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Collaborative Development of Automated Advanced Interoperability Certification Test Protocols for PV Smart Grid Integration

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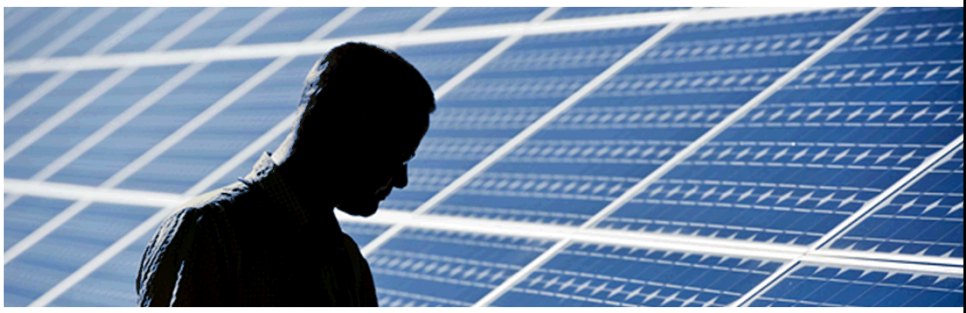

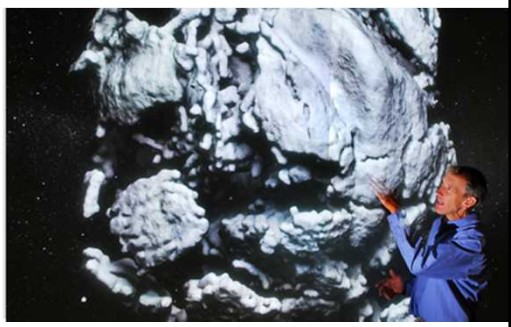

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SIRFN Smart Grid Collaboration

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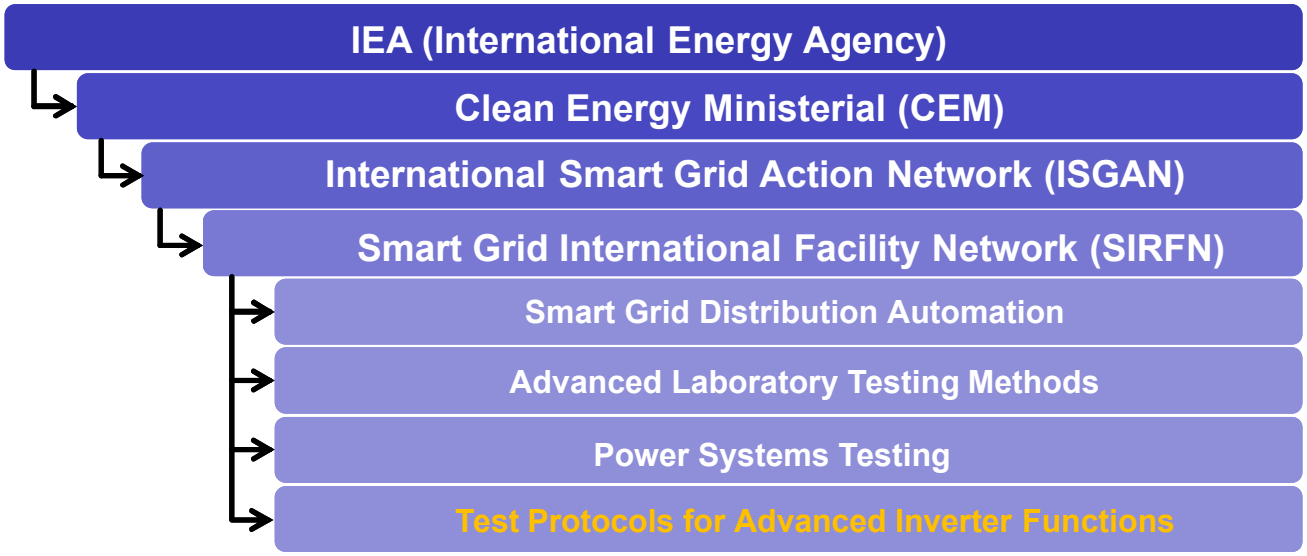
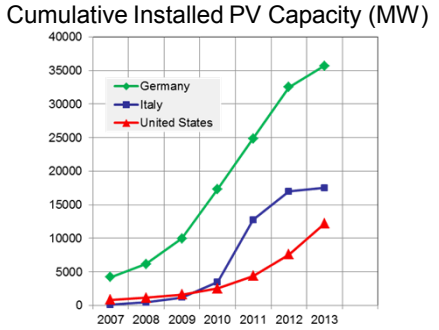


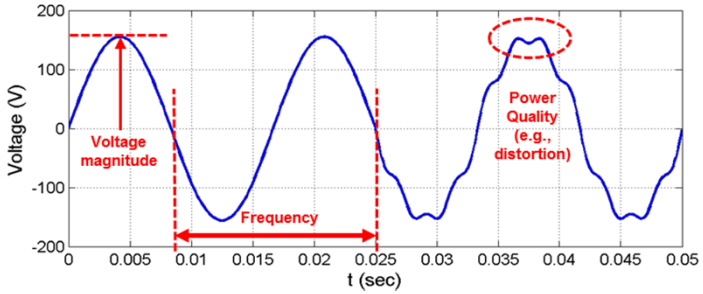
SIRFN - A coordinated network of smart grid research facilities from:

- **Primary goal**: Develop and demonstrate a consensus-based interoperability certification standard for advanced Distributed Energy Resources (DERs).
  - Design, compare, and construct advanced interoperability test-beds.
  - Perform round-robin testing of advanced DER.
  - Compare test results, communications methods, and automation procedures.
  - Gradually improve draft test procedures for advanced DER with the goal of becoming an internationally-accepted standard.

