IEEE SA
STANDARDS ASSOCIATION

IEEE SMART GRID STANDARDS ENABLING SUSTAINABLE AND QUALITY INFRASTRUCTURE

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IEEE

AGENDA

Introduction of the Institute: IEEE & IEEE Standards

IEEE SA Smart Grid Standards

The world's largest professional association

Advancing Technology for Humanity

Global Reach	422,000+ Members 	160 Countries 	124,000 Student Members 	46 Technical Societies and Councils 
Technical Breath	1,800 Annual Conferences 	4,000,000 Technical Documents 	190 Top-cited Periodicals 	1,160+ Active Standards 
Social Impact	Global Public Policy 	Global Humanitarian Efforts 	Continuing Education & Certification 	Ethics in Technology 

IEEE SA STANDARDS ASSOCIATION

IEEE

THE WORLD'S LARGEST PROFESSIONAL ASSOCIATION

Advancing Technology for Humanity

- Aerospace and Electronic Systems
- Antennas and Propagation
- Biometrics Council
- Broadcast Technology
- Circuits and Systems
- Communications
- Components, Packaging, and Manufacturing Technology
- Computational Intelligence
- Computer
- Consumer Electronics
- Control Systems
- Council on Electronic Design Automation
- Council on Superconductivity
- Dielectrics and Electrical Insulation
- Education
- Electron Devices
- Electromagnetic Compatibility
- Engineering in Medicine and Biology
- Geoscience and Remote Sensing
- Industrial Electronics
- Industry Applications
- Information Theory
- Instrumentation and Measurement
- Intelligent Transportation Systems
- Magnetics
- Microwave Theory and Techniques
- Nanotechnology Council
- Nuclear and Plasma Sciences
- Oceanic Engineering
- Photonics
- Power Electronics
- Power & Energy
- Product Safety Engineering
- Professional Communications
- Reliability
- Robotics and Automation
- Sensors Council
- Signal Processing
- Social Implications of Technology
- Solid-State Circuits
- Systems, Man, and Cybernetics
- Systems Council
- Technology and Engineering Management
- Ultrasonics, Ferroelectrics, and Frequency Control
- Vehicular Technology

WHAT DOES THE IEEE STANDARDS ASSOCIATION (IEEE SA) DO?

Vision: To be a world-class standards-development organization

Mission: To provide a high-quality, market-relevant standardization environment, respected worldwide

IEEE standards span a broad spectrum of technologies, such as:

- Aerospace Electronics
- Broadband Over Power Lines
- Broadcast Technology
- Clean Technology
- Cognitive Radio
- Design Automation
- Electromagnetic Compatibility
- Green Technology
- Ethernet/WLAN
- Medical Device Communications
- Nanotechnology
- Organic Components
- Portable Battery Technology
- Power Electronics
- Power & Energy
- Radiation/Nuclear
- Reliability
- Transportation Technology

CLOSE ENGAGEMENT WITH INDUSTRY

In both Individual and Corporate Programs

Influence technology development

- Incubate new technologies, standards and related services in a rapidly changing environment
- Shape the direction of technology and its marketplace applications

Drive the development of corporate standards

- Gain advanced knowledge by engaging in corporate standards projects

Network with global thought leaders

Participate in an engaging environment of technical experts

IEEE SA COMPLETE BUSINESS LIFECYCLE

- **Industry Connections** program addresses emerging technology issues where the needs for standards and related services are at the early formation stage
  - a venue for member collaboration to address new technology issues
- The **IEEE Standards Development** process produces results that reflect the collective, consensus view of participants and enables industries to achieve specific objectives and solutions
- The **IEEE Conformity Assessment Program (ICAP)** facilitates the development of test suites, test programs and certification services to assess whether standards are “met”

WHAT ARE STANDARDS?

Standards are published documents that establish specifications and procedures designed to ensure the **reliability** of the materials, products, methods, and/or services people use every day

Standards form the fundamental building blocks for product development by **establishing consistent protocols** that can be universally understood and adopted

- ✓Standards establish **compatibility, interconnectivity, interoperability,** simplify product development, and speed time-to-market

Standards make it easier to understand and **compare** competing products

As standards are globally adopted and applied in many markets, they also help with **international trade**

Standards fuel **innovation, the development and implementation of technologies** that influence and transform the way we live, work and communicate

AGENDA

Introduction of the Institute: IEEE & IEEE Standards

IEEE SA Smart Grid Standards

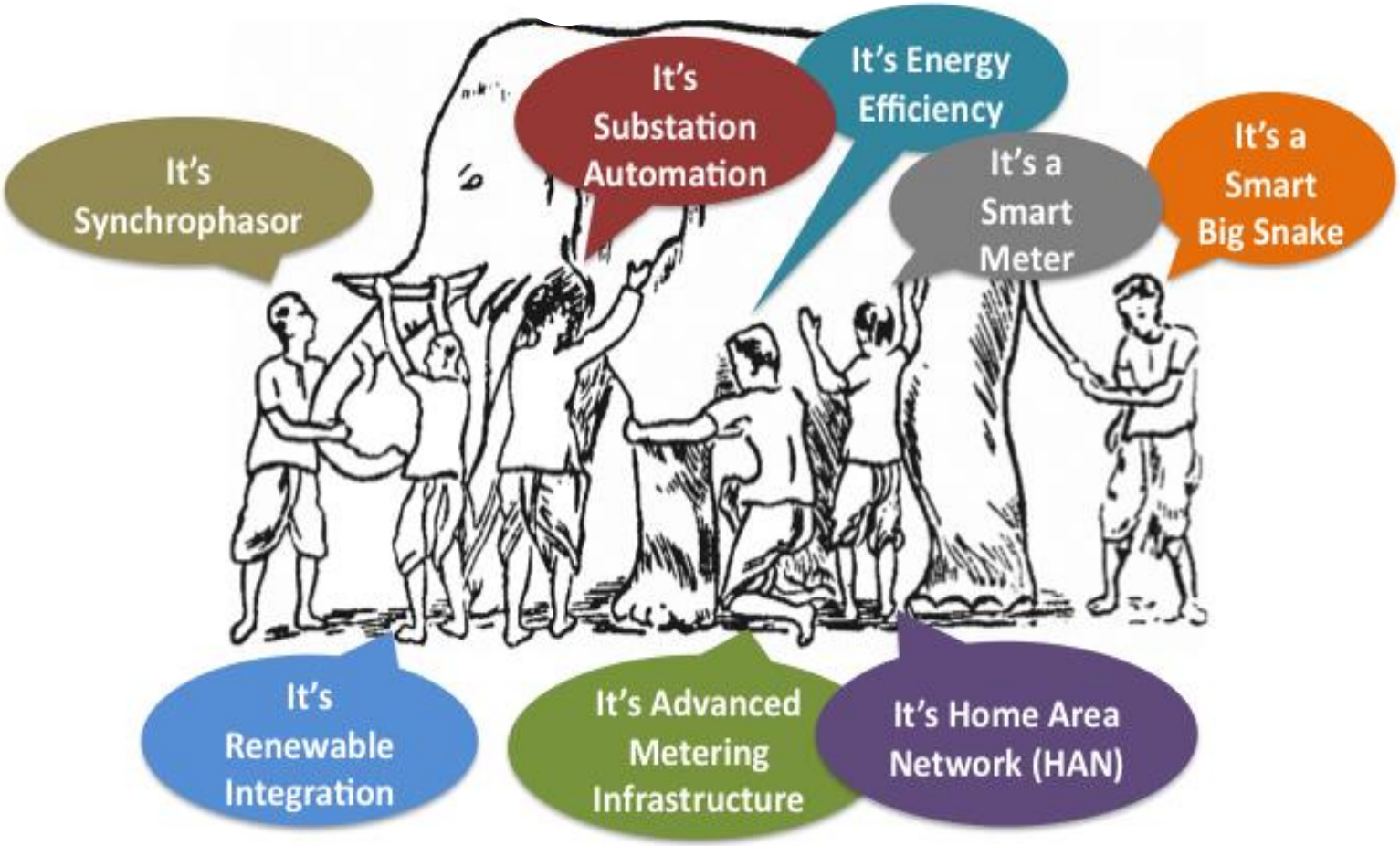
SMART GRID: A NEW BUSINESS FRONTIER

One of the largest opportunities of this century

About $13 trillion will be spent on modernizing power grids worldwide by 2030, of which "hundreds of billions" will flow to smart grid projects

- Source: *Smart Grid Today*

THE HOLISTIC APPROACH TO SMART GRID



WHAT IS A SMART GRID SYSTEM?

