City of Boulder Department of Community Planning & Sustainability
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MEMORANDUM

To: IBM Smarter Cities Challenge Team

From: Kelly Crandall, Special Projects Coordinator

Date: May 11, 2011

RE: Inventory of *SmartGridCity* Infrastructure

INTRODUCTION

The following memo represents a summary of information gathered by city staff primarily from filings at the Colorado Public Utilities Commission (PUC) in dockets relating to *SmartGridCity*.

ANALYSIS

The electric customers comprising the City of Boulder consume electricity that results in approximately 220 megavolt-amperes (MVA) of apparent load. The distribution grid is a 13.2 KV grounded Y electric system in a radial feed with seven distribution substations and 24 feeders.[1] The *SmartGridCity* infrastructure includes smart meters, substation intelligence for reliability and outage management improvements, and data collection software for demand response management and asset condition tracking.

According to Xcel Energy (Xcel), there are five *SmartGridCity* asset categories (see Table 1 and Fig. 1). This memo focuses on the first four asset categories.

Table 1: *SmartGridCity* Asset Categories and Expenditures (in millions)[2]

1. Distribution Communications & Monitoring Systems	$20.9
1. Premise Level Systems	$1.4
1. Substation and Feeder Level Control & Monitoring Systems	$4.6
1. Information Systems Infrastructure	$14.9
1. Development, Testing, & Control Facilities	$2.9

[1] 10A-124E, Direct Testimony of Lynn L. Worrell, on behalf of Public Service Company of Colorado, Mar. 10, 2010, p.2.

[2] 10A-124E, Direct Testimony of Chris Haworth, on behalf of Public Service Company of Colorado, Mar. 10, 2010, p.4 and exh. CRH-1.

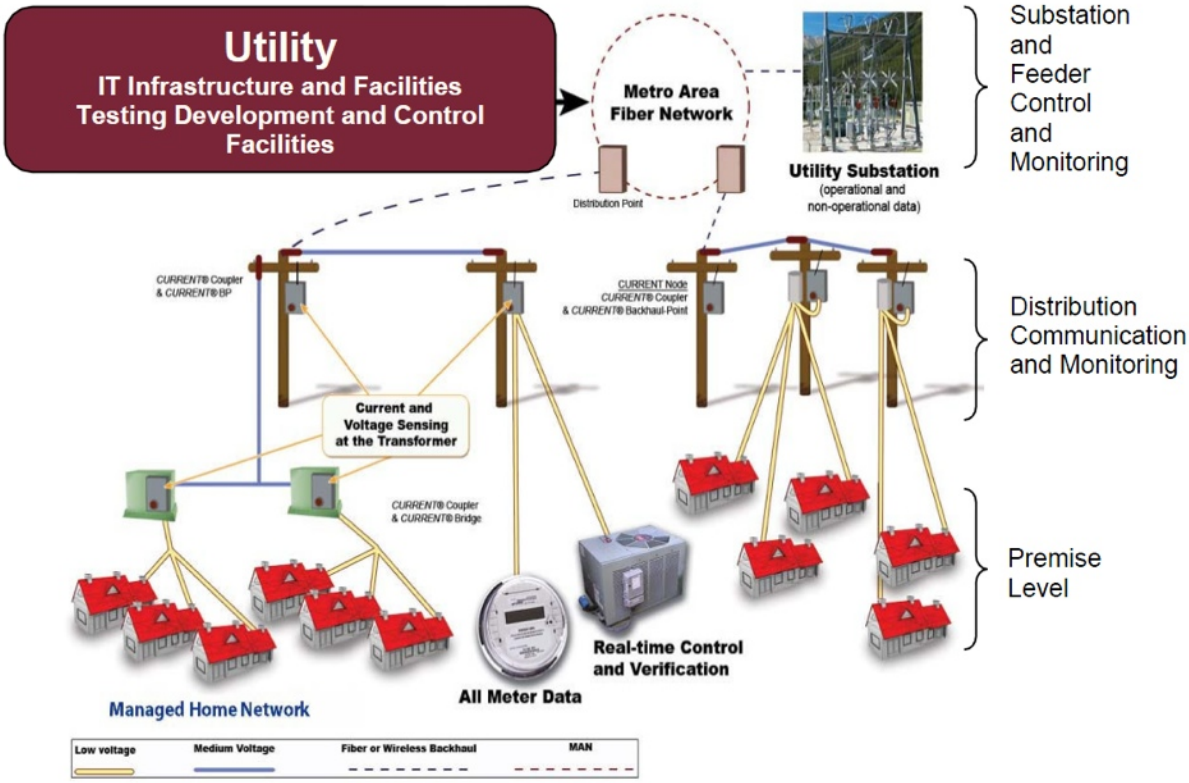

Fig. 1: *SmartGridCity* Overview[3]

1.0. Distribution Communications & Monitoring System (DCMS)

The DCMS is intended to exchange information—including meter readings, demand response signals, and component operating conditions—between Xcel and customer premises.[4] The CURRENT Group provided the major hardware and software for the DCMS.[5] This system has three components: the broadband over power line system, the fiber optic backhaul network, and the substation fiber network.

