV Gateways**
    - Provides data exchange with the vendor's inverter
    - A Graphical User Interface (GUI) for easy PV data monitoring
- *Current Work*
  - **Additional Inverters**
    - Residential solar inverter that has wireless and serial capabilities for communication
    - Microinverter-based system communicating with gateway

Cyber Assessment

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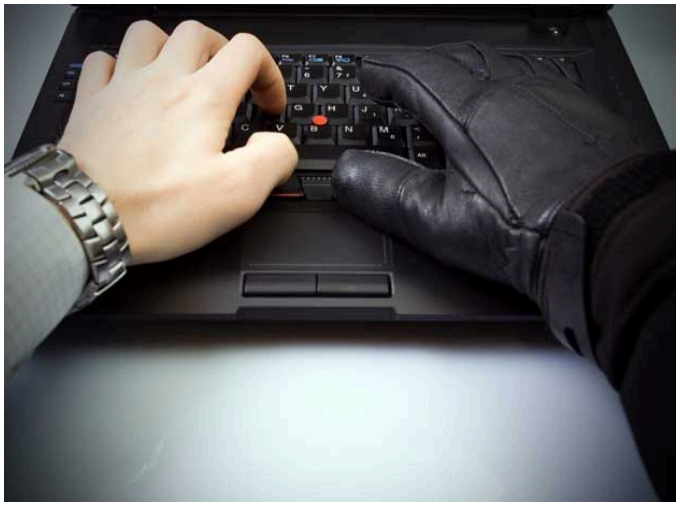
- Test Plan Overview
  - The overall goal of our vulnerability assessment and ethical penetration test were not to seek a "100-percent" secure system, but rather to take a snapshot of the security profile of the system
    - *This enables the team understand potential security risks and provide mitigations*
    - *Recommendations fed back to manufacturers*
    - *Generalized recommendations will be shared with solar industry*
  - For our vulnerability and penetration tests, we used Kali Linux OS and a range of 3rd party tools that are equipped with network scanning and network exploit tools
  - The test cases were modeled based on an adversarial attack pattern that could be carried out on a DER device or network



Source: http://www.security-faqs.com/wp-content/uploads/2011/06/what-is-an-ethical-hacker.jpg

Cyber Assessment

- Test Cases
  - In our assessment, we performed and/or evaluated the following:
    - *Network Reconnaissance*
    - *Packet Replay and Authentication of Data*
    - *Man in the Middle Attack*
    - *Denial of Service Attack*
    - *Vulnerability Scans*
    - *Modification Firmware Upload*
    - *DER Log Management*
    - *Password Handling*
  - Details are presented in the final manuscript paper
  - Two examples are shown in the next slide

Cyber Assessment

- *Packet Replay*
  - Validates the protection and authentication of data transfer from source transmitter (TX) to the destination receiver (RX)
    - Some DER clients' traffic can be replayed impersonating a legitimate user
    - Traffic replay could change inverter functions, settings, DER name, IP address, etc.
- *Man-in-the-Middle Attack*
  - Verifies communication is secure and confidential over authenticated channels
  - Targeted TCP/UDP connection between the client and the DER
  - A successful Man in the Middle intercepts, alters, or blocks communication
    - Address Resolution Protocol (ARP) poisoning forces malicious entries in a victim's ARP table and links the attackers MAC address with the IP address of the victim

Packet Replay

Eavesdrop → **Custom script** → **Digital & Physical effects**
Voltage settings were updated

MiTM

Network Access → **ARP Poison** → **Digital effects**
HMIs report false state

Conclusions

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- New DER interconnection/interoperability standards are **requiring DER to communicate** over open Internet channels to aggregators and utilities
- This **expands the cyber attack surface** of the DER
  - Unauthorized aggregation control of DER devices could cause large-scale power disruptions
- Sandia **investigated DER devices** to understand current security practices and system weaknesses in order to advise the DER industry
- **Extensive recommendations** provided in paper, e.g.:
  - Encrypt and authenticate data exchange ***{Client<->[DER|SERVER]}***
  - Application services should be running on secure ports
  - Update devices to the latest patches and firmware regularly
  - Secure password strategies and polices should be implemented
  - Vulnerable applications like FTP or HTTP should be replaced with better secure versions like FTPS or HTTPS ***{FTP-SSL, HTTP-SSL/TLS}***
  - Implement proper firewall/network gateway rules to mitigate the effects of denial of service or unauthorized access
  - DER devices should be enclosed in a physical barrier to prevent unauthorized access ***{Physical Security}***
  - Manufacturers should practice the *Principal of Least Privilege* on all applications operating on DER devices and systems.

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Q&A

If interested in joining the SunSpec **DER Cyber Security Working Group** please contact Jay Johnson at jjohns2@sandia.gov