An intelligent electricity-delivery system:

- Energy suppliers and consumers: interconnect through a network

Smart meters:

- Are installed at homes and businesses
- Monitor energy consumption
- Transmit that information back to energy providers

Energy providers:

- Track energy consumption
- Automatically throttle down energy consumption on a granular level when demand gets too high.

HOW – THE ACTUAL IMPLEMENTATION

The Smart Grid is:

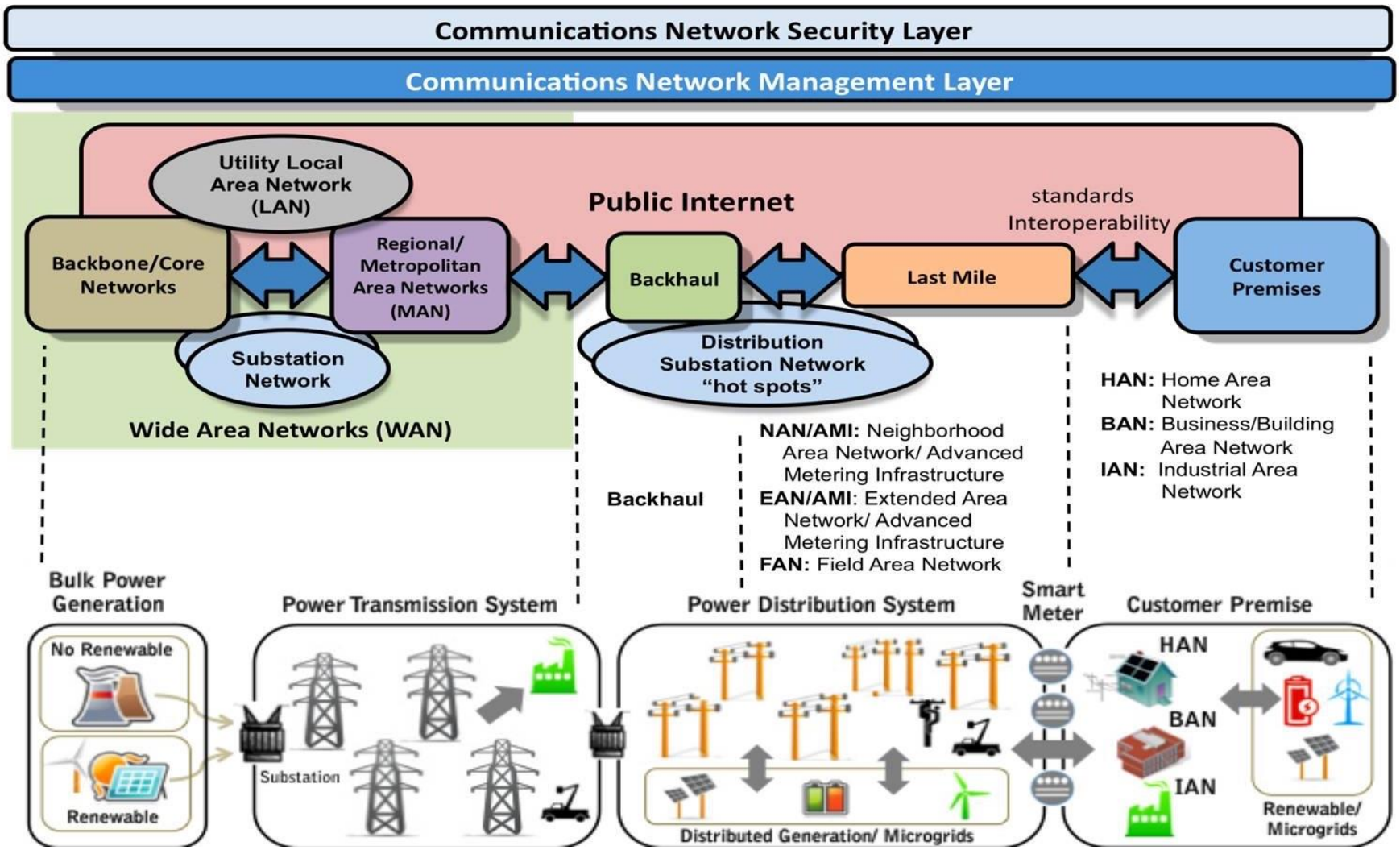
- A combination of hardware, management and reporting software
- Built atop an intelligent communications infrastructure

Consumers and utility companies alike have tools to manage, monitor and respond to energy issues.

Flow of electricity from utility to consumer becomes a two-way conversation

- Saving consumers/utilities energy & money
- Delivers more transparency in terms of end-user use
- Reducing carbon emissions

COMPLEX SMART GRID MARKET



WHY SMART GRID? (1/2)

Integrate isolated technologies : Smart Grid enables better energy management

- Reduces the cost of blackouts $$$

Proactive management of electrical network during emergency situations

Better demand supply / demand response management

- Helps measure and reduce energy consumption and costs

Better power quality

Reduce carbon emissions

- Helps businesses reduce their carbon footprint

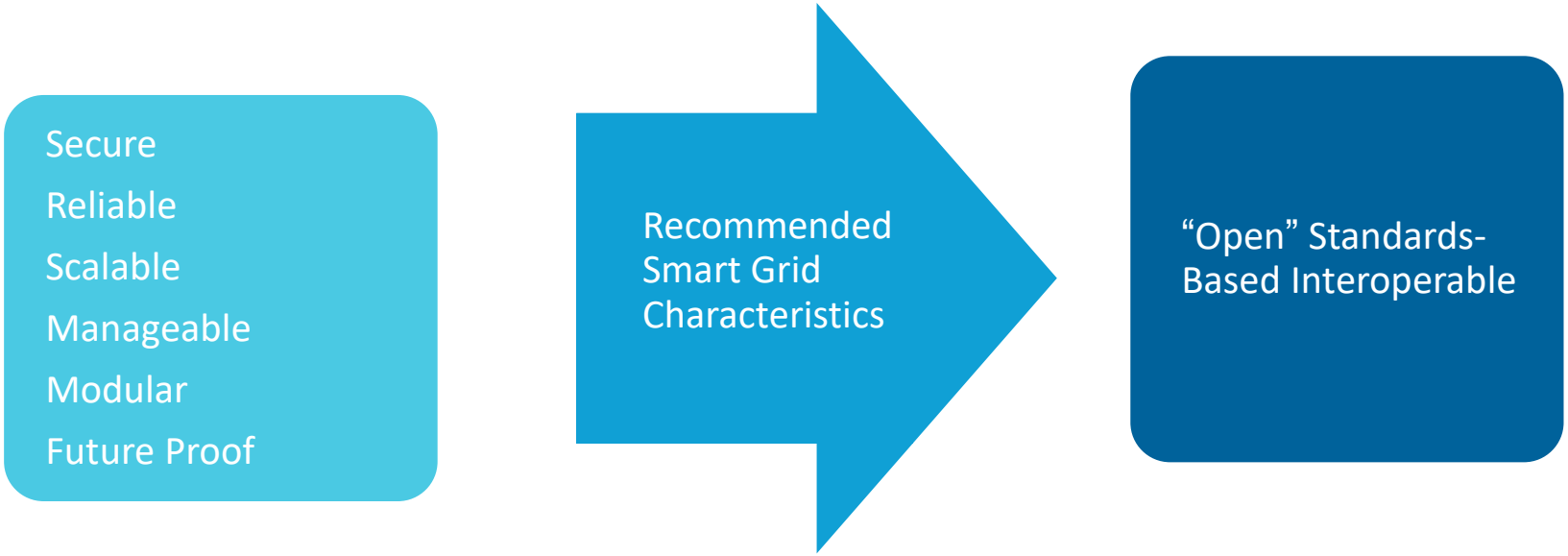
WHY SMART GRID? (2/2)