1.0.1. Broadband Over Power Line Communications System (BPL)

BPL systems are a higher-volume form of power line carrier technology (PLC), where communications signals are transmitted across existing power lines. Xcel defines "broadband" as "systems providing 1Mbps up to 10Mbps bidirectional communications service."[6] In *SmartGridCity*, communications signals are transmitted from the fiber optic backhaul network,

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[3] 10A-124E, Direct Testimony of Randy Huston, on behalf of Public Service Company of Colorado, Mar. 10, 2010, p.4 fig.1.

[4] *Id*. at 5.

[5] *Id*. at 23.

[6] 10A-124E, Hearing Exhibit 93-1, Aug. 31, 2010, at p.1.

travel along the power lines, are routed around transformers by network element service points, and are sent through the premise service drop cables to the smart meters.[7]

The CURRENT Group provided the BPL components, including BPL communications modules in the smart meters and the CURRENT OpenGrid™ software, which collects, stores, and displays data from different intelligent devices across the grid.[8] Each transformer is equipped with network elements that route the BPL signal around the transformer and monitor the transformer's condition.[9]

Xcel states that the BPL system enables distribution automation (DA) and home area networks (HANs).[10] However, it is unclear how Xcel defines DA, and *SmartGridCity* is not intended to make the distribution grid self-healing—capable of automatically recognizing and responding to potential problems—at this time.[11]

1.0.2. Fiber Optic Backhaul Network

The backhaul network consists of rings of fiber optic cable that connect various injection points —where communications signals are injected onto power lines as part of the BPL system—to the information technology environment where signals can be collected, stored, and analyzed.[12] The rings start and end at a distribution point (a "backhaul point") near the Boulder Service Center and track Boulder's 24 distribution feeders.[13] As of July 2009, four feeders were automated and all 24 were being monitored.[14]

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[7] *Id*. at 6.

[8] 09AL-299E, LWG 22-10, Oct. 2, 2009, 22nd Set of Discovery Requests of Leslie Glustrom Served on Public Service Company; 08S-520E, OCC 4-3, Feb. 5, 2009, 4th Set of Discovery Requests of the Office of Consumer Counsel Served on Public Service Company; http://www.currentgroup.com/xcel_energy.php; http://www.currentgroup.com/opengrid.php.

[9] 10A-124E, Direct Testimony of Randy Huston, p.6. As of February 2009, there were approximately 6,635 network elements installed. 08S-520E, OCC 4-3, Feb. 5, 2009; 10A-124E, LWG 7-3, Aug. 3, 2009.

[10] 09AL-299E, Rebuttal Testimony of Randy Huston, on behalf of Public Service Company of Colorado, Oct. 13, 2009, p.7-8.

[11] BOOZ ALLEN HAMILTON, INC. FOR THE NATIONAL ENERGY TECHNOLOGY LABORATORY [NETL], DOE/NETL-2010/1421, ANTICIPATES AND RESPONDS TO SYSTEM DISTURBANCES (SELF HEALS) 3 (2010), http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/09.02.2010_Anticipates%20and%20Responds%20%28Self%20Heals%29.pdf.

[12] 09AL-299E, LWG 22-11, Oct. 2, 2009; 10A-124E, LWG 3-24, July 2, 2010; 10A-124E, Direct Testimony of Randy Huston, p.7.

[13] 10A-124E, Direct Testimony of Randy Huston, p.7. A different document lists 23 feeders, not 24. 10A-124E, LWG 6-26.A1, Aug. 26, 2010.

[14] 10A-124E, Climax/CF&I 3-10.A4, Aug. 27, 2010, 3rd Set of Discovery Requests of Climax and CF&I Served on Public Service Company.

The fiber optic cable was provided by The CURRENT Group, and the largest cables include 144 fibers, although most are much smaller.[15] There are approximately 177.75 miles (938,518 feet) of aerial fiber and 24.55 miles (129,622 feet) of underground fiber, totaling 202.3 miles (1,068,140 feet) in the *SmartGridCity* area.[16] "As-built" drawings provided to the City by Xcel identify the locations of 789,270 feet of fiber in 2009.[17]

While fiber mostly provides the connection between the backhaul point and the BPL system, in about 90 places, Sprint's public radio network connected the backhaul point directly to network element service points "where fiber would have been prohibitively expensive or only a small number of customers needed to be served."[18]

1.0.3. Substation Fiber Interconnections

This system includes fiber interconnections between the four upgraded substations: Leggett, Sunshine, National Center for Atmospheric Research (NCAR), and Boulder Terminal.[19] This amount of fiber is included in the 202 miles listed above. Specific substation upgrades are described in section 3.0.

