Secure Interoperable Open Smart Grid Demonstration Project

Final Technical Report

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Disclaimer

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List of Abbreviations

Abbreviation	Description
AABE	American Association for Blacks in Engineering
AC	Alternating Current
AHJ	Authority Having Jurisdiction
AMI	Advanced Metering Infrastructure
ARRA	American Recovery and Reinvestment Act
ASC	Adaptive Stochastic Controller
BAT	Brooklyn Army Terminal
BAU	Business as Usual
BMS	Building Management System
C&I	Commercial and Industrial
CALM	CALM Energy, Inc. (also, Computer Aided Lean Management)
CBL	Customer Baseline Load
CCLS	Center for Computational Learning Systems (at Columbia University)
CHP	Combined Heat and Power
CIM	Common Information Model
Con Edison	Consolidated Edison Company of New York
DB	Database
DC	Direct Current
DCC	Distribution Control Center
DER	Distributed Energy Resource
DERMS	Distributed Energy Resource Management System
DEW	Distributed Engineering Workstation
DG	Distributed Generation
DO	Distribution Control Center Operators
DOE	Department of Energy
DR	Demand Response
DRCC	Demand Response Command Center
DRMS	Demand Response Management System
DSCADA	Distribution Supervisory Control and Data Acquisition
DSM	Demand-Side Management

DSP....................................... Distributed System Platform

DTC...................................... Dynamic Treatment Controller

E3... Energy and Environmental Economics

ECC..................................... Energy Control Center

EDD..................................... Electrical Distribution Design

EDN .... Energy Delivery Network

EE .... Energy Efficiency

EEI....................................... Edison Electric Institute

EUCI .... Electric Utility Consultants, Inc.

EV.. Electric Vehicle

GCN.................................... Green Charge Networks

GHG.................................... Greenhouse Gas

HAN .... Home Area Network

HTM.................................... High-Tension Monitoring

HVAC .... Heating, Ventilating, and Air Conditioning

ICCP.................................... Inter-Control Center Communications Protocol

IDSM................................... Integrated Demand-Side Management

IEC....................................... International Electrotechnical Commission

IEE....................................... Institute for Electric Efficiency

IEEE .... Institute of Electrical and Electronics Engineers

ISM...................................... Integrated Systems Model

ISO....................................... Independent System Operator

IT .... Information Technology

kW....................................... Kilowatt

kWh..................................... Kilowatt-hour

LIC....................................... Long Island City

LSOC................................... Load Source Optimization Controller

MACRUC........................... Mid-Atlantic Conference for Regulatory Utilities

MDM................................... Meter Data Management

MDMS .... Meter Data Management System

MPLS .... Multiprotocol Label Switching

MW .... Megawatts

NIST .... National Institute of Standards and Technology

NOC.................................... Network Operations Center

NYC .... New York City

NYCEDC .... New York City Economic Development Corporation

NYISO................................. New York Independent System Operator

NYPSC................................ New York Public Service Commission

O&R .... Orange and Rockland Utilities, Inc.

OMS .... Outage Management System

PACE-D .... Partnership to Advance Clean Energy – Development

PMU.................................... Phasor Measurement Unit

PV.. Photovoltaic

RDSI.................................... Renewable and Distributed Systems Integration

REV .... Reforming Energy Vision

RFI....................................... Request for Information

RFP...................................... Request for Proposal

RTO..................................... Regional Transmission Organization

SG.. Smart Grid

SGAM .... Smart Grid Architecture Model

SGDM .... Smart Grid Disturbance Monitor

SGDP.................................. Smart Grid Demonstration Project

SGIG................................... Smart Grid Investment Grant

SME..................................... Subject Matter Expert

SSGU.................................. Smart Storage and Generation Unit

T&D..................................... Transmission and Distribution

TDSM.................................. Targeted Demand-Side Management

TIBCO................................. TIBCO Software

TIS .... Target Information Sensor

UPS...................................... United Parcel Service of North America, Inc.

US.. United States

var .... Volt-amps reactive

VirG .... Virtual Generator

VVC..................................... Volt-var control

XML .... Extensible Markup Language

YMCA................................. Young Men's Christian Association

1. Executive Summary

The Consolidated Edison, Inc., of New York (Con Edison) Secure Interoperable Open Smart Grid Demonstration Project (SGDP), sponsored by the United States (US) Department of Energy (DOE), demonstrated that the reliability, efficiency, and flexibility of the grid can be improved through a combination of enhanced monitoring and control capabilities using systems and resources that interoperate within a secure services framework. The project demonstrated the capability to shift, balance, and reduce load where and when needed in response to system contingencies or emergencies by leveraging controllable field assets. The range of field assets includes curtailable customer loads, distributed generation (DG), battery storage, electric vehicle (EV) charging stations, building management systems (BMS), home area networks (HANs), high-voltage monitoring, and advanced metering infrastructure (AMI). The SGDP enables the seamless integration and control of these field assets through a common, cyber-secure, interoperable control platform, which integrates a number of existing legacy control and data systems, as well as new smart grid (SG) systems and applications. By integrating advanced technologies for monitoring and control, the SGDP helps target and reduce peak load growth, improves the reliability and efficiency of Con Edison's grid, and increases the ability to accommodate the growing use of distributed resources.

Con Edison is dedicated to lowering costs, improving reliability and customer service, and reducing its impact on the environment for its customers. These objectives also align with the policy objectives of New York State as a whole. To help meet these objectives, Con Edison's long-term vision for the distribution grid relies on the successful integration and control of a growing penetration of distributed resources, including demand response (DR) resources, battery storage units, and DG. For example, Con Edison is expecting significant long-term growth of DG. The SGDP enables the efficient, flexible integration of these disparate resources and lays the architectural foundations for future scalability.

Con Edison assembled an SGDP team of more than 16 different project partners, including technology vendors, and participating organizations, and the Con Edison team provided overall guidance and project management. Project team members are listed in Table 1-1.

Table 1-1. SGDP Sub-project and Project Partner Overview

		Sub-project Description	Project Partner
A. Secure Systems Integration	A.1.	Distributed Energy Resource (DER) Management System (DERMS)	Siemens and TIBCO
	A.2.	Demand Response Management System (DRMS)	Alstom Grid (Alstom)
	A.3.	Integrated Systems Model (ISM) and Control Algorithms	Orange & Rockland Utilities, Inc. (O&R) and Electrical Distribution Design (EDD)
	A.4.	Wireless Communication and Meter Data Management (MDM)	Digi and Ambient
B. DR and DER Connectivity	B.1.	DR and BMS Integration	Viridity
	B.2.	Smart Storage and Generation Units (SSGU)	Green Charge Networks (GCN)
	B.3.	Demand Response Command Center (DRCC)	Innoventive
	B.4.	Photovoltaic (PV), Battery Storage, and BMS Integration	New York City (NYC) Economic Development Corporation (NYCEDC)
	B.5.	Streamlined PV Design and Build	Gehrlicher Solar
C. Optimization and Control	C.1.	Smart Grid Disturbance Monitor (SGDM)	Softstuf
	C.2.	Energy Optimizer Controller	CALM Energy, Inc. (CALM)
	C.3.	Dynamic Treatment Controller (DTC) and Load-Source Optimization Controller (LSOC)	Columbia University
	C.4.	Integrated Demand-Side Management (IDSM) Potential Model	Energy & Environmental Economics (E3) and Navigant Consulting, Inc. (Navigant)

Together, the project team executed 13 individual sub-projects, which were implemented across Con Edison's and O&R's[1] service territories. Conceptually, these sub-projects can be organized into three broad categories, also shown Table 1-1 and described below.