Increasing demand for energy: requires more complex and critical solution with better energy management

Economic Growth of Countries

- Opens up new opportunities for tech companies meaning more jobs created

IMPORTANT SMART GRID DESIGN PRINCIPLES



WHAT IS IEEE DOING IN THE AREA OF SMART GRID?

IEEE SMART GRID

Major initiative of IEEE and IEEE SA that graduated in 2015; currently part of IEEE Power Energy Society

- No longer the future! It's happening today!

Encompasses power and energy, communications, and information technology

IEEE SA, as a lead standards developing organization, participated in the development of the "US NIST framework of standards and protocols for the Smart Grid"

- 100+ foundational smart grid standards
- Includes collaboration with IEEE-USA, IEEE Technical Activities, and IEEE societies

IEEE activities are listed on the IEEE smart grid portal:

- http://smartgrid.ieee.org/
- http://smartgrid.ieee.org/standards

PRE-STANDARDS ACTIVITIES – VISION PROJECTS

- ✓IEEE Smart Grid Visions for Communication, Power, IT, Control Systems, and Vehicular Technologies.
- ✓Long term visions of what the smart grid in each technology space will look like 20 to 30 years out.
- ✓Forward looking use cases, applications scenarios for smart grid, and corresponding enabling technologies for smart grid of the future snap shots of years 2015, 2020, 2030, and beyond.

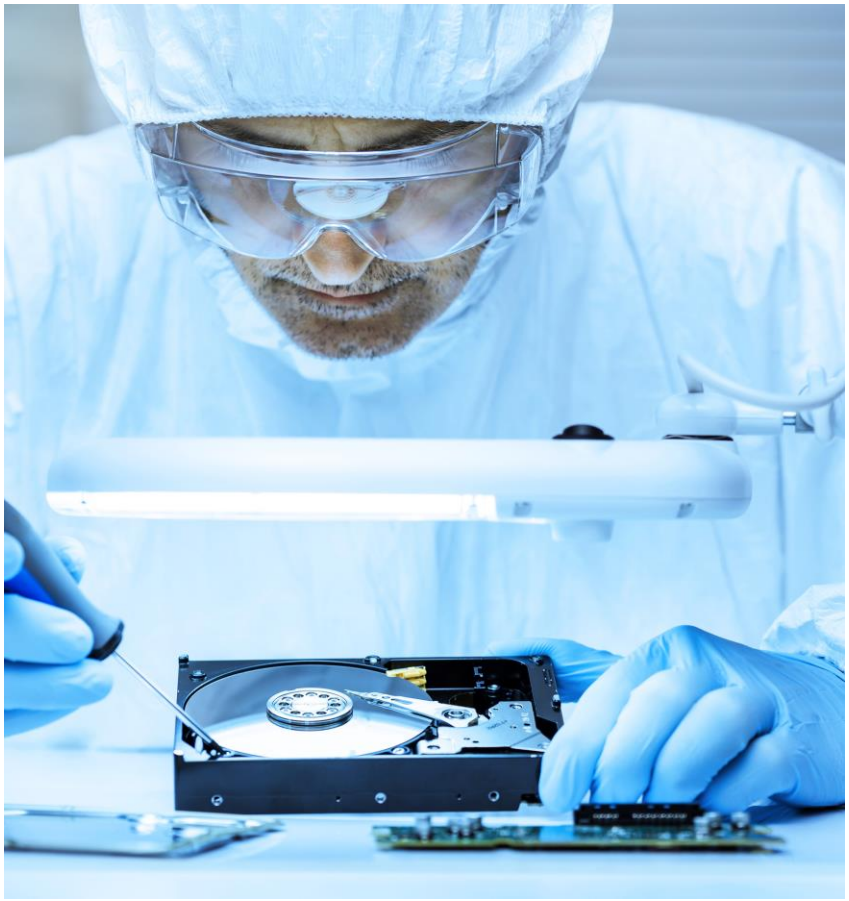
INTELLIGENT VEHICLES AND SMART GRID

2030 and Beyond

- ✓Systems, Operations, Services
- ✓Infrastructures for Intelligent Vehicles and the SG
- ✓Intelligent Vehicle
- ✓V2X Communication
- ✓Connected Traveler
- ✓Social, Economic, Political

IEEE SMART GRID RESEARCH TECHNOLOGY INITIATIVES

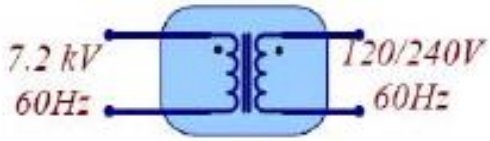
- ✓Electric Vehicles/Wireless Power Transfer
- ✓Power Magnetics/Power Electronics for Distributed Resources
- ✓Data Analytics
- ✓Nano and Molecular Communications



POWER MAGNETICS/POWER ELECTRONICS FOR DISTRIBUTED RESOURCES

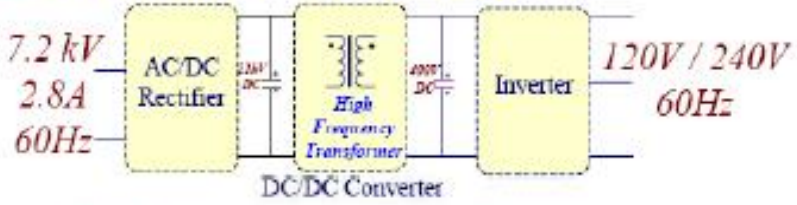
FREEDM Systems Center

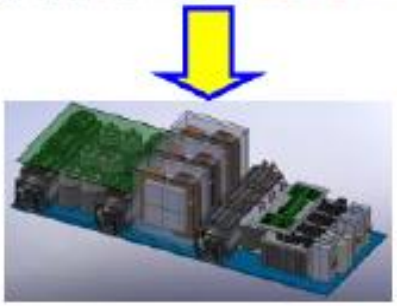
Conventional Transformers



- Low cost, reliable, efficient
- Size and weight, power quality

Solid Sate Transformer (SST)





- Voltage regulation, power factor correction
- Reduction in magnetic materials
- Bi-directional power flow
- Enables active management of load and source (DRER, DESD)

Future Renewable Electric Energy Delivery and Management Systems Center

https://www.freedm.ncsu.edu

IEEE LVDC FORUM INDIA

India - 17% of world population, 2.6% of global GDP

- Energy Demand…2012-32 EJ, 2035 projection-65 EJ i.e. share in global energy demand…from 6% to 9%