2.0. Premise Level Systems (PLSs)

According to Xcel staff, "[t]he purpose of the PLS is to collect, communicate, display, and act upon information at our customers [sic] premises."[20] PLSs include smart meters and home automation systems.

2.0.1. Smart Meters

The *SmartGridCity* smart meter system includes both residential and commercial meters. Out of approximately 44,000 residential meters in the *SmartGridCity* area, around 23,000 are smart meters.[21] Out of approximately 7,600 commercial, institutional, and governmental meters in the *SmartGridCity* area, about 100 have been converted to smart meters for the project.[22]

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[15] 09AL-299E, LWG 22-10, Oct. 2, 2009; 09AL-299E, LWG 22-11, Oct. 2, 2009.

[16] 09AL-299E, LWG 12-4, Aug. 11, 2009. However, a separate document describes 1,072,843 feet of installed fiber. 08S-520E, OCC 4-3, Feb. 5, 2009.

[17] See Xcel SmartGrid 2009 As-Built Map (attached to e-mail).

[18] 09AL-299E, LWG 25-14, Oct. 29, 2009; 10A-124E, Direct Testimony of Randy Huston, p.6-7; 10A-124E, Rebuttal Testimony of Randy Huston, on behalf of Public Service Company of Colorado, Aug. 10, 2010, p.11.

[19] 10A-124E, Direct Testimony of Randy Huston, p.7.

[20] 10A-124E, Direct Testimony of Randy Huston, Mar. 10, 2010, p.8.

[21] An exact number is not available, but there were 22,884 smart meters installed as of June 15, 2010. See 10A-124E, LWG 3-2, June 25, 2010; 10A-124E, LWG 6-40, Aug. 19, 2010 (43,804 residential meters total in the SGC area).

[22] 10A-124E, LWG 6-40, Aug. 19, 2010 (7,581 commercial, industrial, and municipal meters). However, another discovery response states that 689 commercial 1S, 2S, and 12S meters have been installed. 10A-124E, LWG 3-2, June 25, 2010.

2.0.1.1.Relevant Hardware

Xcel uses four classes of meters throughout its Colorado service territory: manual read, two types of meters that transmit via radio frequencies or RF ("bubble up" and "wake up") as part of an automated meter reading (AMR) system, and smart meters.[23] The smart meters installed as part of the *SmartGridCity* project include residential, commercial, and institutional meters. In general, the residential meters are Landis+Gyr brand while the commercial and institutional meters are SmartSynch brand.[24] The Landis+Gyr meters are "AL" model meters (see Table 2 for specifications). The SmartSynch system includes smart meters, the SmartSynch Data Acquisition System, and a wireless GPRS network (see section 2.1.3.).[25] There are approximately 100 SmartSynch meters installed at facilities of the City of Boulder, the University of Colorado, the Boulder Valley School District, and two local hospitals, along with other commercial and governmental buildings.

Form	Clarification	Model	Material #	Catalog #	Description	Vendor Price	No. of Meters Installed
1S	Single phase, 120V	ALF	12G275	EA0000N 0-0S62	Standard	$53	57
2S	Single phase, 120V/ 240V	ALF	12G277	EA1100N0 -0S62	Standard	$29	19,882
2S	Single phase, 120V/ 240V	ALF	12G278	EA1100N0 -0T48	Net	$29	
12S	2 phases, 2 transformers, 120V	ALF	12G405	EA1C00N 0-0S62	Standard	$67	2,994
Source:	LWG 3-1	LWG 4-15					CPUC 1-17

Table 2: *SmartGridCity* Landis+Gyr Meter Specifications[26]

2.0.1.2.Relevant Software

There are three primary software systems used by installed smart meters[27]:

- CURRENT Collector/CURRENT OpenGrid[28]: requests and retrieves interval data from smart meters.

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[23] 10R-799E, Transcript of 4/7/2011 hearing at p.11-12 and exh. 1 (Randy Huston speaking). Bubble-up meters transmit data every few seconds for drive-by data collection, whereas wake-up meters transmit data in response to a signal from the data collector.

[24] In docket 10A-124E, Xcel's testimony (Huston Direct Testimony, p.8) and response to discovery (LWG 3-1) generally refer to the Landis+Gyr meters as residential and the SmartSynch meters as non-residential. However, a separate response to discovery (LWG 3-2) lists 1S, 2S, and 12S meters that are commercial or municipal.

