Sensor/HAN Laboratory

Preliminary – End of Year One Report

California Smart Grid Center, CSU Sacramento

Subtasks of CEC Grant: 500-09-039

March 28, 2011

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Summary

This report will briefly review the activities of the CSGC Sensor/Home Area Network (HAN) laboratory from August 2010 to April 2011 as the first year of the CSGC comes to a close in June 2010. Major milestones during this interval included; the creation and initial equipping of a Sensor/HAN lab in Riverside Hall 3001, the recruitment of over twenty undergraduate students in various projects related to the smart grid, and publishing several smart grid related journal articles and white papers. During this academic year, the Sensor/HAN laboratory researched effective building to grid technologies that allow commercial building operators to reduce energy (baseline reductions), manage time of day usage including demand response (auto DR) during critical energy availability periods, and methods to autonomously determine the building's occupant's energy needs. Examples of the projects include adaptable lighting controls, sensors and instrumentation to determine building state variables, wireless data exchange, room occupancy determination, and algorithms for PH&EV charging control.

Sensor/HAN Lab Focus

The Sensor/HAN lab research and grant activities are a multi-year effort with this first year ramping up to sustained projects for at least the next two years. Soon we hope to have configurable smart meters in three labs – the Sensor/HAN lab, the Power Lab, and the Cyber Security Lab. Smart meters are often described as the enabling device which can give electrical consumers near real time data on their power consumption. Power monitoring devices have existed for many decades but the new key feature is a low cost low power wireless communication module. An ongoing effort is to track the emerging wireless standards from NIST, and industrial specifications such as the ZigBee Alliance (www.zigbee.org). Membership in the ZigBee Alliance is beyond the CSGC financial grasp and the Sensor/HAN Lab will not have an insider's track the evolving specifications. But we will closely monitor the development of ZigBee Smart Energy version 2.0. The focus in both the published Smart Energy Profile 1.X and the evolving version 2.0 is the communication of energy status and data so that timely action can be taken to dynamically manage the consumer's energy needs. For the consumer this leads to a popular approach where the data is sent to an In Home Display (IHD) usually wirelessly. Much like controlling your television, the IHD is seen as the portal where appliances can be scheduled, electric vehicle charging status monitored, lighting controlled, and sophisticated interaction with the consumer's heating and cooling equipment.

So while a smart meter can initiate the chain of possibilities, the lab will be researching how these devices interoperate, and seek to help define how such technologies can reduce electrical consumption. These areas have titles such as Home-to-Grid, Building-to-Grid, Industry-to-Grid, Vehicle-to-Grid and so on. These titles are more descriptions of where the target device resides than an accurate description of the underlying technology development. The broad research question is will the use of low cost and low power sensors feeding equally

low-cost and low-power wireless communication devices give engineers and consumers the information they need to effectively control their energy consumption?

One aspect not yet mentioned is the desired effect on the transmission and distribution system. Most utility companies are actively upgrading their power control systems with emerging digital controls. These newer control devices hope to perform many grid improvements including three fault steps much more quickly and with greater reliability – fault detection, fault analysis and fault recovery. The researchers in the Power Lab will have the greatest effort in this arena, but once again it will be the communications and cyber-security aspects that will be critical in fostering such system improvements. The use of distributed energy resources can be seen as both an adjunct addition to grid capacity and equally as a local resource to be called upon during fault events. So the combination of digital controls, wired and wireless communications, cyber-security, and optimally, renewable energy sources can then form a microgrid down to the individual household with the residential IHD informing consumers about a capacity shortage or outage and what steps their own devices are taking to help relieve the condition. Local energy storage perhaps in the form the charged electrical vehicle battery will assist the distribution grid in coping with these issues.

The time target of the Sensor/HAN lab research is to find and study sensor/HAN efforts that might lead to commercial products in the three to five year time span. Occasionally efforts will examine current products particularly where a grant may desire functional testing of devices. But the three to five year window is far enough into the future to allow us to develop a research plan, recruit students, and enjoin collaboration from other universities and agencies. Research in the five to ten year window is typically more basic science related and the team intends to defer that work to established research universities.