Urbanization… accelerating rapidly

- "Commercial Buildings" - a key energy consumer
- ENERGY EFFICIENCY… a vital issue

Around 300 million people without electricity

Renewable energy – an increased emphasis on growth

- 2002-2012, Renewables Capacity increases multifold
- Solar Mission targets 20 GW between 2012-22

Sharp increase in the number of Micro-Grids…envisaged in

- "The Smart Grid Vision & Roadmap for INDIA"…Ministry of Power, Government of India

IEEE P2030.10 "IEEE standard for DC microgrids for rural and remote electricity access applications"

IEEE P2030.10.1™ "DC Standards for Remote & Rural Applications"

IEEE P2030.10.2™ "Standard for Electricity Access Requirements for DC low power not exceeding 60V "

KEY AREAS OF IEEE STANDARDS…

Smart Grid Foundational Standards

- ✓**IEEE 2030-2011™** Guide to Interoperability
- ✓**IEEE 1547™** series interconnections between utility and distributed resources (DR), Micro-grids, Secondary Networks
- ✓**IEEE 1366™** Guide for Electric Power Distribution Reliability Indices
- ✓**IEEE 802™** Series – Networking
- ✓**IEEE 1901-2010™** Broadband over Power Line Networks
- ✓IEEE Smart meter series

Green Technology

- ✓**IEEE 1888™** series: Ubiquitous Green Community Control Protocol and Networks
- ✓**IEEE P802.3az™**: Energy Efficient Ethernet
- ✓**IEEE 1680™** series (Environmental assessment of electronic products)
- ✓**IEEE P1595™**, Standard for Quantifying Greenhouse Gas Emission Credits from Small Hydro; Wind Power; Baseline Projects; and Grid

IEEE 2030® SPANS THREE DISTINCT PERSPECTIVES

Designed for and developed by:

Power & Energy

Defines the numerous data flows necessary for reliable, secure, bi-directional flow of power and energy throughout the entire electric power system

Communications

Identifies the communications infrastructure necessary for smart grid, from high-speed synchrophaser data to in-premise meter and customer notification systems

Information Technology (IT)

Defines the system-to-system communications requirements and data flow to leverage individual systems into a system of systems

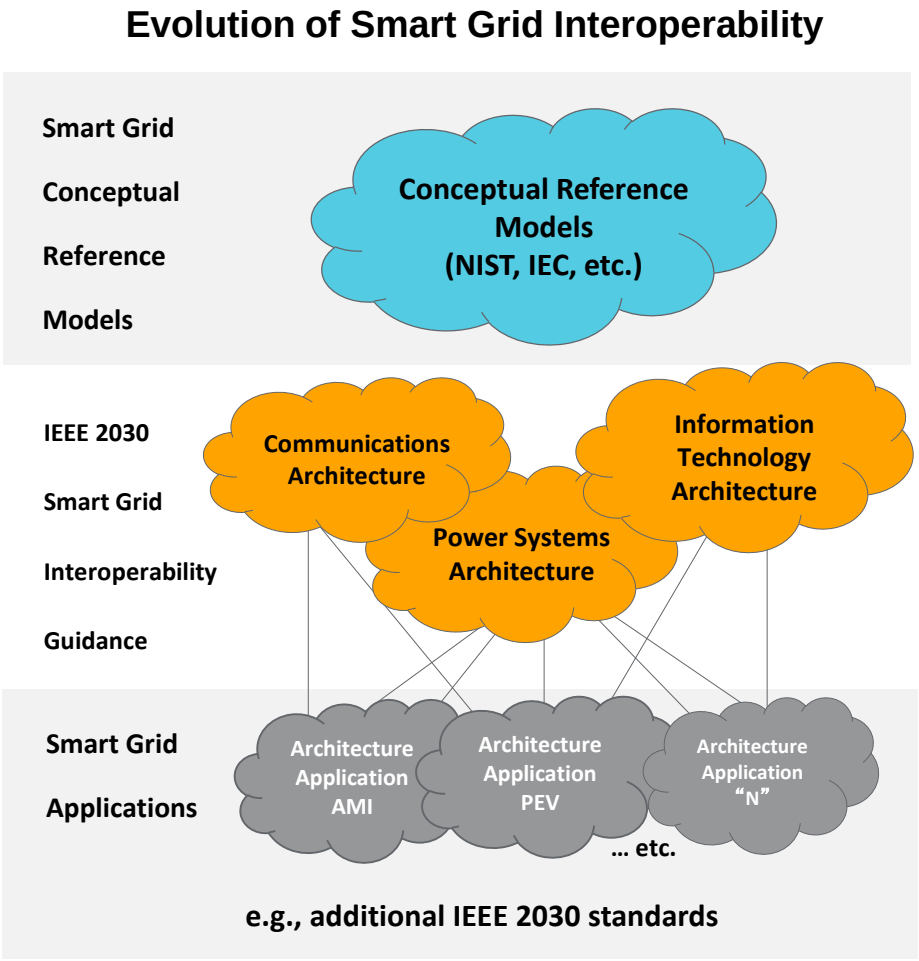
IEEE 2030® SMART GRID FRAMEWORK

Methodological Interoperability Framework composed of:

Three Interoperability Architecture Perspectives (IAP):

- ✓ Power System (PS)
- ✓ Communications Technology (CT)
- ✓ Information Technology (IT)

IAPs Interoperability Tables



IEEE 2030™ SERIES SMART GRID PROJECTS

IEEE 2030™ Series – Smart Grid Interoperability

- ✓**IEEE 2030**™ Guide for Smart Grid Interoperability
- ✓**IEEE 2030.1.1**™ Standard Technical Specifications of a DC Quick Charger for Use with Electric Vehicles
- ✓**IEEE P2030.2**™ Guide for Energy Storage Systems Integrated with the Electric Power Infrastructure
- ✓**IEEE P2030.2.1** Guide for Design, Operation, and Maintenance of Battery Energy Storage Systems, both Stationary and Mobile, and Applications Integrated with Electric Power Systems
- ✓**IEEE P2030.3**™ Standard for Test Procedures for Electric Energy Storage Equipment and Systems
- ✓**IEEE P2030.4**™ Guide for Control and Automation Installations Applied to the Electric Power Infrastructure
- ✓**IEEE 2030.5**™ Standard for Smart Energy Profile 2.0 Application Protocol

IEEE 2030™ SERIES SMART GRID PROJECTS - CONTINUED

- ✓**IEEE P2030.6™** Guide for the Benefit Evaluation of Electric Power Grid Customer Demand Response
- ✓**IEEE P2030.7™** Standard for the Specification of Microgrid Controllers
- ✓**IEEE P2030.8™** Standard for the Testing of Microgrid Controllers
- ✓**IEEE P2030.9™** Recommended Practice for the Planning and Design of the Microgrid
- ✓**IEEE P2030.10™** Standard for DC Microgrids for Rural and Remote Electricity Access Applications
- ✓**IEEE P2030.10.1™** DC Standards for Remote & Rural Applications
- ✓**IEEE P2030.10.2™** Standard for Electricity Access Requirements for DC low power not exceeding 60 V
- ✓**IEEE P2030.100™** Recommended Practice for Implementing an IEC 61850 Based Substation Communications, Protection, Monitoring and Control System
- ✓**IEEE P2030.101™** Guide for Designing a Time Synchronization System
- ✓**IEEE P2030.102.1™** Standard for Interoperability of Internet Protocol Security (IPsec) Utilized within Utility Control Systems