[25] SmartSynch, *Smart Grid Applications*, http://www.smartsynch.com/SmartSynch_smartgridaction.htm.

[26] 10A-124E, LWG 3-1, July 12, 2010; 10A-124E, LWG 4-15, July 12, 2010; 10A-124E, CPUC 1-17, June 1, 2010.

[27] 09A-796E, Direct Testimony of Todd N. Weisrock, Nov. 2, 2009, at p.4.

[28] The Current Group, *Xcel Energy – SmartGridCity™*, http://www.currentgroup.com/xcel_energy.php (last visited Apr. 20, 2011); 09AL-299E, LWG 24-2, Oct. 29, 2009, 24th Set of Discovery Requests of Leslie Glustrom Served on Public Service Company.

- OSI PI: stores and aggregates smart meter data for upstream and downstream use (e.g., for supply decisions and customer interface decisions).
- Ventyx Retail Office: manages demand response by forecasting potential demand reduction to assist capacity planning.

2.0.1.3.Smart Meter Communications

The SmartSynch commercial meters communicate with the back office meter data management system via general packet radio service (GPRS), although limited information is available in Colorado Public Utilities Commission (PUC) filings about this process.[29] Xcel communicates with its residential smart meters via BPL technology which transmits data bidirectionally across a utility's existing power lines.[30] The Landis+Gyr AL meters can communicate both one-way and two-way through PLC (i.e., BPL) or RF.[31] They are theoretically capable of "pushing" data or responding to "pulls"—i.e., they can transmit data automatically or in response to an encrypted signal.[32] For residential meters, the BPL communications pathway from the premises to the smart meter to the fiber backhaul is as follows[33]:

Premises

- BPL modem can extract the PLC signal and convert it to an 802.1 Ethernet signal
- The Ethernet connection can transmit information to in-home devices

Smart Meter

← Signal passes through premise's electrical wiring to outlet or dedicated connection

BPL Communications Card in the meter converts information to TCP/IP packets and sends them over the premise electric drop cable →

Fiber Backhaul

- Multiple premise drop cables connect to a distribution transformer, and transmit their signals to the network element
- Network elements aggregate information from various premises and send it over the distribution feeder to a backhaul point
- Backhaul points aggregate information from numerous network elements and transmit it to the fiber backhaul ring

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[29] 10A-124E, Direct Testimony of Randy Huston, Mar. 10, 2010, p.9.

[30] 10R-799E, Transcript of 4/7/2011 hearing at p.15 and exh. 1 (Randy Huston speaking); DEPARTMENT OF ENERGY, COMMUNICATIONS REQUIREMENTS OF SMART GRID TECHNOLOGIES 17-19 (2010), http://www.gc.energy.gov/documents/Smart_Grid_Communications_Requirements_Report_10-05-2010.pdf.

[31] LANDIS+GYR, FOCUS AL PRODUCT SPECIFICATION AND SCHEDULE SHEET (n.d.), http://www.landisgyr.com/na/apps/products/data/pdf1/FOCUS_AL_Product_Schedule.pdf.

[32] 10R-799E, Transcript of 4/7/2011 hearing at p.15-16 and exh. 1 (Randy Huston speaking) (at least 128-bit encryption).

[33] 10R-799E, Transcript of 4/7/2011 hearing at p.15 and exh. 1 (Randy Huston speaking); 10A-124E, LWG 5-3, July 12, 2010; 10A-124E, LWG 5-11, July 12, 2010; 10A-124E, Hearing Vol. 2, Sept. 1, 2010, p.163-71 (Randy Huston speaking).

Table 3: The BPL Communications Pathway

2.0.1.4.Smart Meter Capabilities

According to Xcel, the Landis+Gyr smart meters can be updated, although not remotely.[34] Xcel's existing Customer Revenue System uses smart meter data to prepare customer bills.[35]

In PUC docket no. 10R-799E, regarding customer privacy for smart meter data, Randy Huston of Xcel stated at the May 4, 2011 hearing that the Landis+Gyr smart meters cannot be retrofit with ZigBee, Wifi, or Bluetooth chips.[36] If a customer asked for any of these capabilities, the company would not be able to provide it. To be ZigBee enabled would require "wholesale replacement" of the smart meters.

This limitation may be particularly important because Xcel states that the Landis+Gyr smart meters are configured as "wake-up" rather than "bubble-up" meters, meaning that the information the meters collect is only transmitted in response to a signal from the company rather than being transmitted out at set intervals.[37] Therefore, customers with devices that passively "listen" to smart meters may not be able to obtain data more frequently than when the utility transmits a wakeup tone. PUC filings and associated discovery indicate that although residential smart meters collect data every 15 minutes, Xcel only gathers the data once nightly.[38] Therefore, residential customer devices might be limited to providing the same data that Xcel's online account provides: day-after energy usage data rather than near-real-time data.