A. **Secure Systems Integration:** Includes the DRMS, DERMS, secure communications for distribution automation, and wireless metering deployed through this demonstration project, which are the core systems integration components supporting the project's new SG functionality, legacy systems, and interconnectivity to external resources.

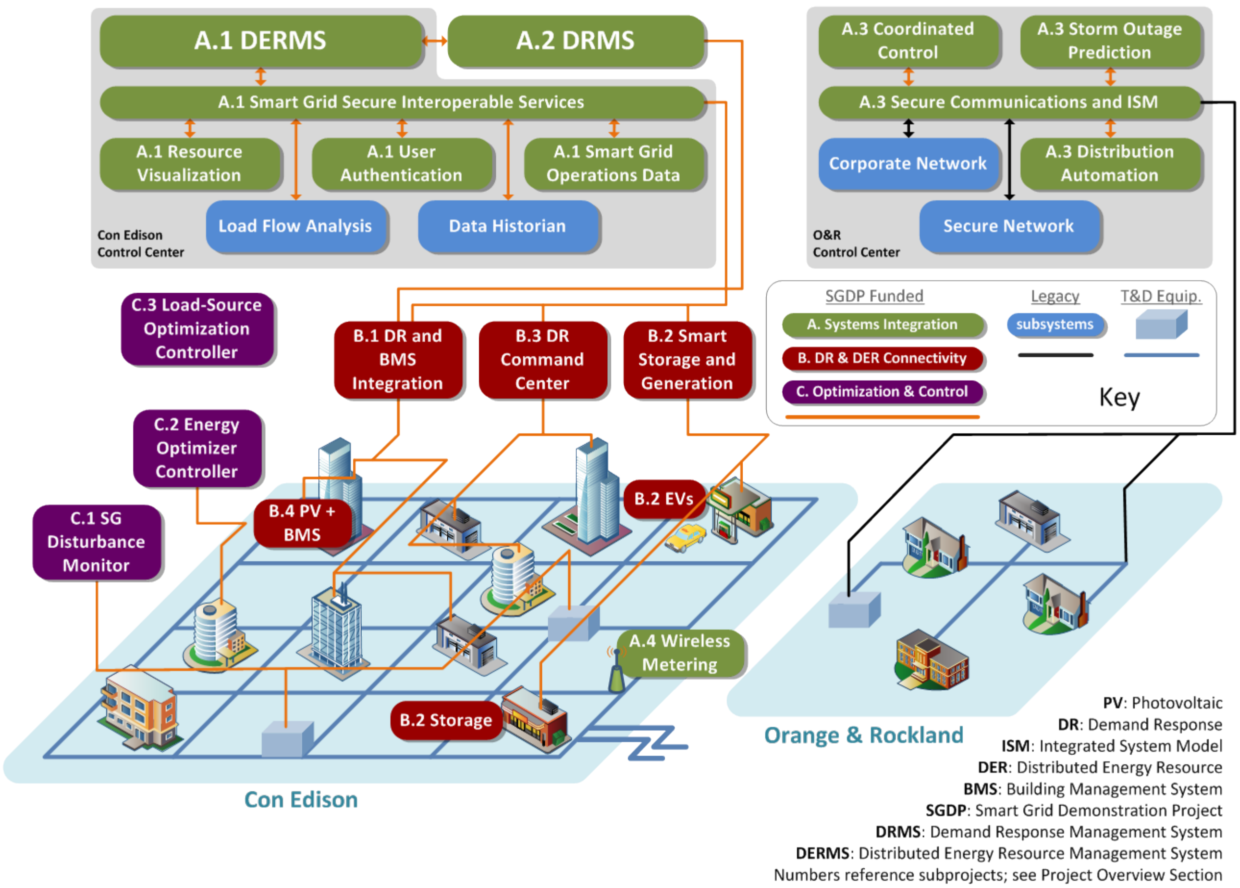
B. **DR and DER Connectivity:** Includes the connection of DR, storage, and DG resources to enhance efficiency, reliability, and economic savings for the utility and end users alike.

[1] O&R is a wholly owned subsidiary of Con Edison.

C. **Optimization and Control:** Includes the optimization and control of these interconnected systems and resources.

Figure 1-1 provides a high-level illustration of how these components fit together to achieve an integrated system.

Figure 1-1. SGDP System Overview Diagram



Note: Con Edison also completed an IDSM Potential Model as part of the SGDP.

Over the course of six demonstrations to the DOE, the SGDP successfully accomplished targeted load reductions, grid management, and grid reliability improvements through the secure integration of the enhanced monitoring and control capabilities and intelligent analysis tools. As a result of the SGDP, Con Edison is now capable of monitoring and communicating with a wide range of DR and DER assets in near real-time from a common, cyber-secure, interoperable platform. Accomplishment of all project objectives was demonstrated through the six iterative and cumulative demonstrations performed over the course of the SGDP.

A significant outcome of the SGDP was development of the DERMS visualization platform, which provides DOs with a wide-area situational view of the interconnected SG DRs and their availability to relieve specific grid load constraints. Other notable project accomplishments include the following:

- Deployment of approximately 500 Digi and 15 Ambient nodes to enhance communications between difficult-to-access meters and Con Edison's MV-90 and Meter Data Management Systems (MDMS).
- Development and implementation of protocols for integrating project-related resources and applications in an industry standard and cyber-secure manner

Over the course of the SGDP, the project team identified and leveraged opportunities to expand the original scope in ways which enhanced the overall outcome, such as:

- Viridity Energy expanded their scope from the integration of five buildings to 23 buildings, due to their early success in the project.
- The DRMS sub-project, provided by Alstom, was added in order to provide DR program management and customer visibility.
- Con Edison added an IDSM Potential Study, which will serve as a comprehensive platform to expand Con Edison's TDSM program, improve capital decision-making, support ongoing efforts to further build DR capability, and establish a set of new programs to maximize both system and customer benefits by network, segment, and building type.
- The wireless communications and MDM project was added as an essential element for success of DRMS project.
- Additional GCN battery storage units were added at Walgreens and United Parcel Service (UPS).
- A 40-kilowatt solar panel installation was added at 4 Irving Place which was not part of the original scope.
- DR and DG resources were mapped and integrated with the DERMS system across the entire Con Edison service area.

While the SGDP started on a limited portion of Con Edison's service area (two boroughs and two networks), the platform is extremely flexible and scalable, and is currently being expanded to encompass the entire Con Edison service area (five boroughs, Westchester County and 64 networks), which will enable the growth expected for DER and DR across Con Edison's territory.

In addition to enabling the increased integration of DR and DER, the results of the SGDP also allow Con Edison to more effectively and efficiently respond to regulatory directives and initiatives such as the proceeding announced by the New York Public Service Commission (NYPSC) in April 2014, known as "Reforming the Energy Vision" (REV).[2] REV will reform New York State's energy industry and regulatory practices to meet the future challenges related to more efficient use of energy, deeper penetration of renewable energy resources (e.g., wind and solar), and wider deployment of DERs (e.g., micro-grids, on-site power supplies, and storage). Overall, the approach and results of the SGDP are consistent with the NYPSC's and Con Edison's shared objectives for increasing the reliability of Con

[2] Information on REV can be found at http://www3.dps.ny.gov/W/PSCWeb.nsf/All/26BE8A93967E604785257CC40066B91A?OpenDocument

Edison's distribution services at improved costs, while leveraging DERs to complement and even offset the need for additional capacity from large, centralized generation plants.