Importance of SIRFN Collaboration

- **SIRFN collaboration on testing standards is important to help accelerate the deployment of renewable energy around the world.**
  - Higher renewable energy penetrations
    → grid voltage and frequency stability concerns
  - Inverters must support/stabilize the grid
    - Revisions to interconnection standards (IEEE 1547) allow EPS support functions to be implemented
    - New interconnection requirements in California and Hawaii soon
  - Urgency in U.S. to certify inverters for new requirements – both electrical performance and communications
    - Need advanced inverter test protocols for CPUC/CEC California Rule 21
    - Sandia protocols act as basis for updates to UL 1741
  - **Final product:** robust consensus certification procedure for advanced inverter functions for adoption by international standards organizations





Smart Electricity Grid

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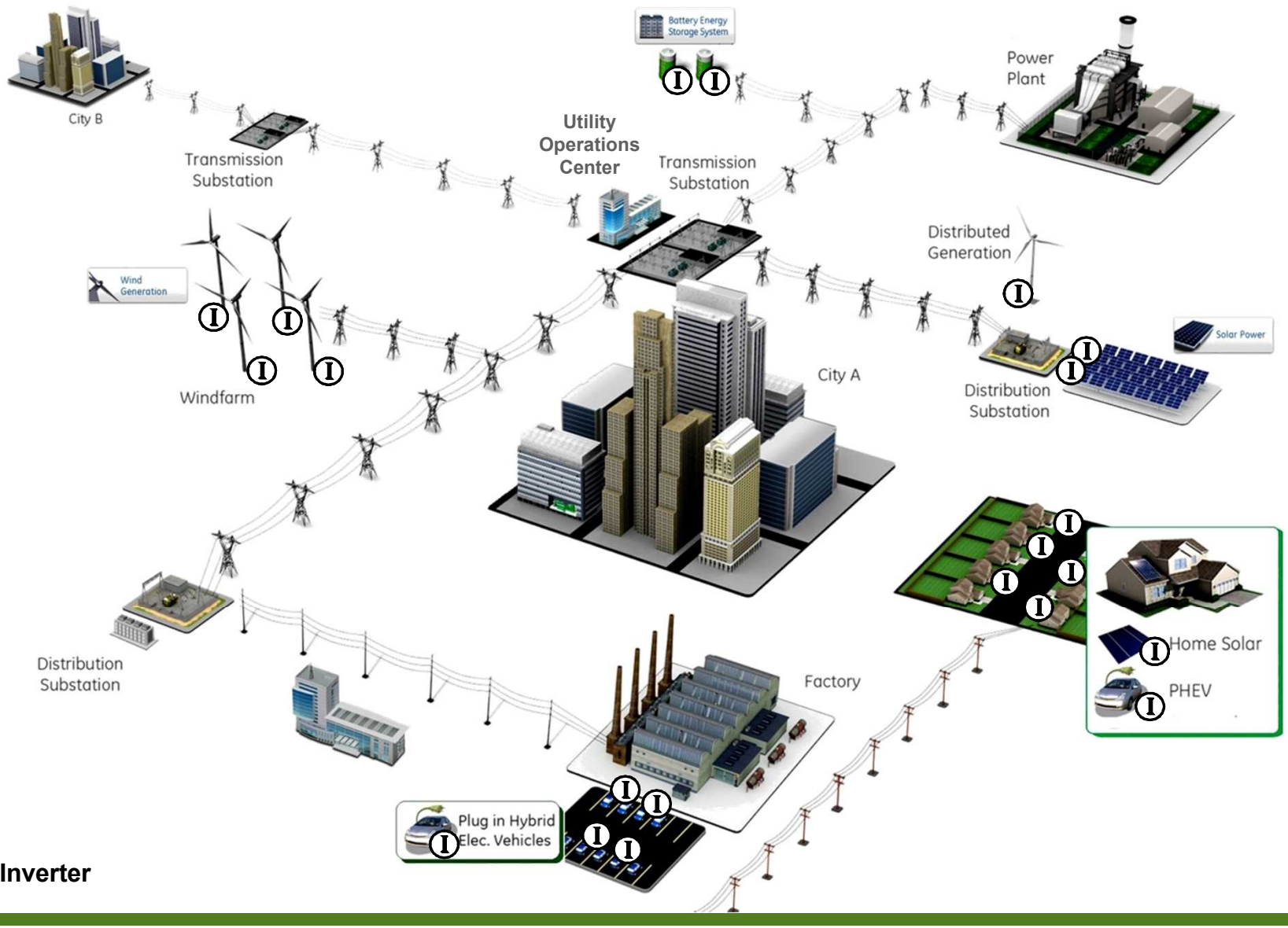