Detailed Discussion on Specific Tasks

Task 4.2 PH&EV

Plug-in-hybrid and electric vehicles are potentially disruptive technology to the existing electrical grid. Disruptive technology can be defined as technology that, when adopted, requires a system response that is often very different from the prior business as usual. Most automotive market forecasters see PH&EV penetration slowly climbing in California to perhaps 15% of all vehicles by 2020 at the earliest (http://phev.ucdavis.edu/Taking_Charge_final2.pdf). After many discussions with various California utilities, it was often repeated that the utilities feel that 10% to 15% PH&EV market penetration is the earliest that the grid will be impacted appreciably. So with a ten year out prospect, it seems that rather than directly tackle the PH&EV impact on the distribution grid, it will be productive to look at the underlying technologies that will be involved in providing the level of power to charge a vehicle, the control algorithms related to effective cost management of such charging, and demand response strategies that become available with a vehicle sized energy storage system. There is a proposed CSGC PH&EV/Battery Management project and further details are given within that proposal.

Task 4.3 Residential and Commercial – Home Area Networks (HAN) and Sensor Networks

Despite considerable media attention to energy policies and potential energy shortfalls, the average electrical consumers seem only slightly concerned over their energy future. It is virtually inevitable that all rate payers will see a change to time of day pricing for their electrical energy. The timing of this change will depend on when the political will emerges but definitely when fossil fuel resources reach pricing levels that make renewable energy sources cost competitive. If climate and global environment husbandry issues carry the political tide, the change to time of day billing may occur much sooner. Those unwilling to reduce power usage will most likely see an increase in their utility bill. Others will be enabled to use energy over the daily cycle in ways and manners that minimize the impact on their energy costs. The vision of the sensor lab is then to have strategies and systems available before they are absolutely needed.

Research Plan: Assumptions: Advanced Metering Infrastructure (AMI) will be in place locally (northern California) by 2012. Automated Demand Response will see movement from pilot projects to larger power users by late 2012. Residential demand response is at least three years away.

1. Establish CGC Sensor/HAN laboratory. Room 3001 in Riverside Hall is about 1,100 square feet and, in August 2010, was dedicated to Sensor and (utility related) home area network research at the residential and commercial level. The lab has been outfitted with basic equipment and is currently engaged in preliminary research on building to grid sensors. Research grade power monitoring equipment has been acquired and is expected to be installed in "parallel" with a revenue grade AMI meters (for example, the SMUD style Landis+Gyr meter) in RVR 3001 by June 2011. AMI meters, provisioning software, data aggregators and wireless equipment will allow the lab to complete a Grid to Home link. Timing: 2010 to 2011
2. Identify the issues associated with HANs and sensor networks and then test systems to give feedback to consumers. The CSGC and SMUD are in the early stages of forming a partnership for the functional testing of home based devices useful in the *Utility HAN* as it is frequently called. This testing is proposed to occur over almost three years during which time vendors should have launched many new products aimed at this market. Thus in cooperation with utilities, vendors and energy policy agencies, the lab will examine the HAN environment and research the interoperability and practicality of wired and wireless systems proposed for residential energy users. Compile a tool set that enables residential consumers utilize energy more efficiently. Where appropriate promote the use of HAN network devices to include Utility HAN aware appliances. Timing: 2011 to 2013
3. Determine and document how to configure, install and commission low power and low cast sensor networks similar to building to grid in both new construction and retrofit applications. Timing: 2011 through 2014
4. Devise sensor, instrumentation and communications strategies that nearly autonomously determine the energy profile of a building. Then apply those strategies to developing

control algorithms that can predict energy usage for some hours to days ahead outlook. Integrate some limited capability to communicate with existing SCADA, and energy management systems (EMS) currently in use in commercial buildings. Timing: 2012 to 2014

