Enabling Technology Development Project
October 1, 2007

ENABLING TECHNOLOGIES FOR THE DISTRIBUTION GRID

Research Opportunity Notice

Overall Objective

The objective of this Research Opportunity Notice (RON) is to solicit R&D proposals for research and enabling technologies development for the distribution grid. Proposed R&D may address part or all of the technologies and/or any related technologies which further the goals described in this RON. R&D projects should focus on research or enabling technologies development as opposed to commercial product development.

Background

In the past two decades, utilities have been automating the operation of the electric distribution grid to provide a higher level of reliability and operation and maintenance efficiency. However, the automation efforts have been modest and if deployed more wide scale, the improvements in reliability and efficiency can be dramatic.

In most part, substations are fairly automated, but the distributed feeders are much less automated. Many of the feeders and feeder equipment are maintained either on a conservative scheduled basis or when there is a failure. In many cases, the utility is unaware of the failure until it is notified by its customers. A more efficient proactive approach is to monitor the equipment and dispatch the maintenance based on the condition of the equipment (condition-based maintenance, CBM). CBM will be greatly enhanced and cost-effective with distribution automation.

Distribution automation (DA) also should be integrated with the emerging AMI systems. The DA system can leverage the 2-way communications infrastructure of the AMI system to back-haul data back to the control centers. More importantly is that data from both systems can be integrated to form a common information data base. This common information base can be shared and used by any utility application. For example, the data can be used in applications to pinpoint faults in the distribution system, to provide automated outage notification, and to provide automated dispatch from the utility outage management system. This is the principle of data being measured once and the resulting information used many times.

Similar to the transmission grid, there have been little investments to update the distribution grid in today's environment of higher loads. Additionally, the distribution grid must begin to handle current flows from distributed energy resources (DER) that were not originally envisioned. Automation will help better utilize the distribution grid in this new environment.

There are perceived and real barriers to more wide scale DA. One is the perceived high cost of equipment, equipment installation and maintenance, and real-time 2-way communications (needed for effective automation). And for the DA products that are available and deployed, the vendors have been slow to adopt interoperability (e.g., communications) standards. Finally, current SCADA systems need to have new paradigms to include DER.

Enabling Technologies

Enabling technologies have the potential to mitigate the barriers by making possible new products and applications that result in:

- Cost-effective equipment, installation and maintenance.
- Improved reliability with condition-based maintenance and faster location and isolation of faults, equipment failure, and fallen lines.
- Better knowledge of the health and condition of the distribution grid with a more information rich environment.
- Early indications of distribution congestion (or slack) for assisting long-tern distribution planning.
- Ability to provide insight into the characteristics of customer load patterns.
- Faster, more efficient, and more reliable control and operation of the distribution grid (e.g., lower frequency and shorter time failures through self-healing paradigms). Better coordination of area-specific demand response.

Some Potential Enabling Technologies

1. ***Integrated MEMS-based line sensors***. These integrated line sensors will sense for both equipment status and condition. For low manufacturing cost and low energy consumption, the sensors will utilize Micro-Electromechanical System (MEMS) technology. Research in this area will leverage research currently underway at UC Berkeley, but other approaches will be solicited.

   Sensing features:
   - Voltage, current, power factor, etc., for equipment status.
   - Temperature, wind speed, and acceleration for line conditions (hot sagging line or fallen line).
   - MEMS-technology sensing.

   Communications features:
   - Integrated with silicon embedded wireless (RF or Powerline) mesh communications – reliable RF/Powerline communications in high electromagnetic interfering environment.
   - Integrated with existing DA equipment such as fault current indicators (FCI).
   - Leverage emerging AMI networks for backhaul.

   Easy installation features:
   - Passive, proximity, and non-intrusive.
   - Self-calibrating.
   - Scavenge energy from the line or the environment (no batteries or wiring for power).