Image: Forbes India

Smart Electricity Grid Communications

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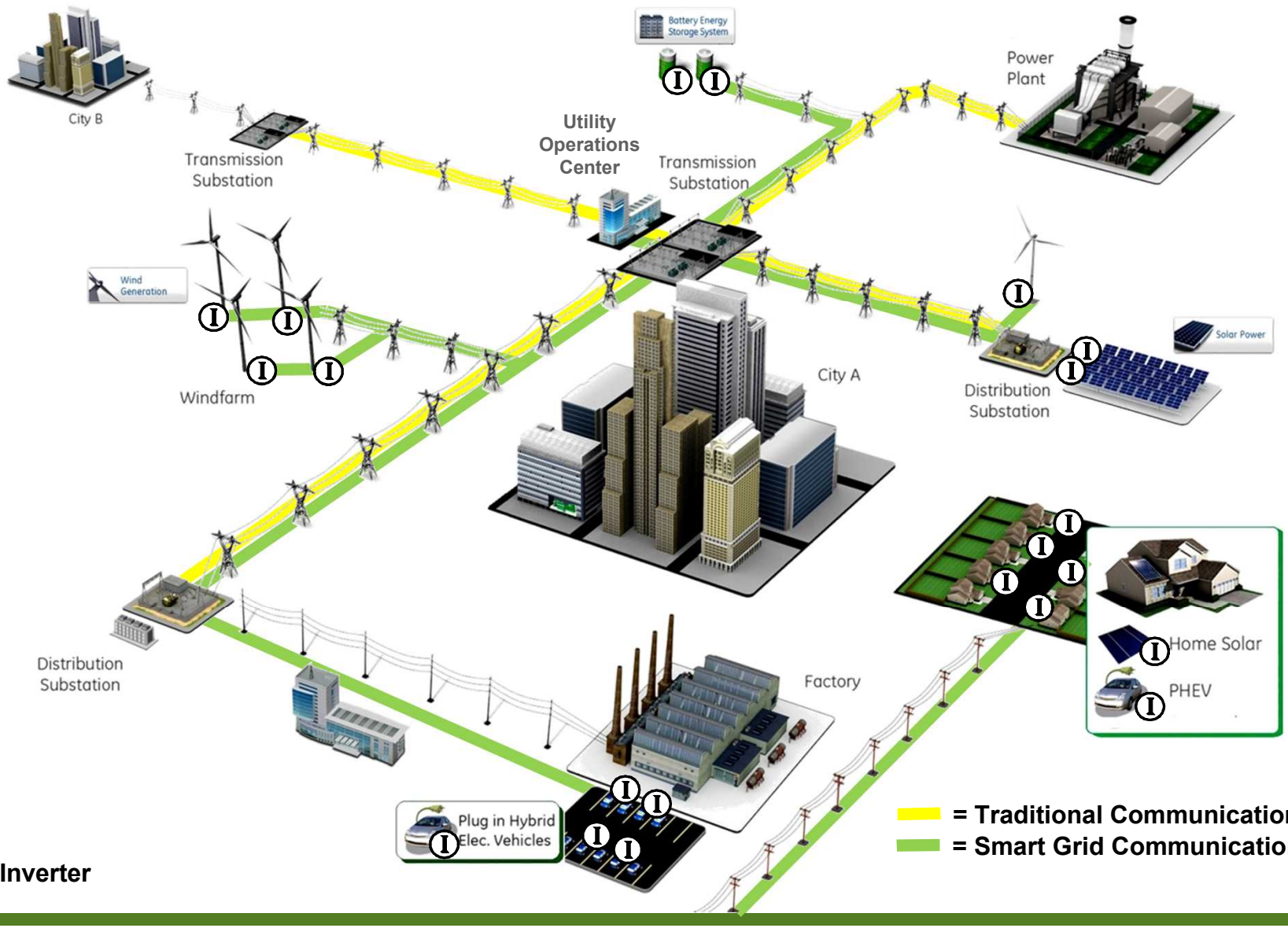

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Smart Electricity Grid Communications

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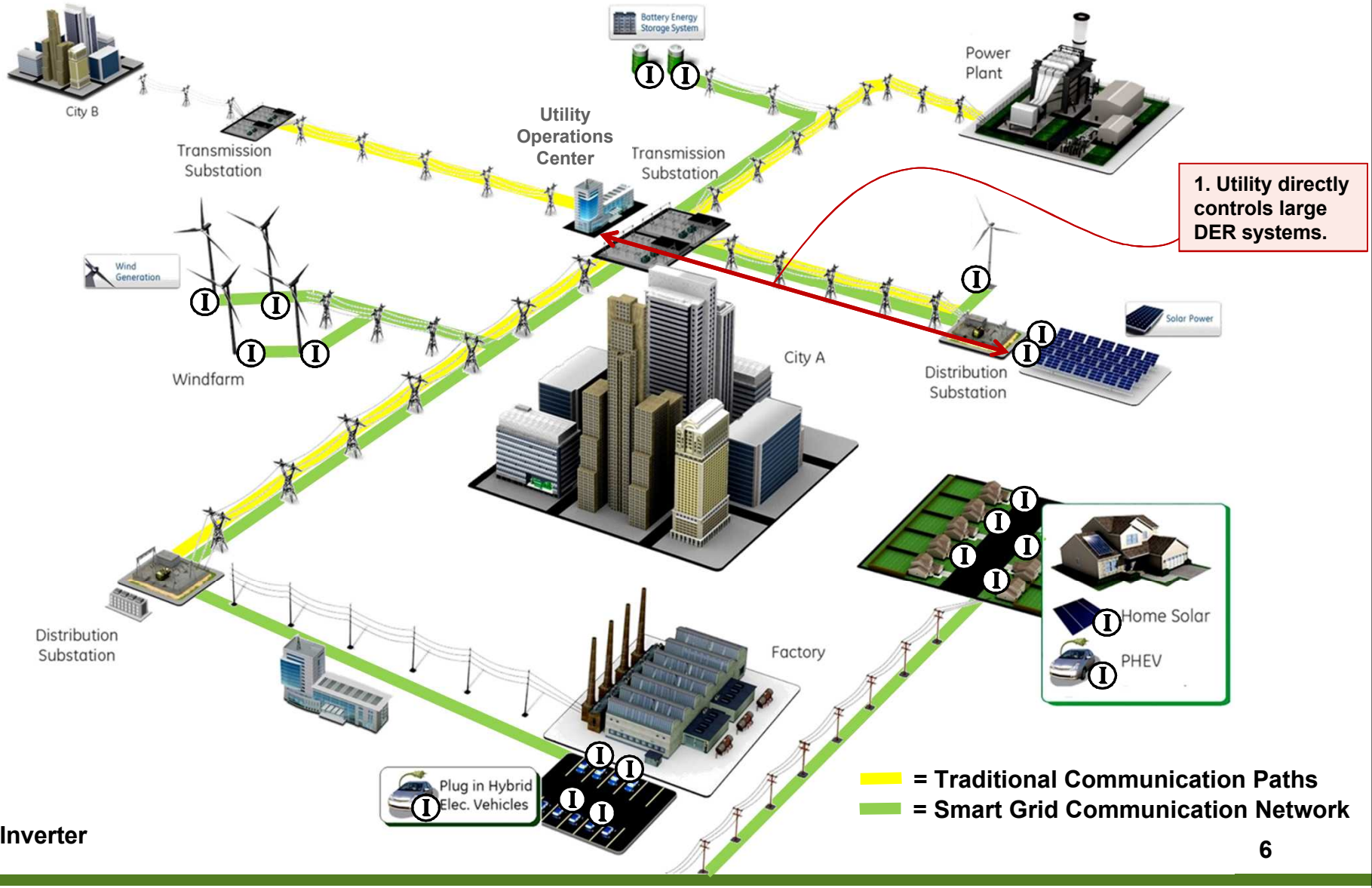

