Smart Grid Technologies within the Built Environment

Alternative Energy Technologies and Electrical Safety Standards
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CAL POLY
FIRE PROTECTION ENGINEERING
Smart Grid Project Background

- NFPA invited to participate in NIST Smart Grid Rapid Standardization Initiative
- Concern that safety of the built infrastructure not appropriately addressed
- Proactive initiative to ensure that the NEC and other NFPA electrical safety standards keep pace with Smart Grid developments
Smart Grid Project Background

- NFPA Smart Grid Task Force formed - 2009
- Grant request submitted to NIST to provide focused support to task force activity - accelerate and support interoperable codes and standards development for Smart Grid
- Approved summer 2010
• Smart Grid technology provides a means to manage the utility generation resources of the grid as well as manage loads on the grid (facility loads)
• The primary conventional generation resources include:
  o Fossil fuel plants
  o Nuclear plants
  o Hydro electric facilities
Utility owned resources may also include:
- Gas turbines (for peak demand loads)
- Wind farms
- Photovoltaic plants
- Micro Combined Heat and Power (MicroCHP)
- Electric vehicles
- Community Energy Storage Systems
The grid also includes a number of nonutility grid connected generation resources, which include:

- Photovoltaic
- Small scale wind turbine
- Micro hydro
- Fuel cells
- Micro Combined Heat and Power (MicroCHP)
- Electric vehicles
- Community Energy Storage Systems
• The smart grid facilitates the bi-directional flow of power to make the greatest use of these distributed resources by allowing them to be dispatched where and when they are needed
• It’s also based on the concept of being able to better manage load, including selective load shedding, when needed
• It includes a communications infrastructure to manage the sources and the loads
• This new technology has implications for:
  o Electrical safety
  o Personnel safety
  o Fire Safety
• The smart grid includes equipment on the customer side of the service point
• The smart grid may permit control from the utility side of the service point
The National Electrical Code® has formed a Smart Grid Task Group that is in the preliminary stages of addressing the impact of the Smart Grid and related emerging building electrical systems that will interface with the grid but are on the customer side of the service point.
1. **Technology Review and Safety Assessment** of the emerging technologies associated with Smart Grid implementation and their impacts on the safety features of the built environment

2. **Regulatory Development and Needs Assessment** of the current weaknesses/gaps in the U.S. fire and electrical safety codes and standards which will impede widespread implementation of this technology

3. **Roadmaps** of needed specific codes and standards development/changes and areas where additional data/research on safety aspects is required
Project Steering Committee Members

Al Scolnik, National Electrical Manufacturers Association
John Thompson, Underwriters Laboratories, Inc.
Dave Clements, International Association of Electrical Inspectors
Bill Galloway, SC State Fire Marshal’s office, representing International Fire Marshals Association
Mike Johnston, NECA, Chair, NEC Correlating Committee
Jim Pauley, Schneider Electric Company
Dean Prochaska, Smart Grid Conformance Program Office, NIST
Mark Earley, Chief Electrical Engineer, National Fire Protection Association
Shawn Paulsen, CSA-International
Industry Workshop March 14 & 15 Washington DC

• Review and input from leaders within the NFPA safety standards development community on the project
• Input for NEC Smart Grid Task Force in consideration of upcoming NEC code change cycle
Outcome

- Report – available for free download at nfpa.org/foundation
- Inspector’s Guide
- IAEI regional meeting presentations
- Webinar scheduled for December 8 at 12:30 EST
- Technical basis for submitted NEC changes
Smart Grid Customer Domain
Building Metering/Information Systems

• Smart Meters
• Energy Management Systems
• Time of Use Metering/Rate Structures
• Load Shedding/Demand Response
Smart Meters

- An advanced electric meter that records consumption in intervals of one hour or less and communicates that information at least daily via some communications network back to the utility for monitoring and billing purposes
- Enable two-way communication between the customer’s meter and the electrical utility serving the customer
- Use real-time or near real-time sensors, power outage notification, and power quality monitoring
Smart Meters

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**SmartMeter™ technology for the future.**

Helping you build a fully networked, energy-efficient home and business. Providing information to give you control over how much energy you use and when you use it.