According to a presentation delivered by Randy Huston and Megan Hertzler at a May 4, 2011 PUC hearing, Xcel is planning to begin presenting unvalidated, fifteen-minute-delayed data to residential customers with smart meters in June 2011.[39] This suggests that Xcel may begin waking up the meters more frequently (if it is not already doing so).

2.0.2. Home Automation Systems

The broad purposes of home automation systems, as viewed by Xcel, are to (1) provide in-premise device control and monitoring, and (2) act as a communications gateway between the

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[34] 10A-124E, Rebuttal Testimony of Randy Huston, Aug. 10, 2010, p.13.

[35] 09A-796E, Direct Testimony of Todd N. Weisrock, Nov. 2, 2009, at p.5.

[36] A transcription of the hearing is not yet available.

[37] 10R-799E, Comments of Public Service Company of Colorado, Apr. 29, 2011, at p.9-10; Megan Hertzler for Public Service Company, Transcript from 4/7/11 Hearing, at p.44, lines 16-20 ("And to the extent that is a more passive situation, I think that he can put a piece of equipment in his home, listen to that meter, and use that information as he likes."). Xcel suggests in this docket that it is concerned about third-party devices "controlling" the meter by sending their own wakeup tones.

[38] *See*, *e.g.*, 10A-124E, Direct Testimony of Randy Huston, Mar. 10, 2010, p.8; 10A-124E, Climax CF&I 1-21, Aug. 27, 2010. Black Hills collects data in five-minute increments. 10R-799E, Transcript of 4/7/11 hearing at p.76-77 (Christopher Burke speaking).

[39] 10R-799E, Hearing Exhibit 6, May 4, 2011. The transcript from this hearing is not yet available.

electricity provider and the premise.[40] While 15,000 home automation systems were originally scoped as part of *SmartGridCity* deployment,[41] they were not installed, reportedly due to security problems with the vendor's design.[42] Instead, Xcel proposed the In-Home Smart Device (IHSD) Pilot as a DSM program, which was subject to 60-day notice and comment by stakeholders in the DSM Roundtable.[43] As part of the IHSD Pilot, Xcel intended to install 1,500 energy management systems (1,100 within the *SmartGridCity* area) among volunteer residential customers.[44] The IHSD Pilot is designed "to test how customers respond to various control strategies and energy consumption information delivered to their homes through in-home energy management devices."[45] The program is to be offered in conjunction with the *SmartGridCity* Pricing Pilot (Docket No. 09A-796E).

In the fourth quarter of 2009, Xcel began a pilot of 25 Control4 systems.[46] However, in 2010, no systems were installed due to difficulties ensuring their security.[47] Xcel appears to still be in the device testing process.[48] As of December 2010, Xcel anticipated that as part of Phase II of the *SmartGridCity* Pricing Pilot—in which participants would be expanded from about 1,200 to 5,000—750 qualifying participants would be offered IHSDs.[49]

2.0.2.1.System Components

Customers must have a functioning central air conditioner (A/C) to participate. The Control4 home energy management system includes a power line interface device (PLID), a Cisco router,

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[40] 10A-124E, Direct Testimony of Randy Huston, Mar. 10, 2010, p.9.

[41] 10A-124E, Hearing Exhibit 42, Aug. 31, 2010, at slide 2.

[42] 10A-124E, Hearing Vol. 3, Sept. 2, 2010, at p.23-25 (Randy Huston speaking).

[43] Xcel Energy, *60-Day Notice Overview*, http://www.xcelenergy.com/Minnesota/Company/About_Energy_and_Rates/DemandSideManagement/Pages/60-DayNoticeOverview.aspx (last visited Apr. 20, 2011); XCEL ENERGY, IN-HOME SMART DEVICE PILOT PROGRAM DESCRIPTION (2009), http://www.xcelenergy.com/SiteCollectionDocuments/docs/In-Home-Smart-Device-Pilot-Program-description.pdf.

[44] 08A-366EG, Public Service Company of Colorado, 2010 Demand-Side Management Annual Status Report 63 (2011).

[45] 09A-796E, Direct Testimony of Jennifer Wozniak, Nov. 1, 2009, at p.3-4.

[46] Xcel Energy, *Colorado DSM Roundtable Discussion*, Nov. 18, 2009, slide 35, http://www.xcelenergy.com/SiteCollectionDocuments/docs/CODSMAug09RoundtablePresentation.pdf.

[47] 08A-366EG, DSM Annual Status Report, at 63.

[48] Xcel Energy, *Frequently Asked Questions – In-Home Smart Device Questions*, http://smartgridcity.xcelenergy.com/learn/frequently-asked-questions.asp#faq5 (last visited Apr. 20, 2011).