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Smart Electricity Grid Communications

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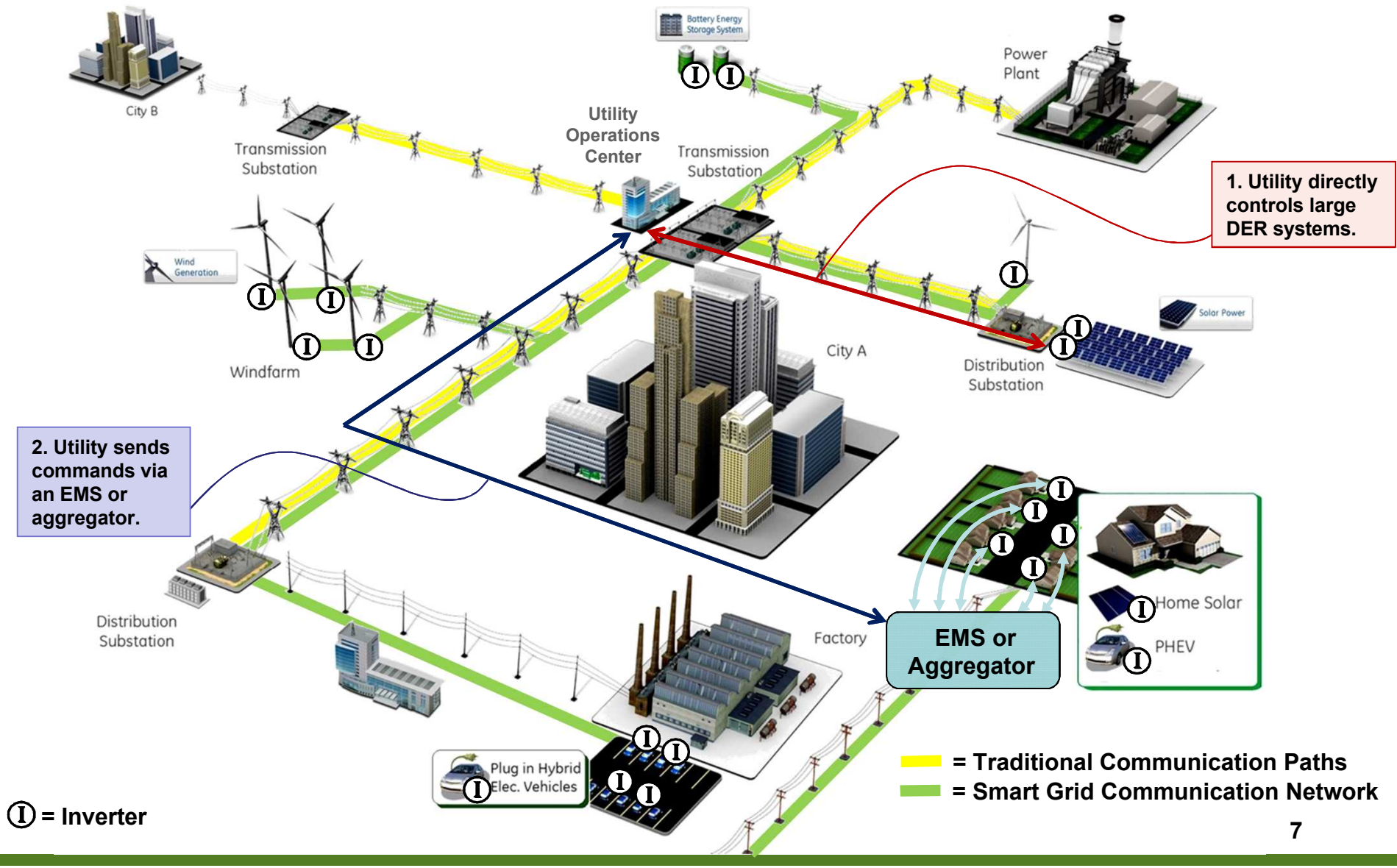

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Smart Electricity Grid Communications