**THERMOSTAT**

See what each adjusted degree of cooling will actually cost based on the price of electricity at that specific time of day.

**SEE YOUR POWER**

In the future, further advances will enable you to control a network of smart appliances and electronics from an energy control hub.

**ELECTRIC VEHICLE**

Program your charging unit to begin charging your electric car during off-peak hours when electric prices are the lowest.

**WEB-ENABLED DEVICE**

Use any web-enabled device to check your energy use even when you’re not at home.

**POWER RESTORATION**

SmartMeter™ technology will alert PG&E if there is a power outage so we can quickly get the lights back on. Plus, if you’re moving and need your service turned on or off, we can do that remotely.

**SMART APPLIANCES**

Appliances such as refrigerators will have the ability to automatically go into power-saving mode to minimize your energy use and cost.

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[1] pg&e.com
Energy Management Systems

• Although common in commercial facilities, Energy Management System (EMS) - also known as Energy Information Systems (EIS) and Energy Monitoring and Control Systems (EMCS) - are relatively new to residential

• A Home Area Network (HAN) interfaces the user with smart grid technology such as smart meters, smart plugs, and smart appliances

• A HAN may be hard-wired; however, most new systems use wireless technologies, enabling retrofitting into existing homes

• If a cabled system is used, cabling needs to be deployed from the electric meter to each major appliance

• Power-line carrier may be used as the communications channel.

• Smart plugs or switches can be used to connect the major appliances to the HAN
Time of Use (TOU) Metering

• TOU net metering employs a specialized reversible smart meter that is programmed to determine net electricity consumption (or contribution) any time during the day
• Time-of-use allows utility rates and charges to be assessed based on when the electricity was used (i.e., day/night and seasonally)
Load Shedding/Demand Response

- Load shedding is an intentional, utility-initiated loss of electrical power to a specific customer or group of customers.
- Utility companies have historically used load shedding as a last-resort in order to avoid a total blackout of the power system.
- With smart meters, load shedding also may be implemented to selectively “shed” designated loads during high demand.
- Demand response appliances could reduce an electrical utility’s base load during peak usage hours via a request from either the customer or utility.
- Residential smart appliances (such as air-conditioning, ovens, dryers, etc.) are being developed to communicate, be monitored, and controlled by a smart meter.
Smart Plug Strip Configuration

Smart Power Strips (InfoSys)

- Smart Plug Strips
  - Ethernet
  - IP

- Server
  - Ethernet

- Web Access (iSmart)
  - Ethernet
  - USB

- PC
Photovoltaic (PV)

- Employs solar panels comprising a number of cells
- Often associated with buildings – integrated, mounted, or nearby
- Arrays are incorporated into the roof or walls of a building
- Roof tiles with integrated PV cells are also becoming more common
Small Scale Wind Turbine

- Conversion of wind energy into electricity
- Capable of producing up to 100 kW of electrical power
- May be utility interactive or may use batteries for energy storage
Fuel Cell

• Electrochemical cell that converts a source fuel into an electric current
• Many combinations of fuels and oxidants are possible
• Hydrogen fuel cell uses hydrogen as its fuel and oxygen (usually from air) as its oxidant
• Other fuels include hydrocarbons and alcohols - other oxidants include chlorine and chlorine dioxide
Micro Combined Heat and Power (MicroCHP)

- Operates like a combination furnace, hot water heater and electricity provider—all in one compact unit
- Hot air and water form the waste heat
- MicroCHPs are usually less than 5 kWh for a residential / commercial building fuel cell
- Generates electric power 24/7 (selling excess power back to the grid when it is not consumed)
- Connected to the grid through the panel using net metering - able to fit inside a mechanical room or outside a home or business
- Designed to integrate with existing electrical and hydronic systems
- System automatically switches to a grid-independent operational mode to provide continuous backup power for dedicated circuits in a residence while the grid is down
Energy Storage Systems