DISTRIBUTED ENERGY RESOURCES INTERCONNECTION

Distributed Energy Resources

Fuel Cell

PV

Microturbine

Wind

Energy Storage

PHEV; V2G

Generator

Interconnection Technologies

Inverter

Switchgear,
Relays, & Controls

Functions

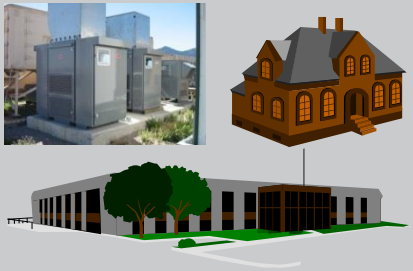
- Power Conversion
- Power Conditioning
- Power Quality
- Protection
- DER and Load Control
- Ancillary Services
- Communications
- Metering

Electric Power Systems

Utility System

Microgrids

Loads



Local Loads

Load Simulators

IEEE SCC21 1547™ SERIES OF STANDARDS

IEEE 1547™(2003 and 2014 Amendment 1) Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE P1547™(full revision) Draft Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE 1547.1™(2005 and 2015 Amendment 1) Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

IEEE P1547.1 (full revision) Draft Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces

Note: IEEE 2030.2™ was published Jun 2015

IEEE 1547.2™(2008) Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE 1547.3™(2007) Guide for Monitoring Information Exchange, and Control of Distributed Resources with Electric Power Systems

IEEE 1547.7™ (2013) Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection

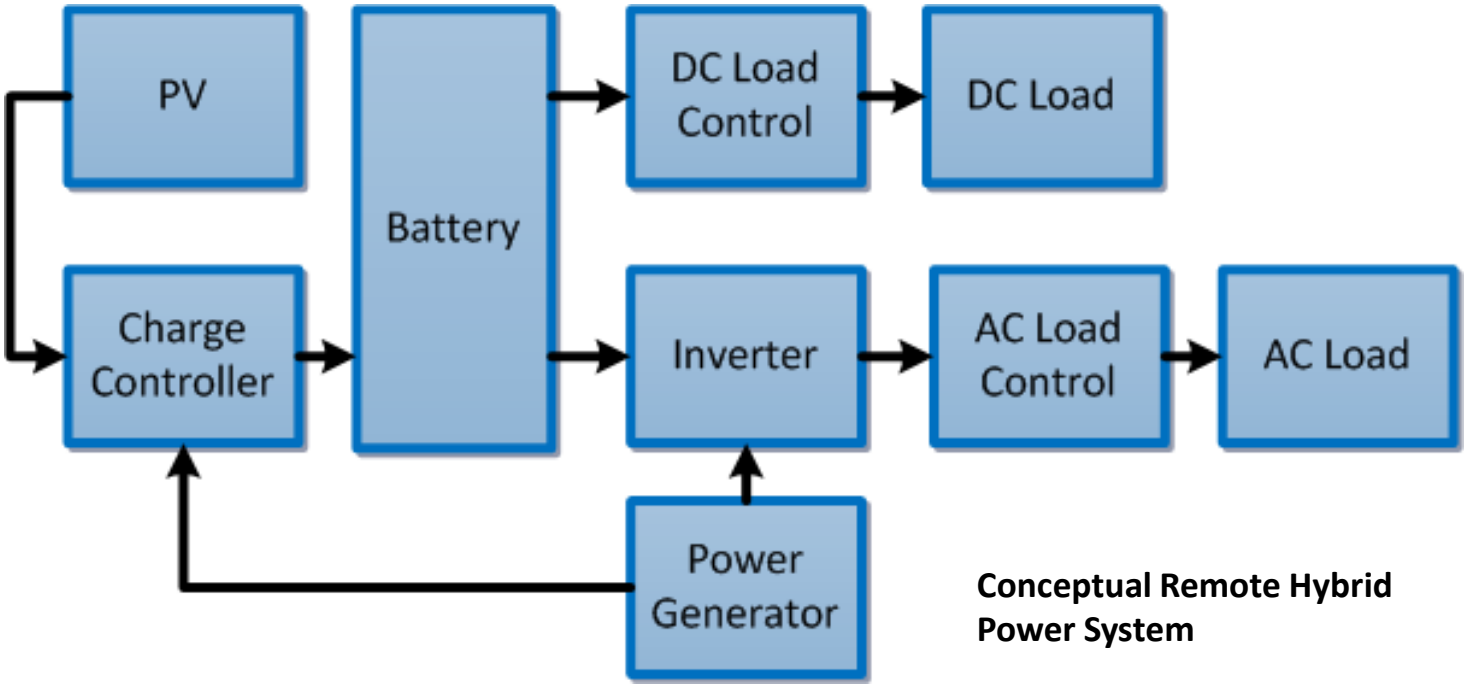
MicroGrid >>

IEEE 1547.4™(2011) Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

IEEE P1547.8™ Draft Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Std 1547-2003

IEEE 1547.6™(2011) Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks

HYBRID PHOTOVOLTAIC SYSTEMS

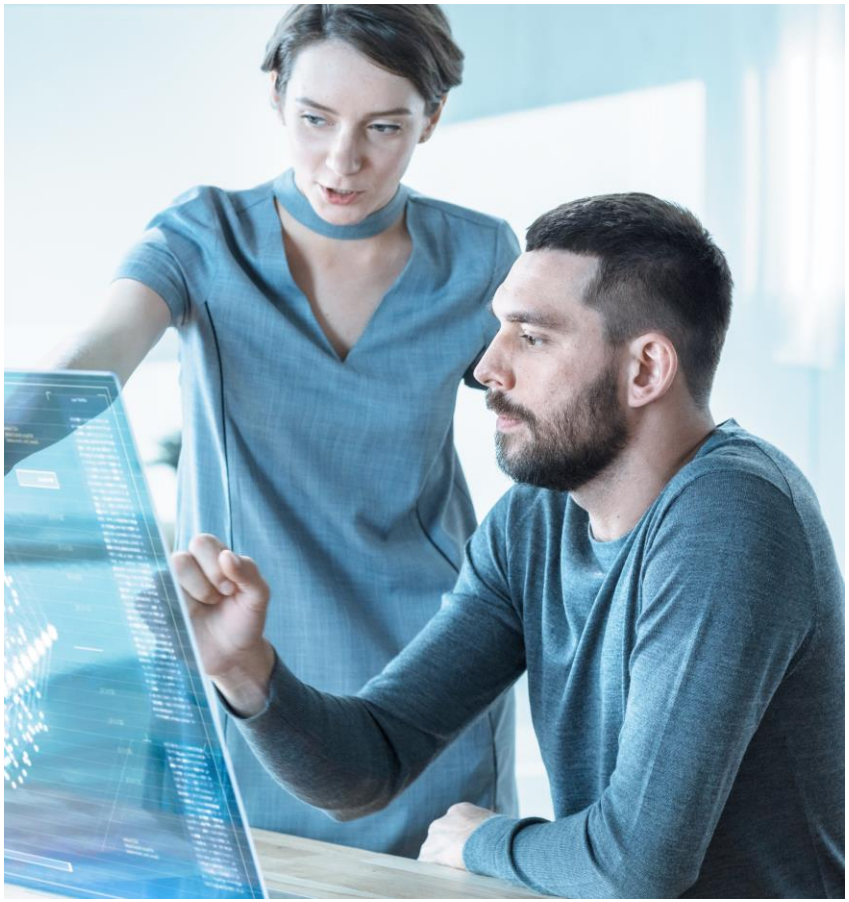


Conceptual Remote Hybrid Power System

- ✓**IEEE 937™** Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems
- ✓**IEEE 1561™** Guide for Optimizing the Performance and Life of Lead-Acid Batteries in Remote Hybrid Power Systems
- ✓**IEEE 1661™** Guide For Test and Evaluation of Lead-acid Batteries Used in Photovoltaic (PV) Hybrid Power Systems