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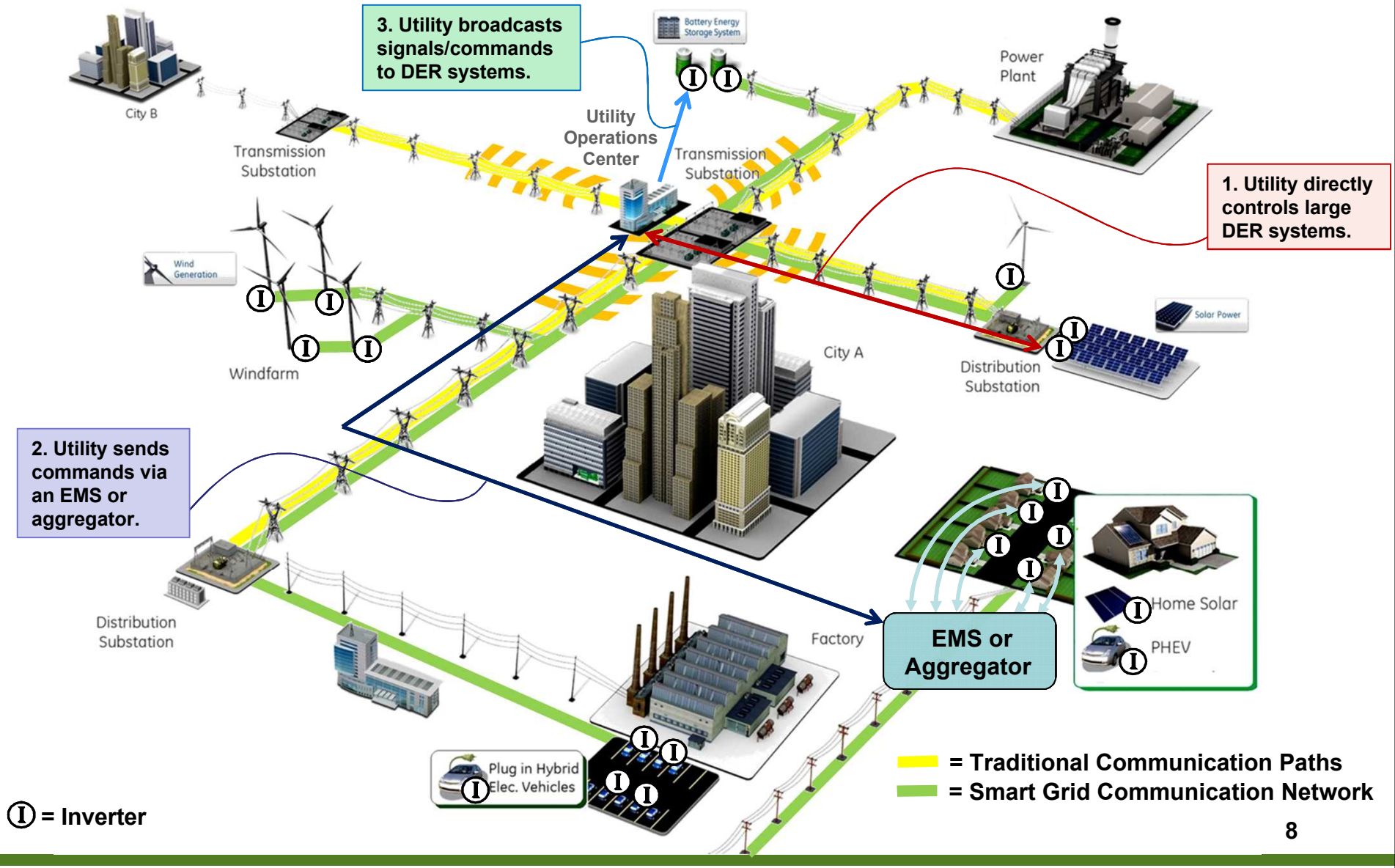
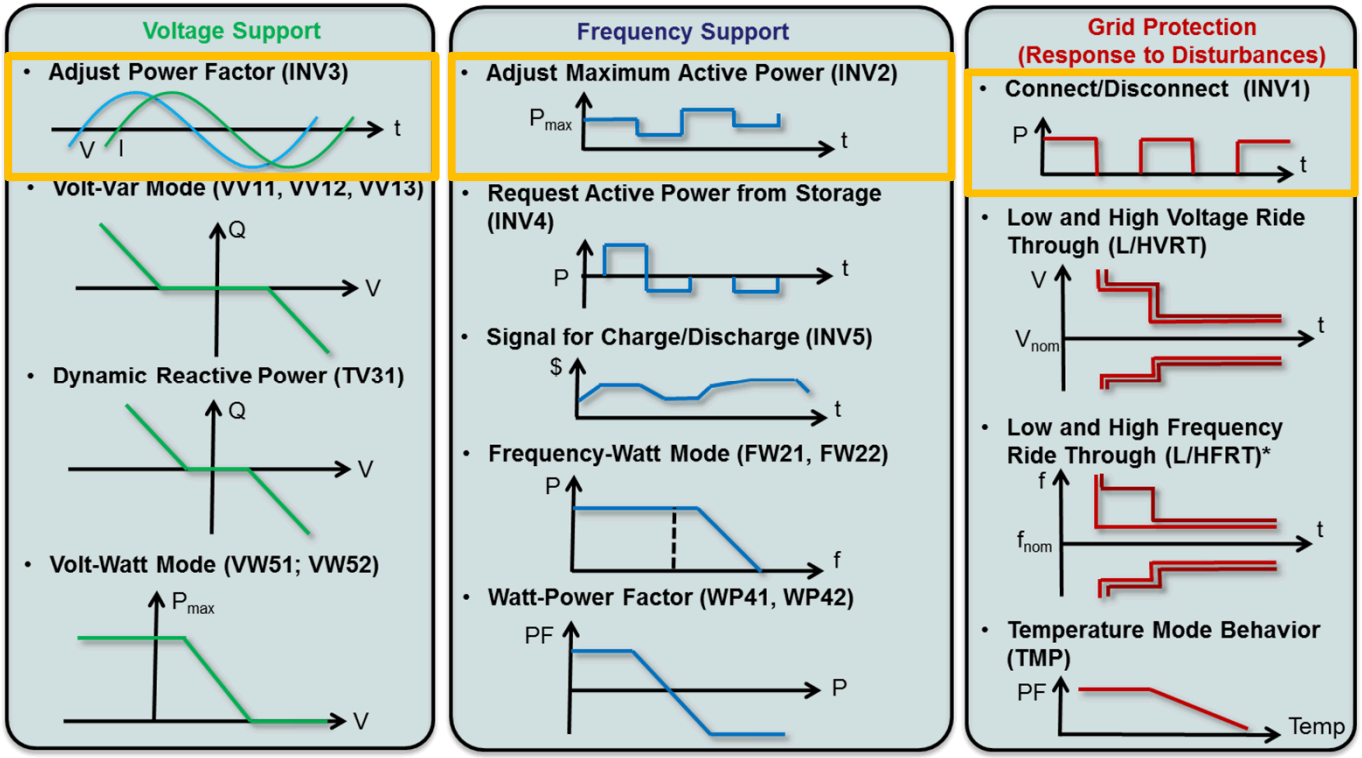


Source: Forbes India

Advanced Interoperability Functions

- New 'smart' inverters will include multiple advanced functions
  - Autonomous: Inverter response to local voltage and frequency conditions
  - Commanded: Remote control (e.g., on/off, set power factor)
- Utilities will modify distributed energy resource (DER) behavior using communications. Reliable interoperability will be required.