2. ***Distribution transformer condition monitoring sensors***. These sensors will monitor the temperature and high concentrations of signature gases that are precursors to impending failure of the transformer. Although distribution transformers are low cost and long-life, there is the cost of an unexpected outage due to a failed transformer. The goal is to have such condition monitoring

sensors be integrated in the transformer packaging, thus the incremental cost is negligible. MEMS technology will be utilized, plus research will also leverage BioMEMS technology and Micro-fluidic technology research at UC Berkeley's Berkeley Sensor and Actuator Center (BSAC).

Sensing features:

- MEMS temperature, gas chromatograph for condition monitoring.
- BioMEMS and Micro-fluidic technology.

Communications features:

- Integrated with wireless (RF or Powerline) communications - reliable RF/Powerline communications in high electromagnetic interfering environment.
- Leverage AMI networks for backhaul.

Easy installation features:

- Integrated with transformer lid or casing
- Scavenge energy from the transformer (thermoelectric) or the environment (no batteries or wiring for power).

3. ***Communications technology***. Many utility DA systems operate on proprietary communications networks. Integration with multiple vendors is difficult and expensive. The solution is the IEC 61850 standard for interoperability. Enabling technologies (can be in any form) than can help enable IEC 61850 interoperability will be very useful to the industry. For example, the technology can be in the form of reusable software code, or communication chip sets.

    - Enable faster implementation or adoption of IEC 61850 for interoperable distribution automation equipment.

4. ***Control and Communications Integration technology***. The research in this technology will look into new ways to operate and control the distribution grid that is different from today's methods. If integrated MEMS-based line sensors are deployed on a large scale, there will be a rich environment of real-time information. In this environment, new control strategies may be viable that were previously not possible. These new strategies may be needed to operate DER successfully as well as protecting the grid and maximizing DER's benefits.

    - Novel new control strategies in a new paradigm of real-time information-rich environment.
    - Applications in micro-grids and distributed energy resources.

Summary

The purpose of this RON is to solicit proposals for research and enabling technologies development for the distribution grid. The outcome of these research and development efforts is not to produce a product but to advance the enabling technology that will contribute to a future distribution grid that is more cost-effective, efficient, and reliable.

Candidate research topics are listed in the prior section. Proposals may address these research topics or other related topics not listed that further the goals described herein.

Acronyms

A/D	Analog to Digital
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
ANSI	America National Standards Institute
BioMEMS	Biomedical MEMS
BSAC	Berkeley Sensor and Actuator Center
C^2I	Control and Communications Integration
C^3I	Command, Control and Communications Integration
CATV	Cable TV
CAISO	California Independent System Operator
CBM	Condition-Based Maintenance
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
DA	Distribution Automation
DER	Distributed Energy Resources
DG	Distributed Generation
DR	Demand Response
DSL	Digital Subscriber Line
EM	Electromechanical
FCI	Fault Current Indicators
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HVAC	Heating, Ventilation, and Air Conditioning
iDEN	Integrated Digital Enhanced Network
IEC	International Electrotechnical Commission
LAN	Local-Area Network
LEO	Low Earth Orbit
LSE	Load Serving Entity
MEMS	Micro-Electromechanical System
NOC	Network Operating Center
OASIS	Organization for the Advancement of Structured Information Standards
PG&E	Pacific Gas and Electric
R&D	Research and Development
RF	Radio Frequency
RON	Research Opportunity Notice
SCADA	Supervisory Control and Data Acquisition
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SMUD	Sacramento Municipal Utility District
SOAP	Simple Object Access Protocol
SVP	Silicon Valley Power
TCP/IP	Transmission Control Protocol / Internet Protocol
TDMA	Time Division Multiple Access
TOU	Time-of-Use
UDC	Utility Distribution Company