2. Project Overview

The Con Edison Secure Interoperable Open SGDP, sponsored by the US DOE, has demonstrated that the reliability, efficiency, and flexibility of the grid can be improved through a combination of enhanced monitoring and control capabilities using systems and resources that interoperate within a secure services framework. The project has demonstrated the capability to shift, balance, and reduce load where and when needed in response to system contingencies or emergencies by leveraging controllable field assets. The range of field assets includes curtailable customer loads, DG, battery storage, EV charging stations, BMS, HANs, high-voltage monitoring, and AMI. The SGDP enables the seamless integration and control of these field assets through a common, cyber secure, interoperable control platform, which integrates a number of existing legacy control and data systems, as well as new SG systems and applications. By integrating advanced technologies for monitoring and control, the SGDP helps target and reduce peak load growth, improves the reliability and efficiency of Con Edison's grid, and increases the ability to accommodate the growing use of distributed resources.

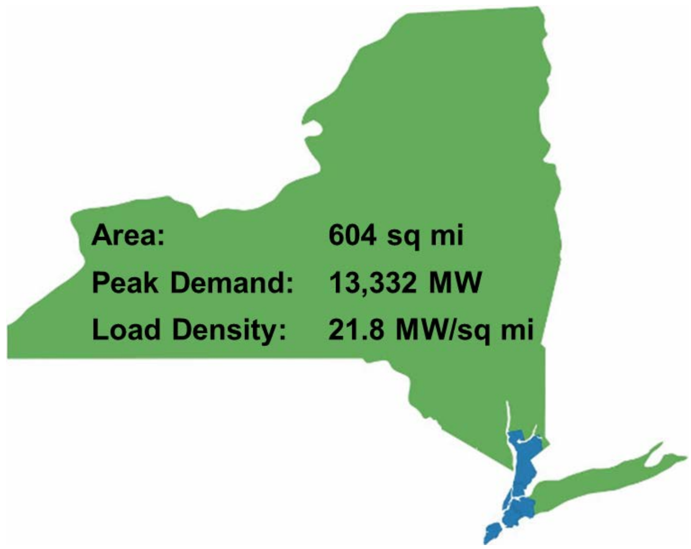
2.1 Project Context

Con Edison owns and operates one of the most complex, yet most reliable, electric delivery systems in the world. Its service territory covers NYC and surrounding areas, including some of the densest electric distribution networks in North America. Figure 2-1 shows a section of the Manhattan skyline, a widely recognized portion of the Con Edison service area.

Figure 2-1. Manhattan Skyline: Con Edison Service Territory

The service area covers over 600 square miles at the southeast corner of New York State, as shown in Figure 2-2. Con Edison serves about 3.3 million residential, commercial, and industrial customers, operates more than 700 megawatts (MW) of electric generation, and manages an electric distribution system of more than 90,000 miles of underground cables and over 30,000 miles of overhead wire. These statistics are shown in Table 2-1.

Figure 2-2. Con Edison Service Territory within New York State



Con Edison's electric service territory includes a mix of high-density urban loads, such as those found in midtown Manhattan, and moderate-density urban and suburban loads found in other boroughs and surrounding counties.

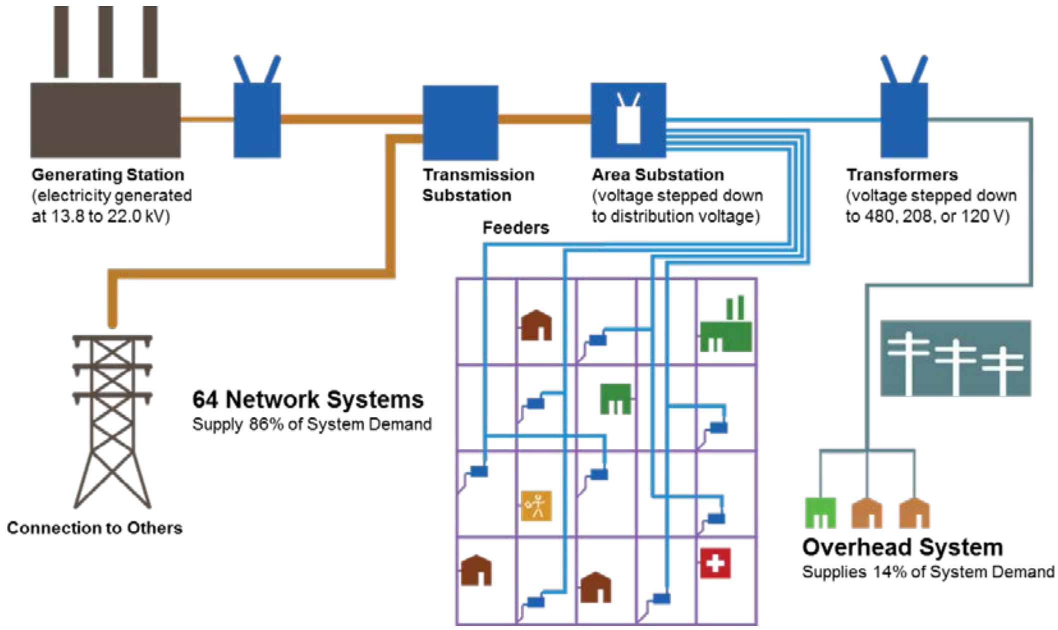
Table 2-1. Con Edison Service Territory Characteristics

Number of Customers	Con Edison	O&R	*Total*
Residential	2,832,764	260,547	***3,093,311***
Commercial and Industrial (C&I)	494,817	40,562	***535,379***
Other	4,726	630	***5,356***
Total	*3,332,307*	*301,739*	***3,634,046***
Electrical Transmission and Distribution (T&D)			
Underground (cable miles)	96,661	1,772	***98,433***
Overhead (wire miles)	36,818	-	***36,818***
Overhead distribution (circuit miles)	-	3,779	***3,779***
Total	*133,479*	*5,551*	***139,030***

Source: Con Edison documentation

Con Edison operates a highly complex distribution system. Approximately 86% of the distribution system demand is met through underground networks, which use a highly reliable design including redundancy of critical components. Con Edison has a dedicated team of employees with a breadth of experience and knowledge in the design and operation of the control systems and equipment for this complex distribution system. Components of the distribution system, including both underground network systems and overhead systems, are graphically illustrated in Figure 2-3.

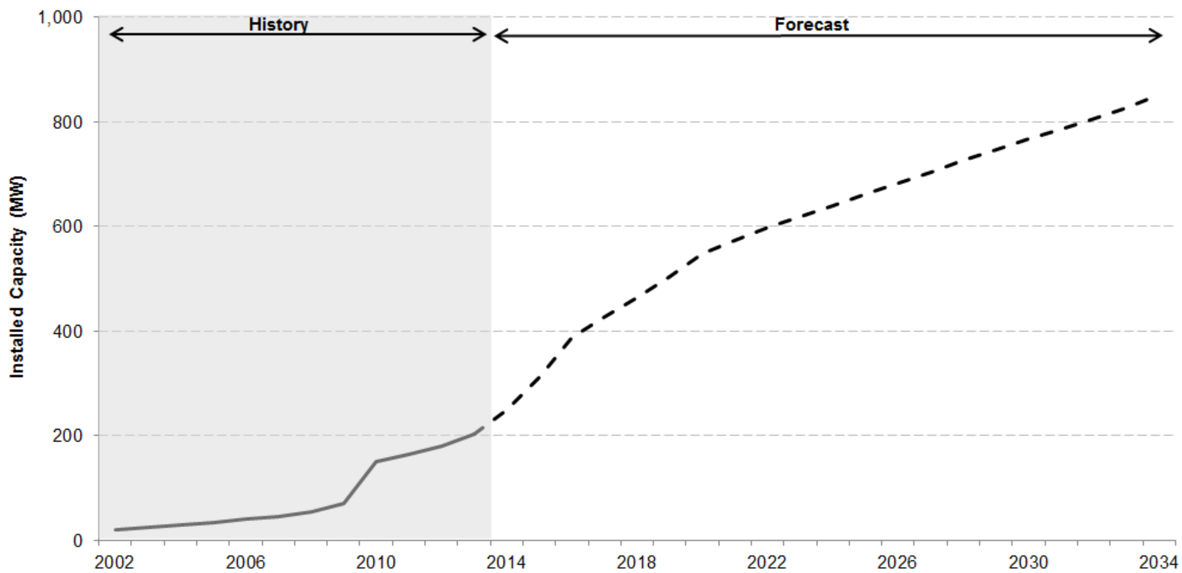
Figure 2-3. Graphical Depiction of Con Edison Distribution System