[49] 09A-796E, Information re: Ph II of the Pilot Program, Dec. 1, 2010, p.2, 4. The cost of IHSDs installed after selection of Phase II participants should be recovered as part of the pricing pilot. 09A-796E, Decision No. C10-0491, Apr. 27, 2010, p.27 ¶ 94. The Colorado PUC is requiring Xcel to file, by May 1, 2011, a detailed plan for how the pricing pilot will be evaluated. 09A-796E, Decision No. C10-0491, Apr. 27, 2010, p.31 ¶ 110.

an energy controller and display, a wireless thermostat, and two smart plugs.[50] The PLID appears to be the interface between the smart meter/BPL and the home area network. The router connects to it and communicates wirelessly with the energy controller and display. The display uses wifi and can be used to program the smart thermostat and smart plugs. The smart thermostat and the smart plugs can be programmed either through the energy controller and display or through a customer's online account. These devices enable direct load control (DLC): during peak energy events, Xcel can raise or lower the temperature on the thermostat and can shut off the smart plugs, turning off any attached devices. Customers can override changes to the thermostat.

3.0. Substation & Feeder Monitoring & Control System (SFMCS)

The SFMCS is intended to improve the operation and maintenance of distribution substations and feeders. Three primary purposes of these upgrades are:

1. To improve real-time voltage regulation,
2. To monitor the condition of assets more effectively and in real time (such as by tracking transformer temperature), and
3. To provide data that Xcel could use should it decide to allow the substations to act autonomously (to make the grid "self-healing").[51]

Xcel upgraded four substations in Boulder: Leggett, Sunshine, NCAR, and Boulder Terminal. These upgrades include fiber termination equipment, electronic relays, local area networks (LANs), and data processing.[52] There are also at least four feeders with automation, and the substations can monitor the health of these feeders.[53] The substation upgrades instruct switches to open and close to isolate problems and reroute power to customers.[54] Overall, the system is intended to assist with reliability, fault detection, isolation, and restoration (FDIR), helping line operators manage outages, and helping restore power to customers after a storm or other outage.[55]

Schweitzer Electrical Laboratories (SEL) supplied microprocessor-based intelligent electronic devices (IEDs) and six synchrophasors.[56] IEDs can collect data about specific assets on the grid and transmit it to local or centralized databases, where different types of information can be

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[50] XCEL ENERGY, HOME ENERGY MANAGEMENT QUICK START GUIDE (2011), http://smartgridcity.xcelenergy.com/media/pdf/ihd-quick-start-guide.pdf. PLID is defined at 10A-124E, Hearing Vol. 2, Sept. 1, 2010 at p.167 (Randy Huston speaking).

[51] 10A-124E, Direct Testimony of Randy Huston, p.10-11; 10A-124E, Direct Testimony of Lynn L. Worrell, p.4.

[52] 10A-124E, Direct Testimony of Randy Huston, p.11.

[53] *Id*. at 10-11; 10A-124E, LWG 6-26, Aug. 26, 2010.

[54] 10A-124E, Direct Testimony of Lynn L. Worrell, p.5.

[55] *Id*. at 3-5.

[56] DAVID J. DOLEZILEK & STEPHANIE SCHWEITZER, PRACTICAL APPLICATIONS OF SMART GRID TECHNOLOGIES 1 (2009), http://www.selinc.com/WorkArea/DownloadAsset.aspx?id=5215; 10A-124E, LWG 8-69, Aug. 24, 2010.

aggregated.[57] The synchrophasors are time-synchronized with GPS and can create "a complete picture of apparatus utilization" by tracking the change in performance of distribution grid assets over time.[58] The CURRENT Group provided volt/VAR control software and feeder voltage sensors (bellwether sensors) for monitoring the voltage and condition of approximately 4,700 distribution transformers.[59] These technologies are being used as part of the "Smart Substation Project" and to test dynamic voltage optimization.

3.0.1. The Smart Substation Project

Based on testimony before the PUC, all four substations appear to have been upgraded. However, the Smart Substation Project seems to be a demonstration project involving two of the four.[60] It includes a substation automation system (SAS) that draws on information from a network of IEDs and synchrophasors to provide real-time information about the substations and their feeder circuits, updated maybe as often as once per second.[61] While the IEDs can communicate with each other, there also appears to be a distribution automation controller (DAC) in each of the two demonstration substations that gathers data from the IEDs and transmits information to reclosers, switches, and feeder relays.[62]

There are at least three major benefits to the utility and its customers that Xcel has stated as having emerged from this demonstration project. First, all of the data collected by the IEDs and synchrophasors is directed to a "historian" database for analysis, trending, and graphical display.[63] Second, this information goes to the Outage Management System (OMS) to detect outages in real-time and monitor power restoration.[64] Third, the IED network can send emails, texts, voicemail, or pages to utility engineers and other personnel to notify them of problems, allowing for proactive maintenance and reducing unnecessary trips to the field.[65]

3.0.2. Dynamic Voltage Optimization and Volt/VAR Control

The CURRENT Group's Dynamic Voltage Optimization (DVO) system includes hardware and software that will enable the following:

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[57] DOLEZILEK & SCHWEITZER, at 2-3.