5. Compile a tool set that enables residential consumers utilize energy more efficiently. Where appropriate promote the use of HAN network devices to include Utility HAN aware appliances. Timing: 2011 to 2013

*Work Started***:**

1. Sensor Lab infrastructure Fall 2010. An existing laboratory was reworked into a sensors and instrumentation lab (Riverside 3001). The lab was equipped with tables, computers and support equipment useful for rapid prototyping and device testing. Five dedicated project work tables were configured with useful test equipment such as power supplies, function generators, multimeters, and oscilloscopes. Four computers were provided by the EEE Dept and the IT group of the ECS College into which were installed data acquisition hardware and LabView software.

2. IT Infrastructure Fall 2010. A research grade local area network was installed that links the sensor lab (RVR 3001), the power lab (SCL 1102) , the energy lab (SCL 1357) and the ECS College data center (RVR 2011A). The LAN hardware will take most research related traffic off the ECS network and also allows for cyber testing of all current protocols. Servers in the data center dedicated to smart grid research received 4 TBytes of hard drive storage.

3. Wireless sensor network Fall 2010. Zigbee wireless sensor nodes were purchased from National Instruments. The NI Zigbee nodes are based on 1.0 of the standard. These sensor nodes permit the development of sensors without a need for integrated wireless components. The sensor nodes themselves permit device characterization to include signal power, propagation characteristics, and hardware layer testing.

4. Sensor data storage was addressed in hardware by the IT infrastructure. Data retrieval and data mining has been initially enabled by the Pi software system donated by OSIsoft.

5. Five undergraduate projects were started in the Fall term that examine some aspect of the sensor and instrumentation goals of Building to Grid (B2G).

Relevant Grant Tasks:

Task 3.3 Ongoing Operations:
The contractor (CSGC) will develop future research plans to ensure continuation of long-term attention to smart grid research and funding partners other than the Energy Commission.
Review of activities (tasks, goals, objectives, research outcomes, deliverables, and status).

Task 4.0 Smart Grid Demonstrations
Develop demonstration test beds in …..

Plug-in-Hybrid and Electric Vehicles (PH&EV)
Residential and Commercial – Home Area Networks and Sensor Networks

Task 4.2 Plug-in-Hybrid and Electric Vehicles (PH&EV)
Conduct literature search on PH&EV issues associated with use [sic] on the distribution system.
Work with the UC Davis PHEV Center and the California Utilities to identify additional issues associated with PH&EV use at the distribution level.
Prepare a report documenting the identified issues.

Task 4.3 Residential and Commercial – Home Area Networks (HAN) and Sensor Networks
The goal of this task is to design and test Home Area Networks (HANs) for residential and sensor networks for residential and commercial buildings.
The Contractor (CSGC) Shall:

- Establish a Smart Grid Home laboratory within existing facilities at CSUS to test smart new and emerging energy devices
- Assess the needs and potential tools for consumers to make intelligent choices to control their energy use with HANs and sensor networks
- Work with Center for Information Technology Research in the Interest of Society (CITRUS), i4Energy Centers, and the California Utilities to identify additional issues associated with HANs and sensor networks
- Survey tools and compile a tool set that enables consumers to conserve energy and reduce their energy bill using Home Area Networking
- Match HAN tools with Utilities Demand Response offerings to design networks that maximize the incentive to use HAN tools and expand the consumer's choices.
- Test, at the Smart Grid Home laboratory, systems that enable a wide range of feedback to consumers on the impact of their behavior on energy consumption
- Test, at the Smart Grid Home laboratory, technologies that provide a bridge between utility advanced metering infrastructure and customer premises networks
- Determine and document how to configure and install sensor netowrks in both new and retrofit applications

Deliverables:

- Subtask report
- Demonstration report
- Behavior report
- Report on the use of HAN tools
- Report on HAN design optimization
- Report on sensor networks