Advanced functions as defined in IEC TC 61850-90-7, *with the exception of FRT.

SNL and KERI Test-Bed Designs

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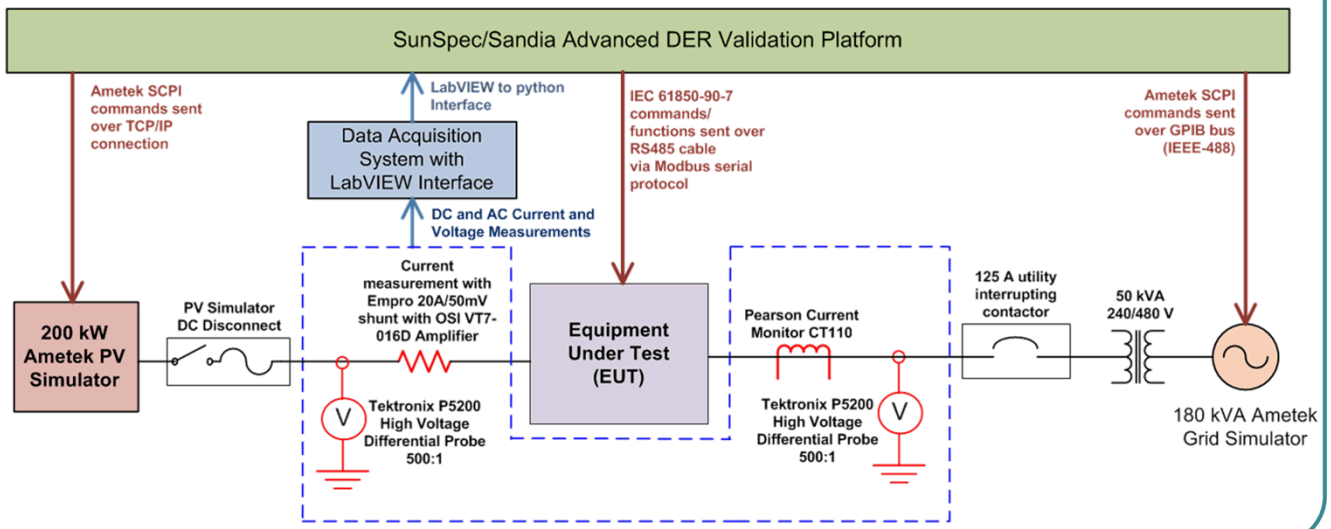
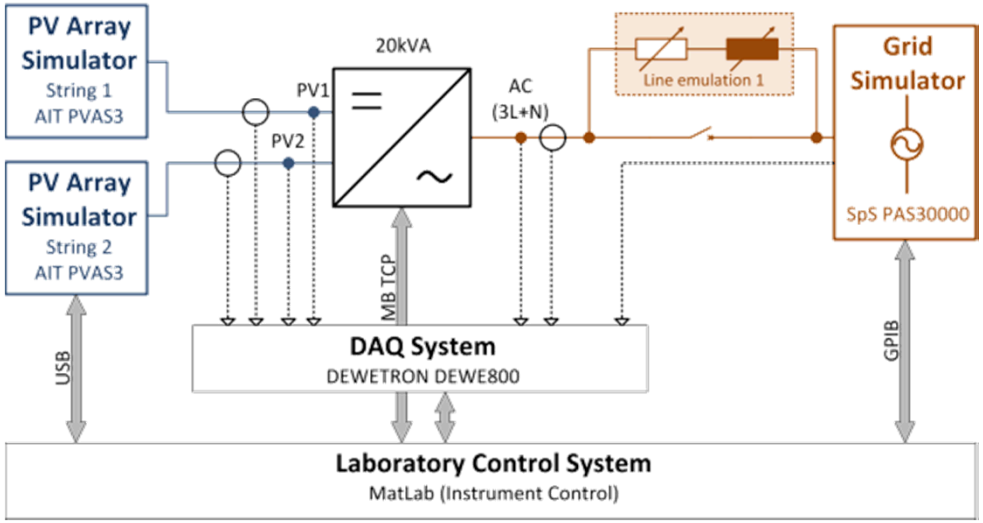


EUTs:
- SNL: 3 kW single-phase inverter
- AIT: 20 kW three-phase inverter
- Tecnalia: 5 kW single-phase inverter

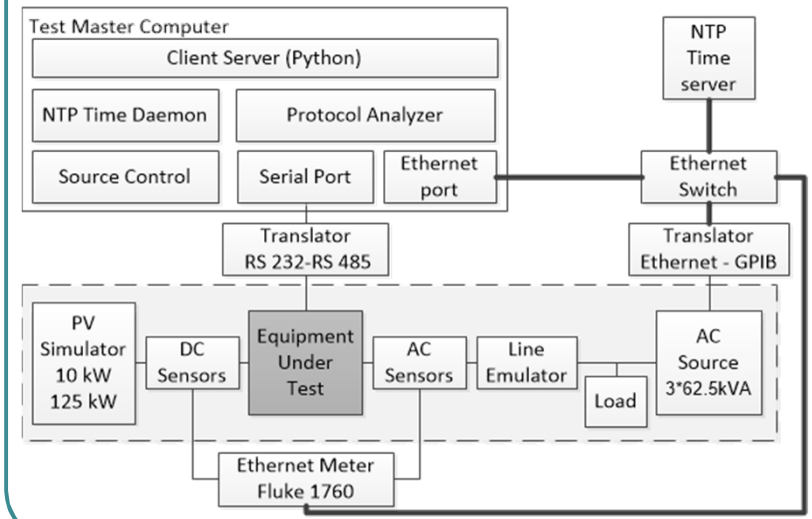
EUT Communications
- SNL: 61850-90-7 over serial
- AIT: 61850-90-7 over TCP
- Tecnalia: 61850-90-7 over serial