IEEE STANDARDS FOR SECURITY

- ✓**IEEE 1686™** – Standard for Substation Intelligent Electronic Devices (IED) Cyber Security Capabilities
- ✓**IEEE C37.240™** – Standard for Cyber Security Requirements for Substation Automation, Protection and Control Systems
- ✓**IEEE 1711™** – Cryptographic Protocol for Cyber Security of Substation Serial Links
- ✓**IEEE 1402™** – Standard for Physical Security of Electric Power Substations



SMART METERS

- **IEEE 1377™** - Standard for Utility Industry Metering Communication Protocol Application Layer (End Device Data Tables)
  - Provide a uniform, structured and adaptive data model to operate in a "plug and play" and multi-source enterprise AMI environment.
- **IEEE 1701™** - Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables
- **IEEE 1702™** - Standard for Telephone Modem Communication Protocol to complement the Utility Industry End Device Data Tables
- **IEEE 1703™** - Standard for Local Area Network/Wide Area Network (LAN/WAN) Node Communication Protocol to complement the Utility Industry End Device Data Tables
- **IEEE P1704™** - Standard for Utility Industry End Device Communications Module
- **IEEE P1705™** - Standard for Compliance Testing Standard for Utility Industry Metering Communications Protocol Standards

IEEE 2030.5™ – SMART GRID USER INTERFACE

The integration of consumer devices into the smart grid

Serves two general purposes:

- Inform the consumer (e.g., energy usage, pricing)
- Request actions to assist the grid (e.g., thermostat changes, PV inverter controls, plug-in electric vehicle charging)

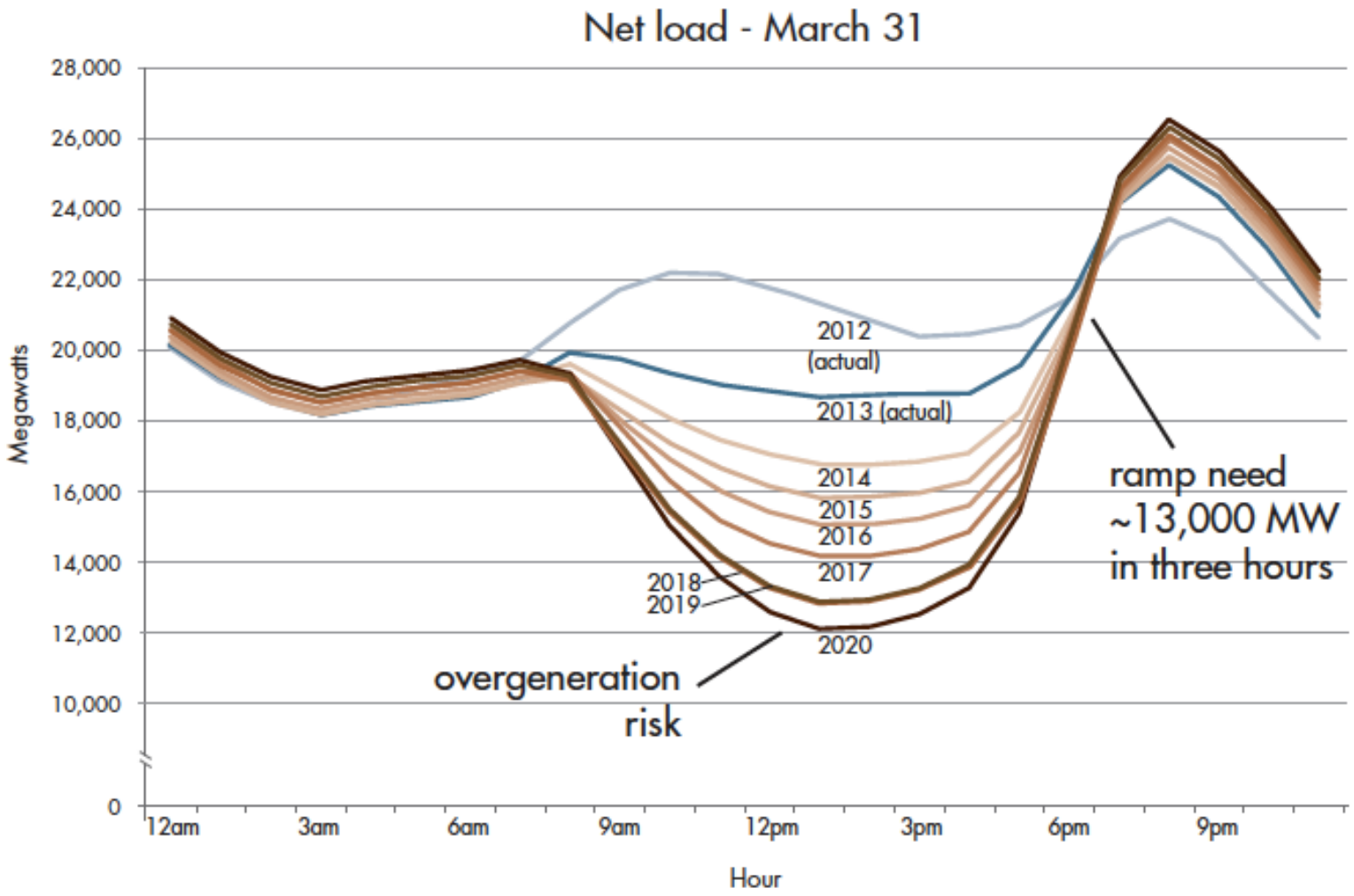
Focus on communications related to efficiency, usage, price, demand response and load control, and service provider messages

An IoT "profile"

Range of backhaul technologies

Optimized for embedded and battery-powered devices

THE "DUCK CURVE"



CALIFORNIA'S RULE 21 AND IEEE 2030.5™

IEEE 2030.5™ named as "default protocol" for smart inverter communications

"IEEE 2030.5™ Common California IOU Rule 21 Implementation Guide for Smart Inverters" developed (CSIP)

Communications between utility and DER aggregator, as well as utility and individual smart inverters

Support for both generation and storage

Supports DER controls, curves, ratings, settings

Many other function sets useful:

- ✓Pricing
- ✓Energy usage (monitoring/metering)

Ability to target groups or individual smart inverters

In addition to remote monitoring and control, allows increased customer engagement and information