[58] 09AL-299E, LWG 25-27, Oct. 29, 2009.

[59] 09AL-299E, Rebuttal Testimony of Randy Huston, p.10; 09AL-299E, LWG22-11, Oct. 2, 2009 (PSCo states that it is monitoring 4,676 transformers); 10A-124E, Rebuttal Testimony of Randy Huston, p.11; 10A-124E, LWG7-3, Aug. 3, 2010; GUOHUI YUAN ET AL., THE FUNCTIONALITIES AND BENEFITS OF A TWO-WAY CENTRALIZED VOLT/VAR CONTROL AND DYNAMIC VOLTAGE OPTIMIZATION 2 (n.d.), http://www.currentgroup.com/uploads/library/Abstract_Functionalities_Benefits_of_a_Two_Way_Centralized_VoltVAR_Control_DVO.pdf.

[60] DOLEZILEK & SCHWEITZER, at 6.

[61] 09AL-299E, LWG 25-28, Oct. 29, 2009.

[62] *Id.*; DOLEZILEK & SCHWEITZER, at 1-2, 5-7.

[63] 09AL-299E, LWG 25-28, Oct. 29, 2009.

[64] *Id.*.

[65] 09AL-299E, LWG 25-27, Oct. 29, 2009; DOLEZILEK & SCHWEITZER, at 2-3.

- volt/VAR control and conservation voltage reduction,
- outage notification and restoration,
- fault detection,
- meter reading and on-demand pinging for customer service,
- asset condition analysis,
- distribution capacitor switching, and
- reports of incipient transformer overloads or failures.[66]

The DVO system is being tested on the NCAR substation, feeders 1554B and 1556B, eight switchable capacitor banks/controls, a transformer load tap changer (LTC) and control, and "dozens" of bellwether sensors.[67] The capacitor banks and LTCs control the voltages automatically.

According to representatives from The CURRENT Group and Xcel, data from the bellwether sensors, SCADA network, capacitor banks, GIS, and other inputs are transmitted along the BPL system and collected by the *CURRENT OpenGrid™ Distribution Manager* software system to monitor the entire feeder network.[68] In tests in 2009, "[t]he software was able to detect voltage and VAR threshold violations, make the correct switching decisions, automatically operate the capacitor banks or make recommendations for LTC tap changes, and eventually bring the system voltage and VAR within the specified range."[69]

4.0. Information Systems Infrastructure

According to Xcel, the *SmartGridCity* Information Systems Infrastructure (ISI) is the collection of software and applications that enable the (1) exchange of information between the different sensors and inputs on the grid, and (2) collecting, storing, and analyzing information to act on.[70] The ISI includes physical and software components.

4.0.1. Physical Components

The physical components of *SmartGridCity's* ISI are the Distribution Point Hut (DP Hut), the wide area network (WAN), and the Lookout Data Center (LOC). The DP Hut, near the existing Public Service Microwave Tower Hut just outside of Boulder city limits, was built to be the aggregation point for the fiber networks.[71] The WAN uses a microwave system apparently owned by Xcel but backed by lines leased from Qwest—to link Boulder and the DP Hut with the

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[66] The Current Group, *Introduction to CURRENT Group, LLC*, slide 8 (Mar. 2009), ftp://ftp.cpuc.ca.gov/stimulus/CAPUC_3-25-09_rev_2_Current.ppt; GUOHUI YUAN ET AL., at 3.

[67] GUOHUI YUAN ET AL., at 2.

[68] GUOHUI YUAN ET AL., at 3-4.

[69] *Id*. at 6.

[70] 10A-124E, Direct Testimony of Randy Huston, Mar. 10, 2010, p.11.

[71] *Id*. at 12.