Control system
- SNL: SunSpec Test Tool (Python)
- AIT: Lab Control System (Matlab)
- Tecnalia: Master computer (Python)

Austrian Institute of Technology



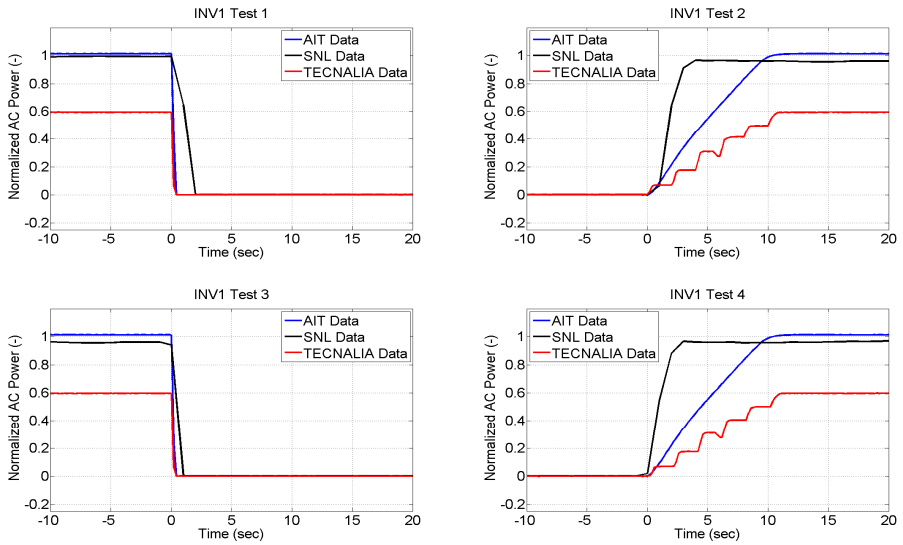
TECNALIA



Example Test Protocol (Procedure)

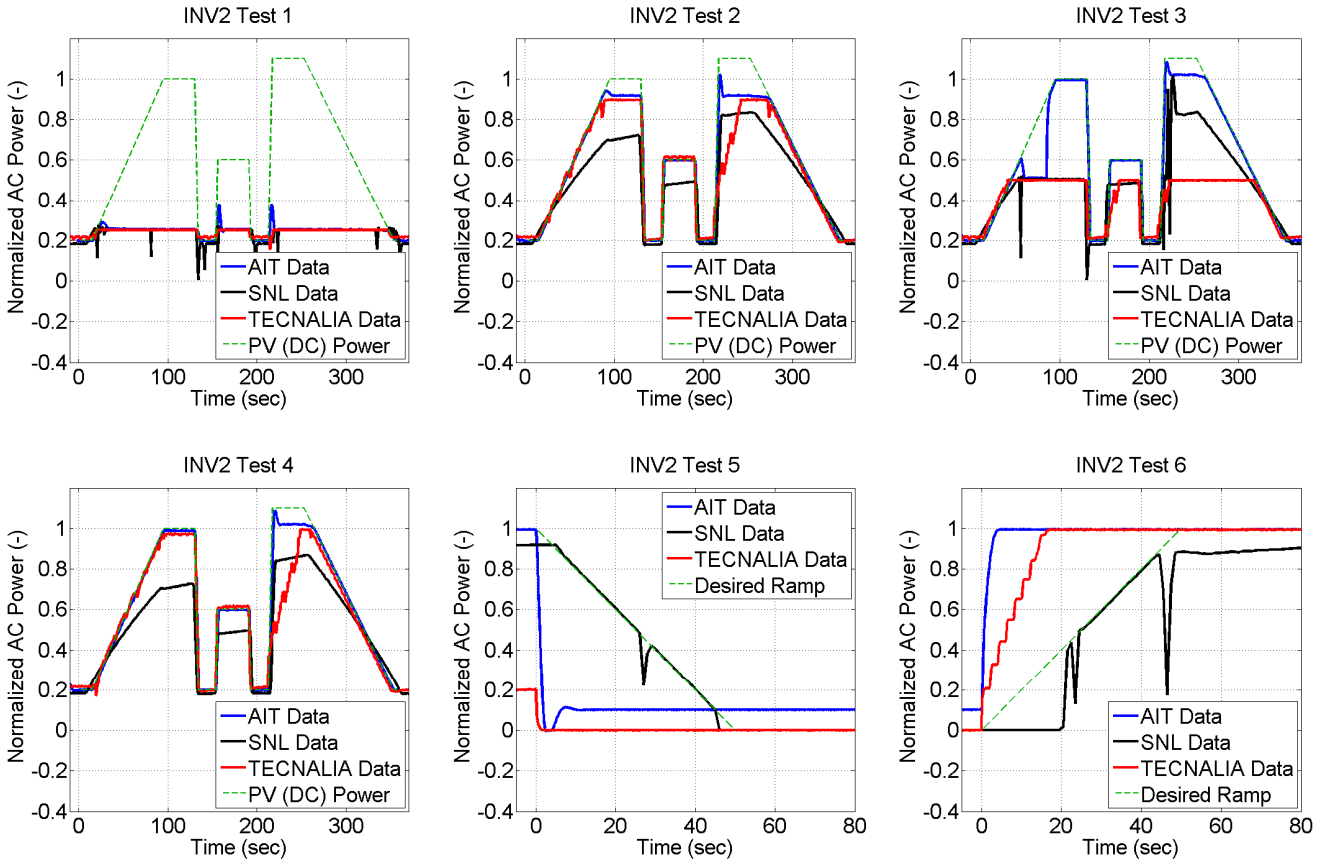
- The Sandia Test Protocols test matrix for the connect/disconnect command.
  - Seven tests with different operating points and parameters.
  - This test can be run autonomously, but others require more human interaction with simulators and DAQ.