Source: Con Edison documentation

Use of distributed resources is growing within the service area, including DR resources, battery storage units, and DG. These resources can help Con Edison lower costs, improve reliability and customer service, and reduce its impact on the environment if they are managed properly. In just the past year (from 2013 to 2014), program enrollment in Con Edison's commercial DR program has increased by 14%, and as Figure 2-4 shows, Con Edison is also expecting significant long-term growth of DG. The growth of these distributed resources, as well as combined heat and power (CHP), is expected to continue.

Figure 2-4. Projections for Con Edison DG Installed Capacity

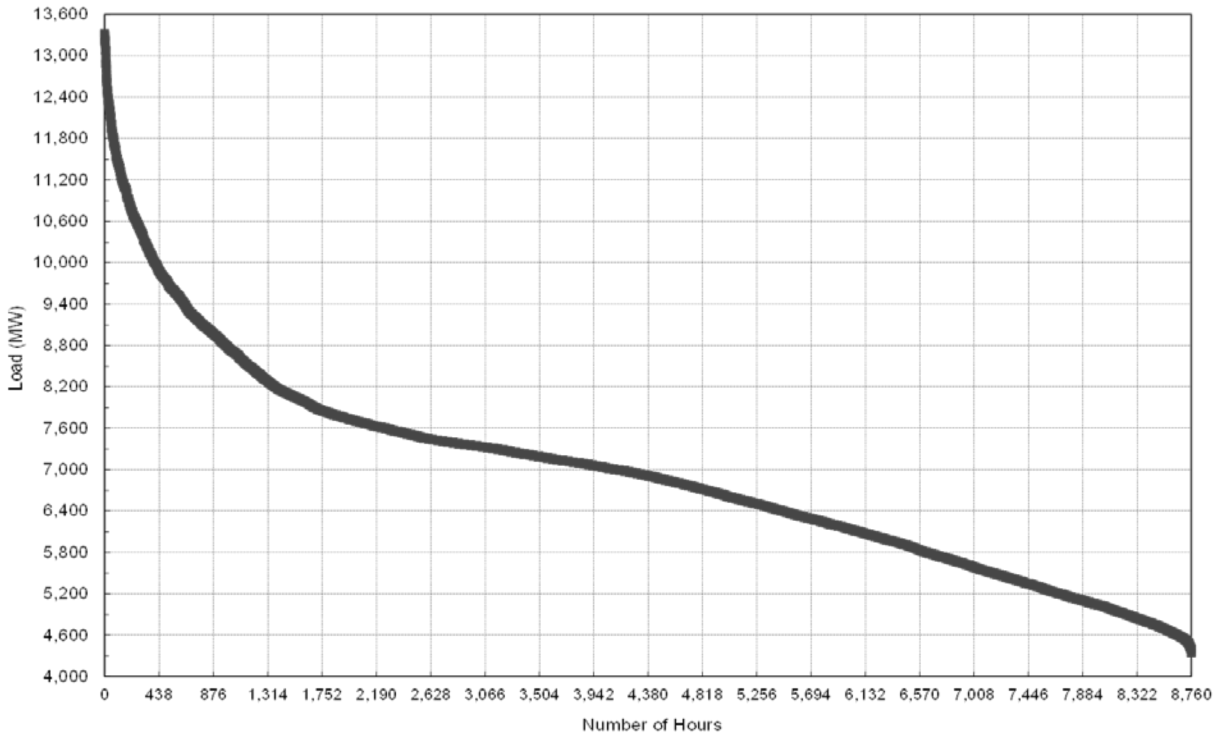


Source: CECONY Distribution Engineering, Strategic Planning.

To reliably and efficiently accommodate the growing penetration of DERs, Con Edison has been working on SG technology that can improve the management of the distribution grid through a combination of enhanced monitoring and control capabilities, along with intelligent analytical tools. Successfully integrating these advanced technologies with distributed resources is a key objective of the SGDP.

In particular, Con Edison is interested in managing peak loads and peak load growth with these resources. As illustrated in Figure 2-5, the peak capacity of the system is only required for very few hours per year. The integration of DR, renewables, and DG enabled by this SGDP will reduce peak capacity requirements and ultimately help defer infrastructure investments.

Figure 2-5 Annual Load Duration Curve for Con Edison (2013)



Source: Con Edison documentation

Con Edison will use the lessons learned through this project to effectively control, dispatch, and potentially monetize a wide range of distribution-level resources. The SGDP also enables several features that may be beneficial for a Distributed System Platform (DSP) model in the future, including DERMS and DRMS integration with DER components, integration with Control Center operations, communication and secure messaging options, and enhanced DR processes.

Finally, results of the SGDP will help Con Edison achieve these goals, while also enabling Con Edison to more effectively and efficiently respond to regulatory directives and initiatives such as the previously mentioned REV proceeding. REV will reform New York State's energy industry and regulatory practices to meet the future challenges related to more efficient use of energy, deeper penetration of renewable energy resources (e.g., wind and solar), and wider deployment of DERs (e.g., micro-grids, on-site power supplies, and storage). It will also promote greater use of advanced energy management products to enhance demand elasticity and efficiencies. These changes, in turn, will empower customers by allowing them more choice in how they manage and consume electric energy. The potential for alignment between the SGDP and REV is discussed in more detail in Section 5.4.

2.2 *Objectives*

The primary goal of the SGDP was to demonstrate that the secure integration of enhanced monitoring and control capabilities with intelligent analytical tools can improve the management of the distribution grid and enable greater deployment of renewable energy resources and SG technologies. To accomplish this goal, Con Edison integrated existing legacy control and data systems along with new SG applications in a common, cyber-secure, interoperable control platform. This has enabled Con Edison to demonstrate seamless integration and control of renewable energy resources and SG technologies, such as EV charging stations, DG, and BMS.

The following list presents the project objectives which were used to guide the project team in accomplishing the project goals. The first five objectives come directly from the original Statement of Project Objectives, and the remaining items are additional objectives that the project team identified in later stages of the project.

1. Improve control capabilities for existing grid assets
2. Determine how to best apply newly developing technologies
3. Minimize peak load growth
4. Improve grid reliability
5. Provide customers with greater visibility, flexibility, and value
6. Leverage controllable field assets that can reduce load where and when needed
7. Provide grid operators and designers with improved, enhanced decision aids
8. Integrate legacy applications, sensor data, and decision aids into the middleware
9. Integrate data from system sensors and control functionality with the middleware

Further discussion on how the SGDP achieved each objective is included in Section 5.1

2.3 Project Team

Con Edison was responsible for recruiting and providing overall project management of the project team. Ultimately, more than 16 different project partners, vendors, and organizations played a role in the SGDP. Provided below are brief descriptions of the primary members of the project team.