One of three communications protocols in new IEEE 1547-2018™

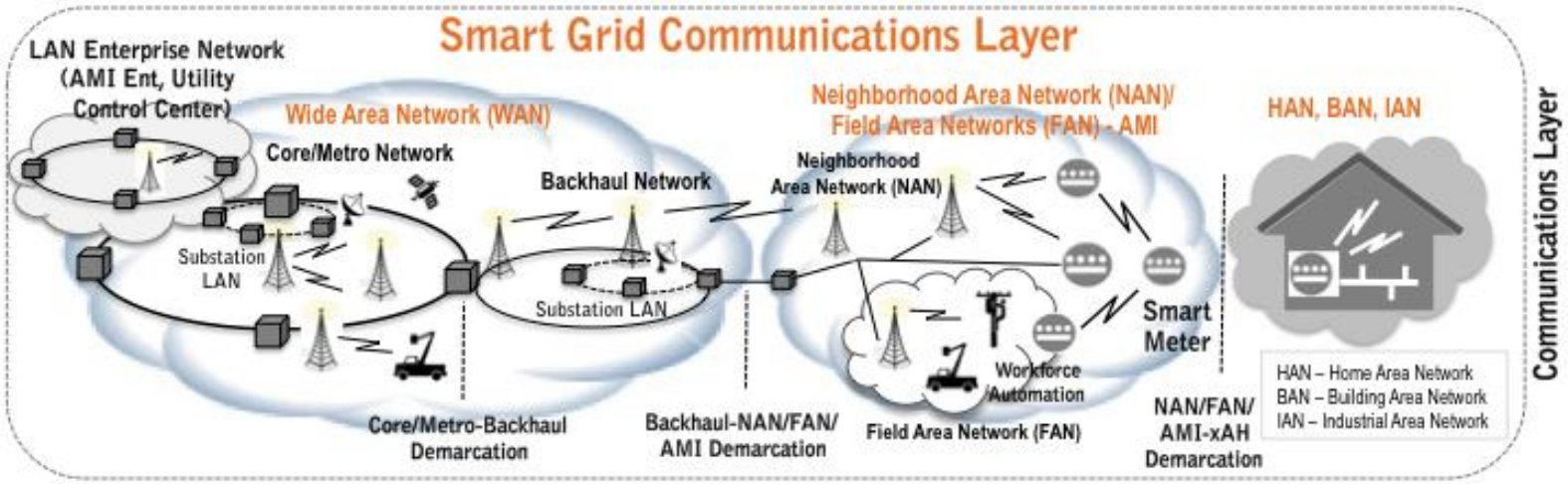
IEEE STANDARDS – SMART GRID NETWORKS

IEEE 1901™ – Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications

IEEE P1901.2™ – Standard for Low Frequency (Less Than 500 kHz) Narrow Band Power Line Communications for Smart Grid Applications

IEEE 1905.1™ – Standard for a Convergent Digital Home Network for Heterogeneous Technologies

IEEE STANDARDS FOR SMART NETWORKING/ COMMUNICATIONS



Smart Grid Network Technology & Protocols Standards Mapping

Wide Area Network (WAN)			NAN/FAN			Smart Meters	HAN, BAN, IAN		Technology Standards
Substation	Core/Metro Network/Backhaul Network		Substaion						
	Wireline	Wireless		Wireline	Wireless		Wireline	Wireless	
LAN IEEE 1815/IEC 61850 Several Options	IEEE 802.1 IEEE 802.3	IEEE 802.16d/e IEEE 802.20 IEEE 802.22	LAN IEEE 1815/IEC 61850 Several Options	IEEE 802.1 IEEE 802.3 IEEE 1901	IEEE 802.11 IEEE 802.15.4 IEEE 802.16	IEEE SC31 (1377, 1701, 1703, P1704)	IEEE 802.1 IEEE 802.3 IEEE 1901 IEEE 1901.2 IEEE P1905.1	IEEE 802.11 IEEE 802.15.4	

IEEE PLC TESTBED PROGRAM

Industry Connection Program: Establishment of PLC Test Beds in India

- One of the significant technologies that will serve as a backbone for the Infrastructure growth is likely to be Power-Line Communications (PLC) supported by the IEEE 1901™
- PLC technology has also been recommended by the Bureau of Indian Standards (BIS) as part of its Smart City Framework Policy Recommendations
- The Test Beds will provide an ecosystem for various stakeholders, ranging from established industries to enterprising startups, to develop and test their solutions that have PLC as the core technology.

Establishment of at least 4 PLC Test Beds: Potential sites identified and initial plans discussed

Periodic Workshops / Conferences with focus on PLC-based solutions for 'Emerging India'

Specific standard clauses that could be added to the existing IEEE 1901™ Standards based on unique challenges in countries like India (ex: how to overcome bad quality of wiring, multihop technology, etc.)

IEEE STANDARDS FOR UTILITY AUTOMATION

- ✓**IEEE C37**™ Series for Synchrophasers
  - ✓IEEE C37.118.1™ Measurements
  - ✓IEEE C37.118.2™ Synchrophasor Data Transfer
  - ✓IEEE C37.242™ PMU testing and installations
  - ✓IEEE C37.244™ Phasor Data Concentrator Requirements
- ✓**IEEE 1815**™ Distribution Network Protocol
- ✓**IEEE P1815.1**™ Exchanging Information Between Networks
- ✓**IEEE C37.1**™ Standard for SCADA and Automation Systems
- ✓**IEEE 1588**™ Time Synchronization
- ✓**IEEE C37.238**™ Precision Time Protocol in Power System Applications
- ✓**IEEE PC37.237**™ Standard Requirements for Time Tags Created by Intelligent Electronic Devices - COMTAG(TM)
- ✓**IEEE P1854**™ Guide for Smart Distribution Applications

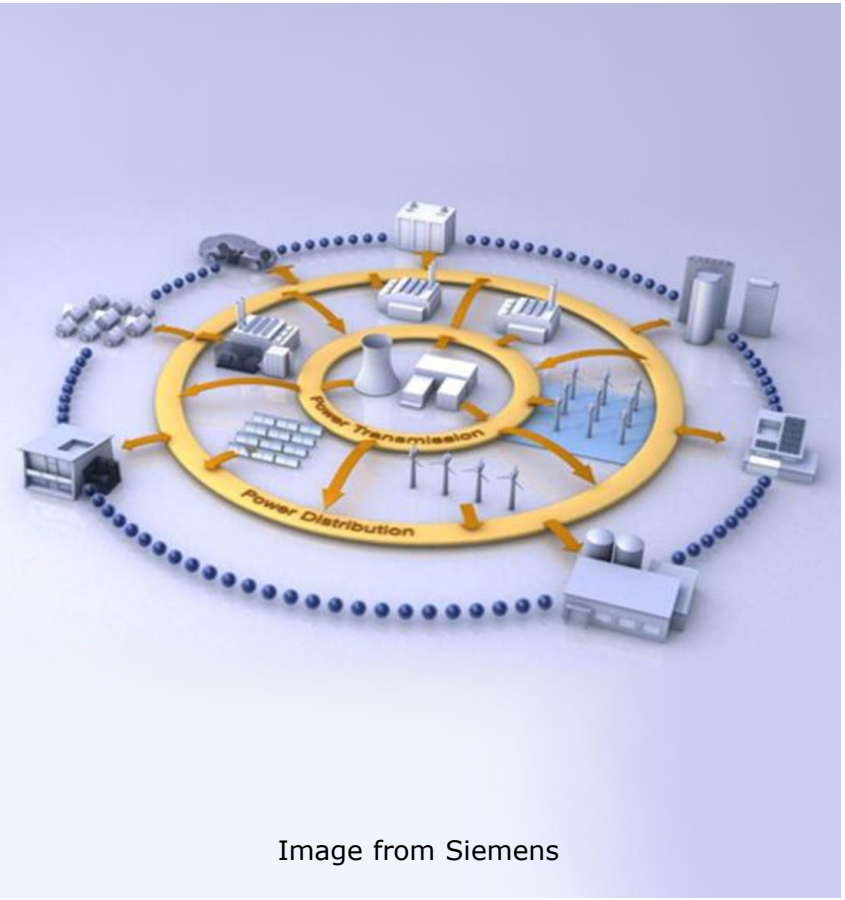
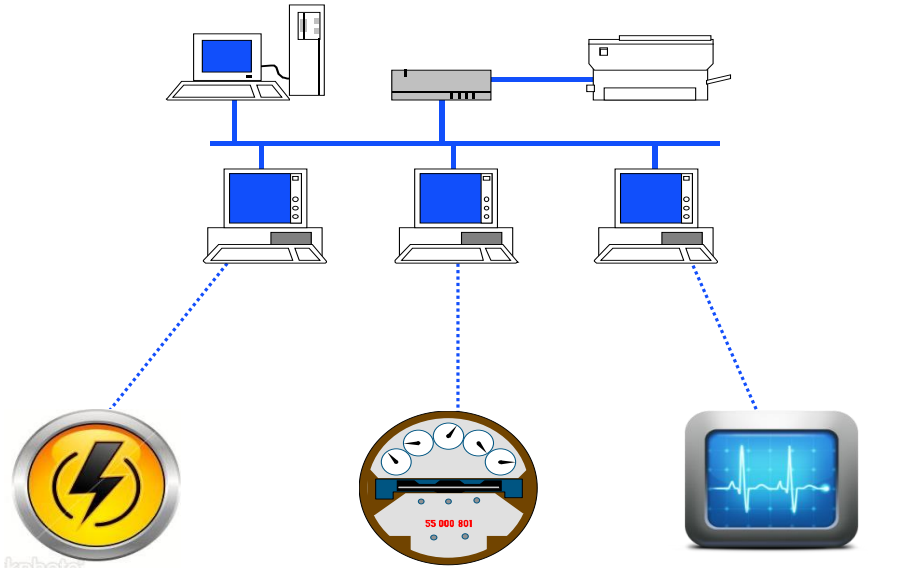