• Batteries
• Uninterruptible Power Supply (UPS) systems
• Thermal Energy Storage
• Vehicle-to-Grid Storage
• Community Energy Storage (CES)
• An early solution to the problem of storing energy for electrical purposes was the development of the battery as an electrochemical storage device
• Batteries have previously been of limited use in electric power systems due to their relatively small capacity and high cost
• Newer battery technologies have been developed that can now provide significant utility scale load-leveling capabilities
• In addition to batteries, capacitive storage provides another possible solution to deal with the intermittent issue of solar and wind energy
Vehicle-to-Grid Storage

- Almost one million Plug-In Hybrid Electric Vehicle (PHEV) charge points will be needed in the United States by 2015\(^1\)
- Residential charging stations are forecast to increase by 650,000+ units within five years
- There is a projected growth of over 380% in non-residential charging stations in the next five years
- Vehicle-to-Grid energy storage describes the use of electric vehicles (when plugged into the energy grid) to release the stored electrical energy in their batteries back into the grid when needed

1. http://www.piker research.com
Summary of Smart Grid Technologies - Smart Meters

Description
A meter that monitors and automatically reports a customer’s electricity consumption to the utility. Smart meters may also interface with customer’s energy systems and devices to provide the customer with additional information, communications with the utility, and demand response or load shedding. Components consist of:

- Energy Management Systems
- Time of Use Metering/Rate Structures
- Load Shedding/Demand Response

The smart meter will be able to provide:

- Home Area Network (HAN) technologies that will give customers more control over the energy usage of appliances, equipment, lighting, etc.
- HAN technology in the home to better match energy supply with demand
- Smart charging for electric vehicles, taking advantage of off-peak rates
- Integration of customers' on-site energy generation to reduce the need for utility energy and a customers’ vulnerability to outages
- Smart charging for electric thermal storage systems
Summary of Smart Grid Technologies-
Smart Meters

Possible NEC Issues

- Dramatic increase in data communication between smart grid appliances / plugs and smart meters, or between devices and home energy management / control systems
- Critical circuits for life-safety systems - including special needs equipment such as patient care equipment (ventilators, diagnosis equipment, etc.) - will need to remain powered during load shedding
- Power or control wiring installed by licensed electrical contractors may be required to tie into panelboards / load centers
- Grounding and bonding for all components will need to be provided
- Sensors will be needed to connect major electrical loads to a smart meter
- Susceptibility of smart systems to frequent inrush currents from switching large appliance loads
- Limitation should be established on the amount of harmonics induced from Class 2 wiring
- Equipment to be certified / listed
- Qualification of installers
- Inspection of installations by qualified persons
Summary of Smart Grid Technologies - Smart Meters

NFPA Articles Affected

- NFPA 70
  - 90
  - 210.11
  - 422.31
  - 424.19
  - 517.31
  - 700.4
  - 701.4
  - 705
  - 705.20
  - 705.40
  - 708.22

- NFPA 70E
  - 100

- NFPA 110
  - 6.2.2
  - 6.2.5

- NFPA 111
  - 6.2.4.2
  - 6.2.4.2.4
  - 6.2.4.5.1
  - 7.1.4
  - 8.4.1

penenergy.com
Summary of Smart Grid Technologies-
Energy Micro-generation, Co-Generation, and Generation

**Description**
Some grid-connected electricity customers have the ability to generate their own electricity through photovoltaic systems, fuel cells, backup generators, etc. These systems may be used to power the customer’s equipment or add energy to the grid, especially during peak hours for economic incentives or to help with load shedding. Currently, however, backup generators are not normally permitted to supply power to the grid.