Consolidated Edison, Inc.
Con Edison is one of the nation's largest investor-owned energy-delivery companies. The company provides a wide range of energy-related products and services to its customers, primarily through its two regulated utility subsidiaries, Con Edison and O&R, and its three competitive businesses. Con Edison was the prime recipient of the SGDP award.

To support this project, Con Edison maintained schedules and budgets, dictated communications - protocols, tracked risks and issues, and established and maintained change control procedures. The project management team was responsible for managing the integration and implementation of the various monitoring, control, and decision support initiatives required to interface with other project participants to achieve the goals and objectives of this project. These responsibilities included defining the configuration management, software development, and test and evaluation plans for the software products deployed at Con Edison.

Con Edison was also responsible for planning, scheduling, and hosting six demonstrations of the project's capabilities. Con Edison provided ongoing coordination of the installation of servers, workstations, and software applications at their 4 Irving Place Headquarters Data Center, which supports the Manhattan Distribution Control Center (DCC). These equipment and applications supported the demonstrations that enabled integrated functions in service territories supported by the Manhattan DCC, the Energy Control Center (ECC), and the Brooklyn/Queens Control Center.

Siemens

Siemens SG Enterprise Architecture Solutions (SOL) group executed the Con Edison SGDP integration project. The SOL business unit deploys commercial product solutions for the electric utility industry including Substation Automation, Metering, Energy Management Systems, Distribution Management Systems, Energy Market Management applications, DRMS, Common Model Management Systems, and Enterprise Integration.

As part of the SGDP, Siemens partnered with TIBCO (see below) to integrate and interconnect existing applications, new SG applications, and external service connections in a secure and industry-standard compliant design. The project leverages Siemens' expertise in Utility Real-Time Operations domains and information technology (IT), in tandem with TIBCO's service-oriented middleware architecture, to bridge functional silos, collect data from heterogeneous applications, and establish secure, reliable communication connections between them. Siemens' platform additionally enables Con Edison users to visualize and monitor integrated data from a range of sources and take informed actions.

TIBCO Software

TIBCO is a technology leader in providing commercial products for interoperable secure services to real-time systems.

As discussed above, TIBCO partnered with Siemens to integrate and interconnect existing applications, new SG applications, and external service connections as part of the SGDP. TIBCO was deployed for secure services interoperability within the control center and to external customer sites, directly and through third-party providers. TIBCO's application suite utilizes centrally defined policies for security, auditing, logging, and service-level agreements. The software is a standards-based service creation, orchestration, and integration product, enabling exposure of existing systems as services and the creation of new services to internal legacy systems as well as interoperability with external systems.

Alstom Grid

Alstom Grid, a division of Alstom, designs, manufactures, installs, and services power T&D system technologies.

For the SGDP, Alstom Grid developed a DRMS that supports many of the DR management functions, including enrollment, reporting and DR settlement. This system interoperates with Con Edison's information systems, streamlines a number of business processes, and enables Con Edison to measure customer performance using automated baseline calculations.

Orange and Rockland Utilities, Inc.

O&R, a wholly owned subsidiary of Con Edison is an electric and gas utility headquartered in Pearl River, New York. O&R and its two utility subsidiaries, Rockland Electric Company and Pike County Light & Power Co., serve a population of approximately 750,000 in seven counties in New York, northern New Jersey, and northeastern Pennsylvania. Its system features more than 4,000 miles of overhead electric wires and approximately 2,000 miles of underground cable to accommodate a suburban and agricultural customer base.

As part of this project, O&R worked collaboratively with TIBCO and Siemens to install a middleware solution, which enabled the integration of various Control Center applications into a common platform. EDD provided modeling software for this project. O&R supported the integration activities and provided subject matter experts (SMEs) for each of the systems they integrated.

Digi International and Ambient Corporation

Digi International has expertise in machine-to-machine communications, combining products and services as end-to-end solutions to drive business efficiencies.

Ambient's software platform enables utilities to deploy and integrate multiple SG applications and technologies, in parallel on a single communications infrastructure, supporting Smart Metering, Distribution Automation, Distribution Management, DR, DG, and more.

Con Edison brought Digi International and Ambient Corporation to the project to support the enhancement of communications between interval meters and Con Edison's MV-90 and MDMS. Digi and Ambient were selected due to their expertise and product offerings around wireless communication nodes.

Viridity Energy

Viridity Energy provides its clients, primarily university and C&I customers, with intelligent decision tools that increase energy savings while creating new revenue streams obtained by participating in various utility and regional transmission organization (RTO)/independent system operator (ISO) energy markets. Viridity's VPower™ platform enables customers to dynamically shift, shave, and balance energy load; integrate advanced energy technologies; and convert existing energy investments into new revenue streams through integration with power markets.

Viridity Energy established interfaces to customer BMSs across the Con Edison service territory. Data provided through VPower by the BMSs, DG, and battery systems includes capacity, amount of stored energy, and capability rate for discharge of batteries. This information enables distribution system operators to make informed decisions about customer curtailment and deployment of energy storage.

Green Charge Networks

GCN is a company that specializes in energy storage solutions that enable the use of electrical equipment while limiting high energy consumption peaks. GCN's systems accommodate local demand for electricity under existing generation and storage capacity restraints. GCN works directly with utility companies and public- and private- sector organizations.

With a special focus on EV charging, GCN built and deployed customer-sited SSGUs for this project to reduce customer energy spending and achieve increased efficiency.

Innoventive

Innoventive manages load curtailment and DG programs for large commercial firms and large residential facilities. As part of the SGDP, Innoventive integrated a previously developed software system, known as the DRCC, with Con Edison's DERMS platform. The DRCC (developed under DE-FC26-08NT02869) allows the remote dispatch of 23 facilities, representing a total of 20 MW.

New York City Economic Development Corporation

NYCEDC is NYC's primary agent for economic development. Acting under annual contracts with the City of New York, NYCEDC serves as the catalyst for promoting economic development and business growth. NYCEDC was a sub-awardee in the Con Edison SGDP and installed a PV and battery storage system at their Brooklyn Army Terminal (BAT) site.

Gehrlicher Solar

Gehrlicher Solar is an internationally operating PV company. Gehrlicher participated in the SGDP by installing a 40-kilowatt (kW) solar installation at Con Edison's 4 Irving Place headquarters.

Softstuf, Inc.

Softstuf specializes in the design of advanced analysis systems for measuring performance of large electrical power systems during fault and disturbance conditions. Softstuf's contribution to the SGDP included the instrumentation of relay protection circuits associated with 11 345-kilovolt (kV) circuit breakers with Target Information Sensors (TIS), as well as global positioning system clocks to synchronize these measurements. In addition, approximately 4,000 sensors, including those associated with the 11 breakers, were integrated into a user interface that can be used by engineers and technical personnel to conduct remote analysis.

CALM Energy

CALM develops and deploys Computer-Aided Lean Management (CALM) to help optimize grid operations. CALM developed an ISM Decision Aid platform. In addition, CALM built a building smart node energy optimization controller, which was used to securely communicate with the utility's platform for energy monitoring and DR.

Columbia University's Center for Computational Learning Systems (CCLS)

Columbia University's CCLS dedicated research resources to develop the Adaptive Stochastic Controller (ASC) and a LSOC for equipment failure prediction, day-ahead load and price forecasts, and optimization of the real options for maximizing energy efficiency (EE) and minimizing costs within the SG.