Image from Siemens

IEEE STANDARDS FOR POWER QUALITY

- ✓**IEEE 1159™** Recommended Practice for Monitoring Electric Power Quality
- ✓**IEEE 1159.3™** Recommended Practice for the Transfer of Power Quality Data
- ✓**IEEE 1250™** Guide for Identifying and Improving Voltage Quality in Power Systems
- ✓**IEEE 1409™** Guide for the Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1 kV Through 38 kV
- ✓**IEEE 519.1™** IEEE Draft Guide for Applying Harmonic Limits on Power Systems



IEEE CONFORMITY ASSESSMENT PROGRAM (ICAP)

IEEE 1547™ CONFORMITY

Four main aspects

- ✓ Type Test of inverter
- ✓ Production Test
- ✓ Commissioning
- ✓ Periodic Interconnection Test (lifecycle)

Only having a certified inverter ≠ a DER site being IEEE 1547™ compliant

Full compliance to IEEE 1547™ is critical before communications and transactions can take place.

ONSITE COMMISSIONING TEST PROCEDURE

The IEEE 1547™ Conformity Assessment Steering Committee (CASC) has developed a universal commissioning plan

Document to be completed by the authorized commissioning agent, with input from the DER project developer and utility

Test template contains the following scope:

- ✓ DER Operational Description
- ✓ Diagram of system interconnection
- ✓ Relevant DER system details
- ✓ Confirmation drawings match physical system
- ✓ Visual inspection of DER settings related to utility 1547 requirements
- ✓ Testing of site specific functions as required by the utility

Systems demonstrating compliance to IEEE commissioning requirements will be eligible for IEEE certification

IEEE Certified

ICAP POWER & ENERGY CERTIFICATION OFFERINGS

IEEE 1547™ – Distributed Energy Resources (DER) Interconnection

✓ Interconnection commissioning plan for DERs to the Electric Power System

IEEE Nuclear Standards Certification Program

✓ Certification program for Class 1E devices in Nuclear Power Plants

IEEE EV Charging Program

✓ Certification Program for DC Fast Chargers based on the IEEE 2030.1.1 Standard

IEEE 1588™ Power (IEEE C37.238™)

✓ Standard specifies a common profile for the use of IEEE 1588 Precision Time Protocol (PTP) in power system protection, control, automation, and data communication applications utilizing an Ethernet communications architecture

IEEE C37.111™ COMTRADE

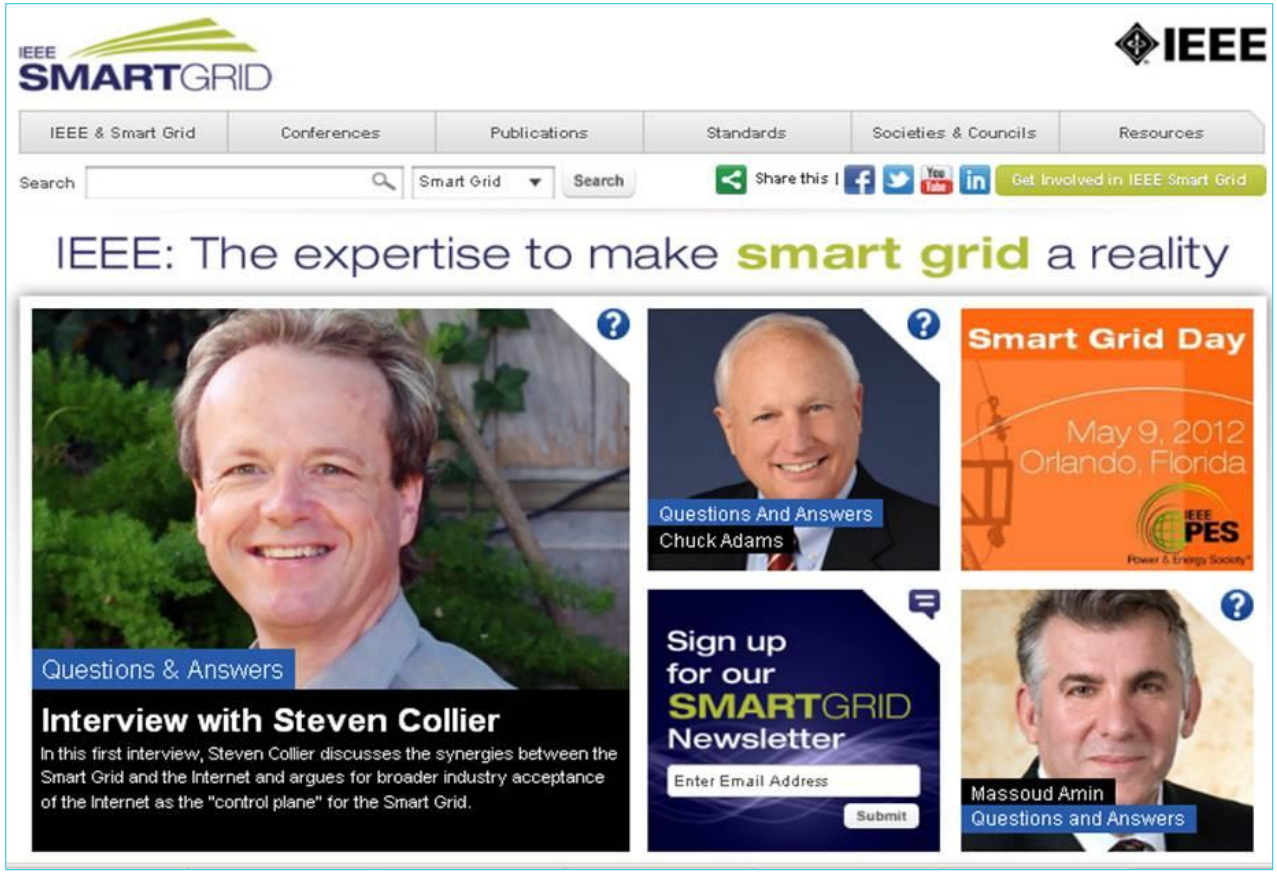
✓ Software Tool Evaluation for COMTRADE File Format and online community of COMTRADE users

IEEE 2510™ Sensors

✓ Certifying Quality of Sensors Data (QoD)

IEEE SA SMART GRID PORTAL

Single location to identify all IEEE Standards, publications, conferences and IEEE resources associated with Smart Grid **www.smartgrid.ieee.org**



THANK YOU