Test	EUT Initial Operating State	Command	Time Window (sec)	Timeout Period (sec)
1	>50% rated power, unity power factor	Disconnect 1	Default (e.g., 0)	Default (e.g., 0)
2	Inverter off	Connect 1	Default (e.g., 0)	Default (e.g., 0)
3	>50% rated power, unity power factor	Disconnect 2	0	Default (e.g., 0)
4	Inverter off	Connect 2	0	Default (e.g., 0)
5	>50% rated power, unity power factor	Disconnect 3	90	30
6	>50% rated power, unity power factor	Disconnect 4	60	0 (No Timeout)
7	Inverter off	Connect 4	60	0 (No Timeout)



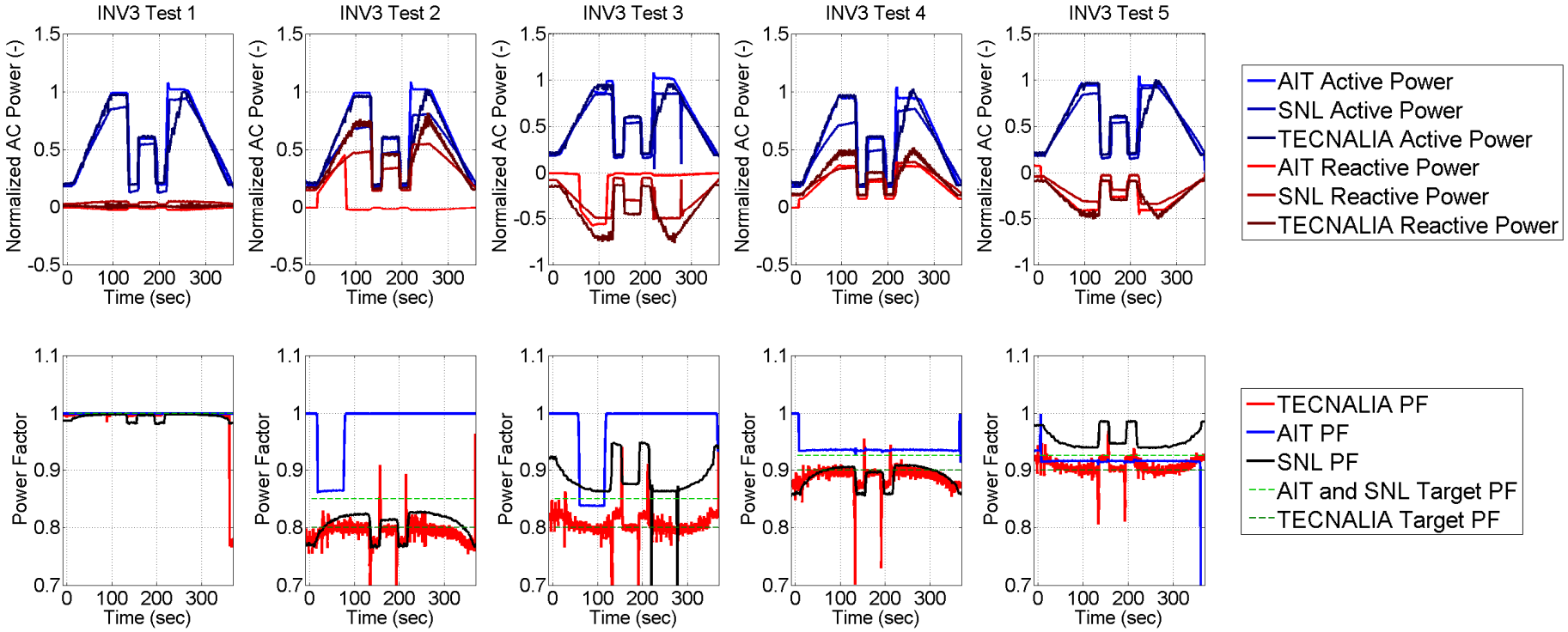
J. Johnson S. Gonzalez, M.E. Ralph, A. Ellis, and R. Broderick, "Test Protocols for Advanced Inverter Interoperability Functions – Appendices," Sandia Technical Report SAND2013-9875, Nov. 2013.

Real Power Curtailment (INV2) Results



Test	WMax (% nameplate)	Ramp Rate (% nameplate watts/sec)	Time Window (sec)	Timeout Period (sec)	PV Power Profile
1	25	0	0	0	Fig. A2- 1
2	90	0	300	0 AIT:60	Fig. A2- 1
3	50	20	60	30 AIT:60	Fig. A2- 1
4	100	0	0	0	Fig. A2- 1
5	0 AIT:10	2	0	0	Const.
6	100	2	0	0	Const.

Fixed Power Factor (INV3) Results



Test	Power Factor (INV3)	Ramp Rate (% nameplate watts/sec)	Time Window (seconds)	Timeout Period (seconds)
1	1.00 (default)	Default	0	Default
2	MinPFOverAval (e.g., 0.80 Overexcited)	Default	60	600
3	MinPFUnderAvail (e.g., 0.80 Underexcited)	Default	300	Default
4	0.5+MinPFOverAval/2 (e.g., 0.90 Overexcited)	10	Default	Default
5	0.5+MinPFUnderAvail/2 (e.g., 0.90 Underexcited)	Default	Default	1800

Conclusions

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- PV inverters advanced functions help stabilize the grid
- Need a standardized method for verifying the functionality
- SIRFN is improving certification protocols so they may be recommended as an international standard, by:
  - Building test-beds for advanced inverter testing (electrical performance and interoperability)
  - Comparing results from advanced DER functions
- This project identified differences in lab testing methodologies and led to improved testing protocols:
  - Must clean up ambiguous statements, e.g., when does the PV profile begin?
  - Need common definitions of measured and calculated (e.g., power factor) data channels
  - Need to better define sampling and recording rates to get repeatable results
  - However, different DER will lead to variability in results, e.g., reconnection time

Questions?

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Extra Slides