WAN	Wide-Area Network
XML	Extensible Markup Language

Definitions

ANSI C12	Series of ANSI standards that pertain to electricity metering.
Apparent Power	Apparent Power (Kva , kilovolts-amps) is the vector sum of the Real Power and Reactive Power. (See Real Power, Reactive Power, and Power Factor)
Advanced Metering Infrastructure	Advanced Metering Infrastructure refers to systems that measure, collect and analyze energy usage, from advanced devices such as electricity meters, gas meters, and/or water meters, through various communication media on request or on a pre-defined schedule. This infrastructure includes hardware, software, communications, customer associated systems and meter data management software.
Biomedical MEMS	MEMS technology for biomedical applications (See MEMS below)
Condition-based Maintenance	Equipment maintenance is based on the equipment's health, rather than based on a schedule or equipment failure.
Demand Response	Reducing demand in response to a curtailment notification or short term price signal
Distribution Automation	The use of communications along with remotely operable equipment and computer-based equipment to monitor and control the electricity distribution grid
Distributed Energy Resources	Distributed energy resources are small-scale power generation technologies (typically in the range of 3 to 10,000 kW) located close to where electricity is used (e.g., a home or business) to provide an alternative to or an enhancement of the traditional electric power system
Dynamic Tariff	A tariff in which the retail electricity rate is characterized by one or more dispatchable prices intended to reduce and/or shift peak load. (See Tariffs)
Firmware	Software that is embedded in the electronic device.
IEC 61850	An international standard for substation that is a part of the International Electrotechnical Commission's (IEC) Technical Committee 57 (TC57) architecture for electric power systems. IEC 61850 uses a model-driven approach with mappings to a number of communications protocols
Local-Area Network	A network consisting of nodes that are confined within a localized area. For example, a floor of a building, or the building itself. (See Wide-Area Network)
MEMS	Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro-fabrication technology
Micro-fluidic Technology	Technologies that deals with the behavior, precise control and manipulation of micro-liter and nano-liter volumes of fluids. The behavior of fluids at the micro-scale differ greatly from the macro-scale
Modulation	Method of superimposing a signal on a carrier wave form. For example, in radio broadcasts, AM (amplitude modulation) and FM (frequency modulation) are used.

Multi-phase	Alternating current (AC) electricity that consists of more than one phase of current. For example, common residential 240V AC power used for electric ovens and clothes dryers is multi-phase. (See Single-phase)
Non-contact	No physical connection to the current-carrying wire.
Platform	Hardware and software with the ability to perform multiple functions
Power Factor	Ratio of Real Power to Apparent Power. Also the cosine of the angle between the Real Power vector and the Apparent Power vector. (See Apparent Power, Real Power, and Reactive Power)
Reactive Power	Electrical power (Kvar, kilovolts-amps reactive) consumed by a capacitive or inductive load. The Reactive Power vector is orthogonal to the Real Power vector. (See Apparent power, Real Power, and Power Factor)
Real Power	Electrical power (KW, kilowatts) consumed by a resistive load and is the power that is used for real work. The Real Power vector is orthogonal to the Reactive Power vector. (See Apparent power, Reactive Power, and Power Factor)
Revenue Meter	Meter that can be used for billing purposes.
Revenue-grade	Measuring accuracy that meets the requirements needed for billing purposes.
Single-phase	Alternating current (AC) electricity that consists of one phase of current. For example, common residential 120V AC power is single-phase. (See Multi-phase)
Soft	Can be re-programmed with new software.
Stranded	Made obsolete because the technology is no longer supported.
Tariffs	The effective rates for electricity that includes rules, rate schedules, and service area maps.
Web Services	A modular collection of web-protocol based applications that can be mixed and matched to provide business functionality through an internet connection. Web services use standard Internet protocols such as HTTP, XML, and SOAP to provide connectivity and interoperability between companies.
Wide-Area Network	A network consisting of nodes that are dispersed over a wide area. For example, nodes that are located in different buildings, or in different cities. (See Local-Area Network)
Wireless	No wires between source of information and receiver of the information