Energy and Environmental Economics

E3 is a consulting firm specializing in solving business and regulatory issues related to the electricity industry. With assistance from Navigant, E3 designed and built the IDSM Potential Model to help Con Edison determine how to optimally deploy Targeted Demand-Side Management (TDSM) strategies on specific capacity-constrained feeders and networks.

Navigant Consulting, Inc.
Navigant's EE and Demand-Side Management (DSM) division has expertise in assessing markets, developing market intervention strategies, designing and implementing EE programs, and evaluating the effectiveness of those programs. Navigant worked with E3 to develop data inputs for the IDSM Potential Model discussed above.

2.4 *Sub-projects*

To accomplish the objectives outlined in the preceding section, Con Edison and the project partners organized the work into 13 individual sub-projects, which were implemented across Con Edison's and O&R's service territories. Conceptually, the sub-projects can be organized into three broad categories, as shown on the left side of Table 2-2.

A. Secure Systems Integration

B. DR and DER Connectivity

C. Optimization and Control

These three categories, and their subprojects, are described in more detail in Section 3.

Table 2-2. Sub-project and Project Partner Overview

		Subproject Description	Project Partner
A. Secure Systems Integration	A.1.	DERMS	Siemens and TIBCO
	A.2.	DRMS	Alstom Grid
	A.3.	ISM and Control Algorithms	O&R and EDD
	A.4.	Wireless Communication and MDM	Digi and Ambient
B. DR and DER Connectivity	B.1.	DR and BMS Integration	Viridity Energy
	B.2.	SSGUs	GCN
	B.3.	DRCC	Innoventive Power
	B.4.	PV, Battery Storage, and BMS Integration	NYCEDC
	B.5.	Streamlined PV Design and Build	Gehrlicher Solar
C. Optimization and Control	C.1.	SGDM	Softstuf
	C.2.	Energy Optimizer Controller	CALM
	C.3.	DTC and LSOC	Columbia University
	C.4.	IDSM Potential Model	E3 and Navigant

Sub-project accomplishments and results are also presented in the relevant sections of the document below, and additional details are provided in Appendix A.

2.5 *Demonstration Timeline*

The project officially began on January 4, 2010, when Con Edison entered into a cooperative agreement with the DOE. Con Edison demonstrated successful completion of the project objectives by developing and hosting a series of six demonstrations (Table 2-3).

Table 2-3. SGDP Demonstrations

	Demonstration Name	Demonstration Purpose	Demonstration Date
1	Long Island City 1 (LIC)	Demonstration of Situational Awareness and targeted DR	March 27, 2012
2	O&R	Demonstration of message communication between environments at Con Edison.	September 28, 2012
3	LIC 2	Demonstration of additional sites for situational awareness and targeted DR.	October 19, 2012
4	Demonstration of integrated system with Con Edison's ECC Systems	Demonstration of demand-side resources (DR and DG) integrated with substation status. Demonstration of situational awareness across full energy grid.	Preliminary walk through with operators on June 20, 2013
5	Demonstration of integrated system with Con Edison's Bowling Green distribution network	Demonstration of additional sites in Bowling Green for situational awareness and targeted DR.	October 19, 2012
6	Capstone – demonstration of integrated system	Demonstration of previous phases combined.	July 15, 2013

These demonstrations showed how data from disparate systems can be securely communicated, integrated, and displayed to the operator, and how that information can be analyzed in legacy power flow applications to identify the location of curtailable loads that can be leveraged to mitigate overloaded grid components. Additional discussion on the accomplishments of each demonstration and how those accomplishments relate to the project objectives can be found in Section 5.1

3. Technical Approach

As part of the SGDP, Con Edison demonstrated how a variety of disparate systems can work together to optimize demand-side resource utilization in response to system operational events, environmental and equipment conditions, and market conditions, while using the latest industry standards for cyber-security. The SGDP provides the ability to link different internal and external data sources and legacy applications. The SGDP enables existing tools to identify DER and could relieve overloaded distribution system components. Furthermore, the SGDP platform optimizes the application of controllable field assets in both normal and contingency operations for increased energy delivery, reliability, and security.

This section provides an overview of sub-projects within the SGDP. The sub-projects that link these systems and data can be grouped into three broad categories (as also described in Section 2.3), with illustration of how these components fit together shown in Figure 3-1.

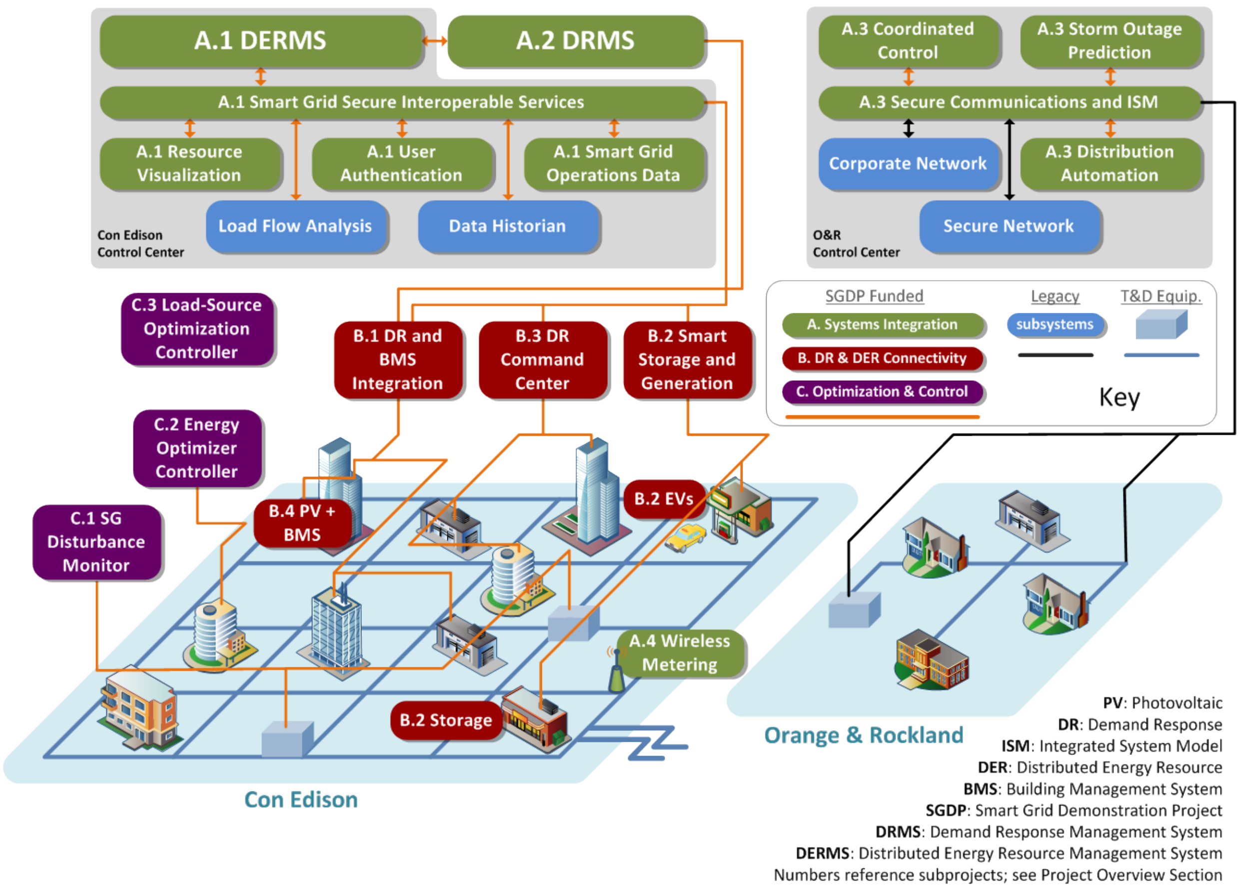
A. **Secure Systems Integration:** Includes the DRMS, DERMS, secure communications for distribution automation, and wireless metering deployed through this demonstration project, which are the core systems integration components supporting the project's new SG functionality, legacy systems, and interconnectivity to external resources.