Currently, the most common forms of microgeneration technologies include:
- Photovoltaic
- Small scale wind turbine
- Micro hydro
- Fuel cell
- Plant microbial fuel cell
- Micro Combined Heat and Power (MicroCHP)
Possible NEC Issues

- Requirements for system interconnection
- Additional notification and safety devices required to alert personnel to and protect them from the presence of two-way power
- Protection for chemical conversion of hydrocarbon fuels into electrical energy
- Direct current output from an EMGS to a building
- Accommodations for manual disconnect switches
- Interconnection of the grounding system
- Shutoff and/or dummy-load devices for wind power generation during high winds, or when power generated exceeds requirements / storage system capacity
- Manual overrides of automatically controlled circuits
- Use of direct current by consumers directly from their EMGS
- Conversion of DC generated power into AC or for feeding excess power into a commercial power grid via an inverter or grid-interactive inverter
- Limiting harmonics that may be introduced into the electric grid by inverters
- Wiring Methods
- Overcurrent and overload protection
- Certified / listed equipment
Summary of Smart Grid Technologies - Energy Micro-generation, Co-Generation, and Generation

NFPA Articles Affected

- NFPA 70
  - 220.3
  - 230.82
  - 240.3
  - 250.3
  - 705.30

- NFPA 70E
  - 100

- NFPA 110
  - 52

herbinator.blogspot.com
Summary of Smart Grid Technologies-
Energy Storage Systems

Description
Storage systems may be used by customers to reduce demand during peak hours, as a backup in case of grid failure, or as a way to increase the flexibility of renewable energy.

The most common types of energy storage are:
- Batteries
- Uninterruptible Power Supply (UPS) systems
- Thermal Energy Storage
Possible NEC Issues

- Battery meter (for charging rate and voltage) installation requirements
- Protection of overcharging energy storage systems to prevent failures
- Charging and discharging of ESS
- Charge controller for charging the batteries or other energy storage
- Provisions for converting DC battery power into AC as required for many appliances, or for feeding excess power into a commercial power grid, an inverter or grid-interactive inverter
- Protection against overcharging of batteries to prevent explosions
- Guidelines for the placement of, and clearance requirements for, fuel cells
- Load & Demand factors
Summary of Smart Grid Technologies-
Energy Storage Systems

NFPA Articles Affected
- NFPA 70E
  - 100
  - 120
  - 320

renovationsexperts.com
Summary of Smart Grid Technologies - Plug-in Vehicles

**Description**
These vehicles have an energy storage system on-board. The storage can be charged by connection to the grid and may be able to supply the grid if needed.

Equipment includes:
- Plug-in Vehicles
- Charging EV’s and Charging Stations
- Vehicle-to-Grid Storage Systems

[Image of smart grid technology diagram]

[Source: theautochannel.com]
Possible NEC Issues

- Battery meter (for charging rate and voltage) installation requirements
- Meters for power consumption
- Protection of overcharging energy storage systems to prevent failures
- Charging and discharging of Vehicle-to-Grid storage systems
- Charging and discharging of PHEVs, PEVs, and other on-site energy storage systems
Summary of Smart Grid Technologies - Plug-in Vehicles

NFPA Articles Affected

- NFPA 70
  - 210.2
  - 210.52
  - 220.3
  - 220.14
  - 220.44
  - 230.82
  - 240.3
  - 250.3
  - 625.26

- NFPA 70E
  - 100

gigaom.com
Description
A local energy storage with limited backup time that is available to a small group of customers. CES units allow excess energy from the customers to be captured and re-dispatched with less line loss than a mass-storage system located far away.
Possible NEC Issues

- Voltage flicker provisions
- CES unit guidelines
- CES unit placement guidelines
- Grounding and bonding provisions
Summary of Smart Grid Technologies - Community Energy Storage & Large Switching Loads

NFPA Articles Affected

- NFPA 70
  - 210.19
  - 215.2
  - 220.3
  - 230.82
  - 240.3
  - 230.82
  - 250.3
  - 705

- NFPA 70E
  - 100

marketwire.com
# Summary Matrix

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Research in Support of NFPA Technical Committees

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Smart Grid Technologies within the Built Environment

THANK YOU!