LOC.[72] The LOC, located in Golden, includes servers that aggregate data from the rest of the system.[73]

4.0.2. Software

Based on the categorization of work orders offered by Xcel in docket 10A-124E, the ISI includes investments in software from at least Ventyx and The CURRENT Group.[74] The Ventyx software includes the *Asset Suite* and the *Service Suite*, which help schedule maintenance and manage truck rolls efficiently, and *Retail Office* and *Generation Management*, which monitor demand response, communicate price signals, and improve load forecasting (see Virtual Power Plants below).[75] *Retail Office* apparently will assist with the In-Home Smart Device Pilot.[76] The CURRENT Group's INDE software appears to gather and transmit smart meter and transformer data to be used by other applications, such as the Ventyx software.[77]

4.0.3. Virtual Power Plants (VPPs)

VPPs are aggregations of distributed energy resources (DERs) that can be dispatched like other elements of a generation mix, as a single power plant.[78] DERs include distributed generation, distributed storage, and demand response (both price-based and incentive-based). They are aggregated by type of program and geographic location for load and price forecasting and more agile demand management.[79] *SmartGridCity* used Ventyx's Smart Grid Operations system for VPP management.[80] The Smart Grid Operations system includes a dashboard that helps operators visualize VPPs, view forecasted megawatt and negawatt data, and send signals to dependent systems like customer portals.[81]

NEXT STEPS

The following list represents some questions that remain at the time of writing, from the city staff perspective, with respect to the inventory of *SmartGridCity*. These questions may be added

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[72] *Id.*; 10A-124E, Transcript of 9/1/2010 hearing at p.169 (Randy Huston speaking).

[73] 10A-124E, Direct Testimony of Randy Huston, Mar. 10, 2010, p.12-13; 10A-124E, Transcript of 9/1/2010 hearing at p.164 (Randy Huston speaking).

[74] 10A-124E, Direct Testimony of Christopher Haworth, at CRH-1.

[75] VENTYX, VENTYX SMARTGRID SOLUTIONS 2 (n.d.), http://www1.ventyx.com/pdf/xcel-energy/Ventyx-Smart-grid-solutions.pdf.

[76] 10A-124E, LWG 1-21, May 24, 2010.

[77] 10A-124E, Direct Testimony of Christopher Haworth, at CRH-1; 09AL-299E, LWG25-19.A1, Oct. 29, 2009.

[78] 09AL-299E, Rebuttal Testimony of Randy Huston, at 8.

[79] Carlos Romero, *LightsOn™: Virtual Power Plants: Making Distributed Energy Resources Actionable in Smart Grid Commercial Operations*, ELECTRIC ENERGY T&D MAGAZINE, July-Aug. 2009, http://www.electricenergyonline.com/?page=show_article&mag=58&article=367.

[80] Ventyx, Press Release, *Leading Analyst Firm Lists Ventyx Solution at Xcel Energy Among "Handful" of Worldwide Virtual Power Plant Projects*, Mar. 16, 2010, http://www.ventyx.com/news/2010/03-15-10-virtual-power-plants.asp.

[81] Ventyx, *Smart Grid Operations*, http://www.ventyx.com/solutions/smart-grid.asp (last visited Apr. 25, 2011).

to over time, by city staff or consultants as appropriate. It may be beneficial to prioritize answering these and other questions for short- and long-term planning purposes.

1. The model number of SmartSynch meters, how many have actually been installed, and where (City Staff expects a memo from Xcel that should touch on these issues). Additionally, Xcel appears to have installed commercial smart meters throughout its Colorado service territory, beyond the 100 suggested—are these part of *SmartGridCity*?
2. Whether the Landis+Gyr meters are all residential (there was some conflicting evidence). It would also be good to know the shortest intervals the meters are capable of collecting data at and whether there are other deployments using this model—Landis+Gyr is being used in several utilities' smart grid deployments, but the model numbers do not appear to be publicly available. Is remote connect/disconnect feasible and enabled for these meters? Is RF functionality enabled for the meters or are they PLC-only?
3. How many home automation systems have actually been installed? How many smart meters have been installed as of the current date?
4. The extent of Xcel's Smart Substation and Dynamic Voltage Optimization projects.
5. Information relating to the differences between synchrophasors, IEDs, bellwether sensors, and network elements; including technical specifications, what they monitor, and how they communicate with the utility.
6. Information relating to any additional components of the *SmartGridCity* infrastructure (aside from Ventyx's Smart Grid Operations system) that can serve to maximize the ability of the smart grid to accommodate increasing penetration of renewable and distributed energy.
7. Interoperability and cyber security require additional investigation as well. Synchrophasor data is published using the IEEE C37.118 protocol, and the Landis+Gyr FOCUS meters and their BPL modules store information according to ANSI C12.19.[82] The smart substations were considered "non-critical assets" and so are not using the IEEE 186-2007 cyber security standard.[83]
8. Technical specifications for the "BPL communications module" by The CURRENT Group, especially as they relate to the ability of the smart meters to comply with the new PAP 0 and PAP 2 interoperability standards for upgradeability and "off the shelf" wireless technology performance.

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[82] 09AL-299E, LWG 12-1, Aug. 13, 2009.

[83] *Id*.