B. **DR and DER Connectivity:** Includes the connection of DR, storage, and DG resources to enhance efficiency, reliability, and economic savings for the utility and end users alike.

C. **Optimization and Control:** Includes the optimization and control of interconnected systems and resources.

The remainder of this section describes the integration of the sub-projects and Con Edison's systems in the context of these categories. Appendix A provides more detailed descriptions of each of the sub-projects.

Figure 3-1. SGDP System Overview Diagram



Note: Con Edison also completed an IDSM Potential Model as part of the SGDP. This model is not pictured here, but is described below under Optimization and Control.

3.1 Secure Systems Integration

The core systems integration components deployed through this demonstration project include DRMS, DERMS, secure communications for distribution automation, and wireless metering.

A.1 DERMS: The DERMS is a command and control center for a DR network. Siemens and TIBCO designed this system to visualize and optimize the use of DR, DG, and energy storage. DERMS has been deployed on a service architecture to interface to internal Con Edison systems and external customer sites. Key features of the platform include the ability to model and visualize DR and DER on existing Con Edison distribution system displays. The services also support receiving the near real-time status of these resources for distribution system impact analysis.

A.2 DRMS: The Alstom Grid DRMS is an information management system (IMS) that is expected to efficiently manage and optimize Con Edison's growing DR portfolio and streamline DR-related business processes. The DRMS moves DR-related data to and from Con Edison's back-office systems including: Customer Information System, MDMS, PI (OSIsoft), and load forecasting systems. This system supports multiple DR-related functions, including DR program enrollment, event notification, customer performance calculation, settlement calculation, and reporting. Con Edison may also use this system in the future to control resources via the OpenADR 2.0 protocol and dispatch DR resources on an economic or targeted basis.

A.3 Distribution Automation and Secure Communications: The O&R sub-project also focused on systems integration, but in contrast to the Con Edison DERMS/DRMS sub-projects that focused on resource integration, O&R leveraged some of the same secure infrastructure to further automate their distribution system. O&R accomplished this by developing model-centric, coordinated volt-var control (VCC), auto restoration control, and a storm prediction model, which will be integrated into the utility's real-time systems and data stream.

A.4 Wireless Communication and MDM: The MDMS feeds near real-time customer interval meter data into the DERMS and DRMS platforms described above. Reliable transmission of interval metering data from some customer premises (e.g., where land lines have failed or do not exist) to the MV-90xi system that feeds the MDMS is an ongoing challenge for Con Edison. The goals of this sub-project were to install additional hardware to enhance communication to those premises and to improve the necessary systems and hardware required to support increased throughput of 15-minute-interval meter data collection. This near real-time visibility of customer response during DR events greatly improves the effectiveness of targeted demand-side strategies and allows integration with the DRMS for customer baseline calculation and settlement purposes.

3.2 DR and DER Connectivity

The integration of the systems described above enabled the connection of DR, storage, and DG resources to enhance efficiency, reliability, and economic savings for the utility and end users alike. The sub-projects demonstrating these capabilities included the following:

B.1 DR and BMS Integration: This project, led by Viridity, enabled proactive customer involvement in the markets by the integration of customers' BMS systems into its Network Operations Center (NOC) and the DERMS. To do so, this project coupled real-time information and insight into the electricity market with advanced communication protocols. This information enables operators to make informed decisions about customer curtailment and deployment of energy storage. The VPower system, a web-based software platform with customer-facing portal, optimizes building system operations for the customer while giving system operators access to curtailable load. Customers will gain greater visibility of their energy needs, consumption, and costs, which they can use to develop strategies to improve efficiency. This project illustrates the value of load management to individual participating customers, the local utility, and the system as a whole.

B.2 SSGUs: The primary accomplishment of this project, led by GCN, was the development of a behind-the-meter energy storage system. These systems were outfitted with the equipment and controls necessary to charge EVs, accept energy from local PV installations, and participate in utility DR incentive programs. These SSGUs are intended to reduce the monthly demand charges assessed on commercial ratepayers. This project was unique in its focus on providing power (kilowatt [kW]) from the storage units, rather than energy (kilowatt-hour [kWh]) arbitrage.

B.3 DRCC: Innoventive worked with Con Edison to integrate the DRCC, which was developed as part of Con Edison's Renewable and Distributed Systems Integration (RDSI) project, with the DERMS. The DRCC allows the remote activation of DG resources that are owned and maintained by an independent third party (telecommunication provider). This DRCC allows Con Edison to access, through a secure, Internet-based communication path, 20 MW of diesel generation, which can be deployed for DR events. The DRCC is also designed to allow the DR resource owners to simultaneously participate in the New York Independent System Operator's (NYISO) DR program.

B.4 PV, Battery Storage, and BMS: The NYCEDC developed a demonstration project at their BAT in Sunset Park that integrates three main components: 1) a 100-kW solar PV array, 2) a BMS, and 3) a 720-kWh battery for on-site energy storage capable of delivering 100 kW for four hours. The project set out to demonstrate the benefits of on-site renewable energy generation coupled with energy storage and management systems to reduce demand on the grid, offset energy costs, and advance the City's PlaNYC sustainability objectives by reducing greenhouse gas (GHG) emissions associated with energy generation and use.

B.5 Streamlined PV Design and Build: In cooperation with Gehrlicher Solar, Con Edison also undertook a sub-project to demonstrate DG connectivity by installing a 40-kW PV system on their Irving Place headquarters. This allowed them to gain firsthand knowledge of the challenges of a behind-the-meter solar installation, the complexities and logistical challenges of installing solar on a high-rise building in NYC, the process for meeting landmarks certification, and to provide a test bed for connecting behind-the-meter solar.

3.3 Optimization and Control

In addition to securely integrating systems and connecting several types of DER, this demonstration project also included several sub-projects aimed at optimizing and controlling interconnected systems and resources.

C.1 SGDM: The SGDM sub-project, executed by Softstuf, integrated sensor data from 4,000 sensors to a single data repository and developed automated analysis tools. These analysis tools leveraged a new type of TIS which can be deployed on electro-mechanical relays without necessitating interruptions of service or upgrade to costly digital relays. Integration of these sensors enabled Con Edison and Softstuf to develop algorithms to enable fault current modeling and sequence–of-events reports, which typically would not have been possible using legacy equipment.

C.2 Energy Optimizer Controller: Also in the realm of optimization and control, CALM developed and demonstrated a low-cost building Energy Optimization controller for small and mid-sized commercial buildings that was able to communicate directly with Con Edison's DERMS. These communications included low-cost thermostatic control of multiple optimization capabilities to reduce peak loads and reduce energy usage in commercial buildings.

C.3 LSOC: Columbia University's CCLS was responsible for developing ASCs, including a DTC, to assist distribution system operations in optimizing decisions about maintenance actions and an LSOC for optimizing the dispatch of SG resources. The ASCs used sophisticated sets of algorithms to determine the optimal actions to be taken. These algorithms incorporate disparate data, such as pricing information, system loads, weather, and the impact of proposed actions on future flexibility to respond to system conditions.

C.4 IDSM Potential Model: Con Edison is also developing an IDSM Potential Model as part of the SGDP. E3, with assistance from Navigant, is developing the model, which is expected to be completed in September 2014. The model will aid in evaluating the market potential for technologies that are commercially available now or within the next three to five years, including EE, DR, energy storage, and customer-sited DG technologies. This effort also includes the development of an integrated set of models and decision tools to conduct integrated DR analyses. The technology assessment and requisite decision tools will serve as a comprehensive platform to expand Con Edison's TDSM program, improve capital decision-making, support ongoing efforts to further build DR capability, and establish a set of new programs to maximize both system and customer benefits by network, segment, and building type.

4. Methodology

This section summarizes the methods used in the various sub-projects to achieve the goals of the overall project. Individual project partner inputs to the Final Technical Report, which discuss the objectives, methods, and accomplishments of each sub-project in more detail, can be found in Appendix A.

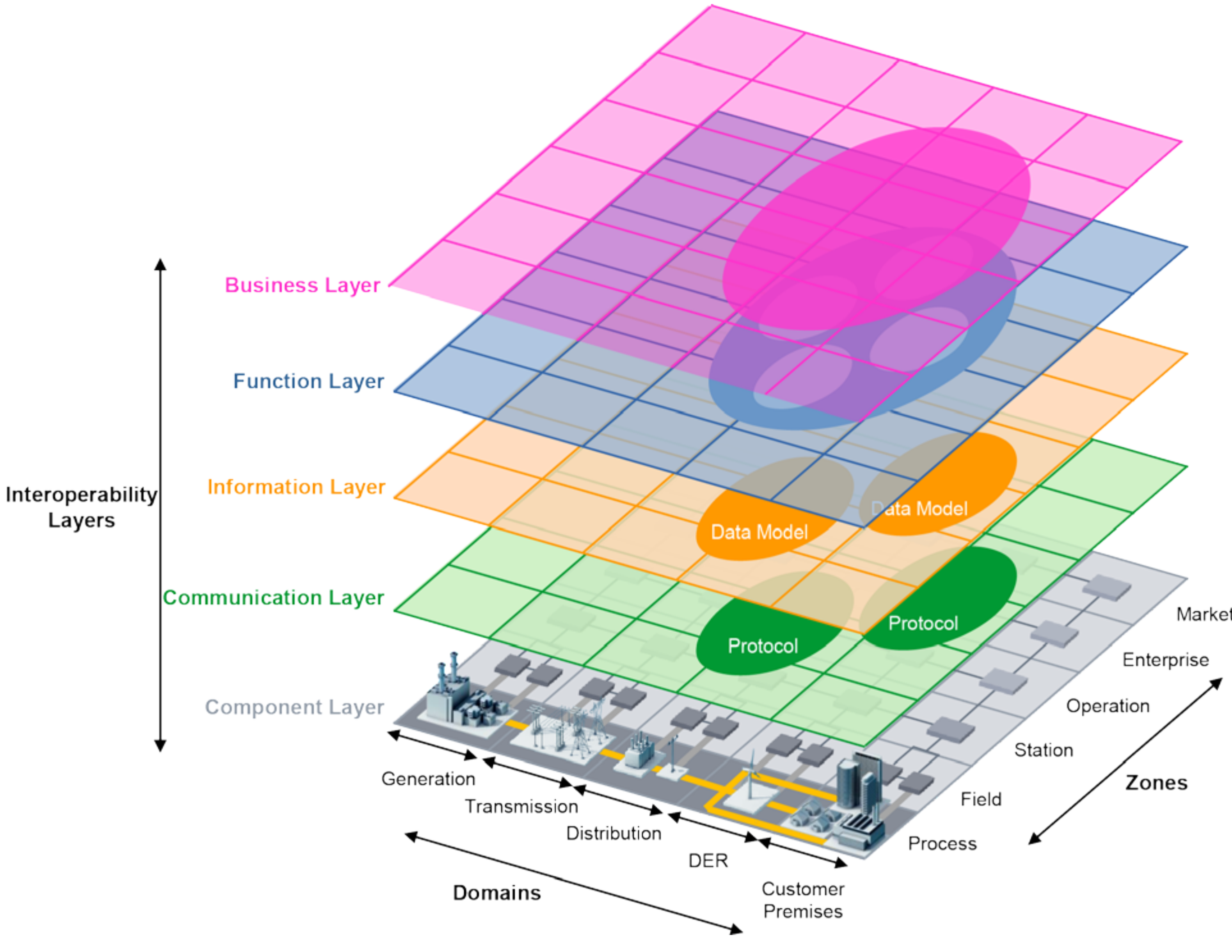
4-A. Secure Systems Integration

The systems integration design focused on establishing a secure interoperable service bus that supports industry-standard service architecture with new SG functionality and legacy systems, as well as interconnectivity to external resources. The design also supports virtualization of new SG applications where possible and integrating legacy systems on the service bus to enable a service framework.

The Secure Services Platform at Con Edison was designed to interface up to 10,000 DR sites for the SGDP. The architecture design started with SGDP use cases derived from the project objectives. Stakeholders drove the services architecture and technical and functional requirements. The process aligned the architecture with the National Institute of Standards and Technology (NIST) 1108 conceptual framework and International Electrotechnical Commission (IEC) SG roadmap to identify domains, actors, and services within the SG domains. The SGDP interoperability requirements were aligned with NIST 7628 and IEC specifications. Cyber-security requirements were driven in part by NIST 7628 Guidelines for Smart Grid Cyber Security and the NIST 800-30 risk management guide.

This process resulted in a SGDP Architecture, Interoperability, and Cyber-Security framework that was shared, reviewed, and updated by Con Edison technology departments, the project partners, NIST, and the DOE. The Smart Grid Architecture Model (SGAM) is a comprehensive "all-in-one" SG toolbox. The SGAM divides the energy industry into five domains, six zones of information management, and five layers of interoperability. Siemens leveraged the reference architecture model in Figure 4-1 to design and implement the interoperability platform used by DERMS and the other projects in this section. While the SGDP does not span all the zones and domains shown in the figure below, the Siemens platform does allow flexibility and scalability to incorporate all of them as part of Con Edison's roadmap.

Figure 4-1. The SGAM



Source: European SG Coordination Group; based on NIST SG 1108 and 7628

The SGDP team focused on developing an architecture design based on open-services architecture to support interconnectivity between legacy systems and new SG applications, and interoperability with external DR resources. As noted above, the approach for achieving interoperability and cyber-security was based on aligning the SGDP applications, functions, services and interfaces with the NIST and IEC reference architectures to develop SGDP reference architecture. This process identified SG functions, common services, and data flows in alignment with the reference architectures so that available standards could be identified and applied.

The SGDP architecture design was based upon open-services architecture to support interconnectivity between systems and services. The implementation required a SG Secure Interoperable Service bus to support standard service interoperability between SG systems. As noted above, the approach for achieving interoperability and cyber-security was based on aligning the SGDP applications, services, and interfaces with the NIST and IEC reference architecture. This process identified SG functions, common services, and data flows in alignment with the reference architectures so that available standards could be identified and applied.

The goal of such standards-compliant services is to help integrate legacy control center applications, new SG applications, external IT applications, and other external participating entities. As these services are well defined and standards compliant, other applications who wish to use them are free to implement them. The following four sub-projects all utilized these standards-compliant services and open architecture to achieve their integration.

4-A.1. DERMS

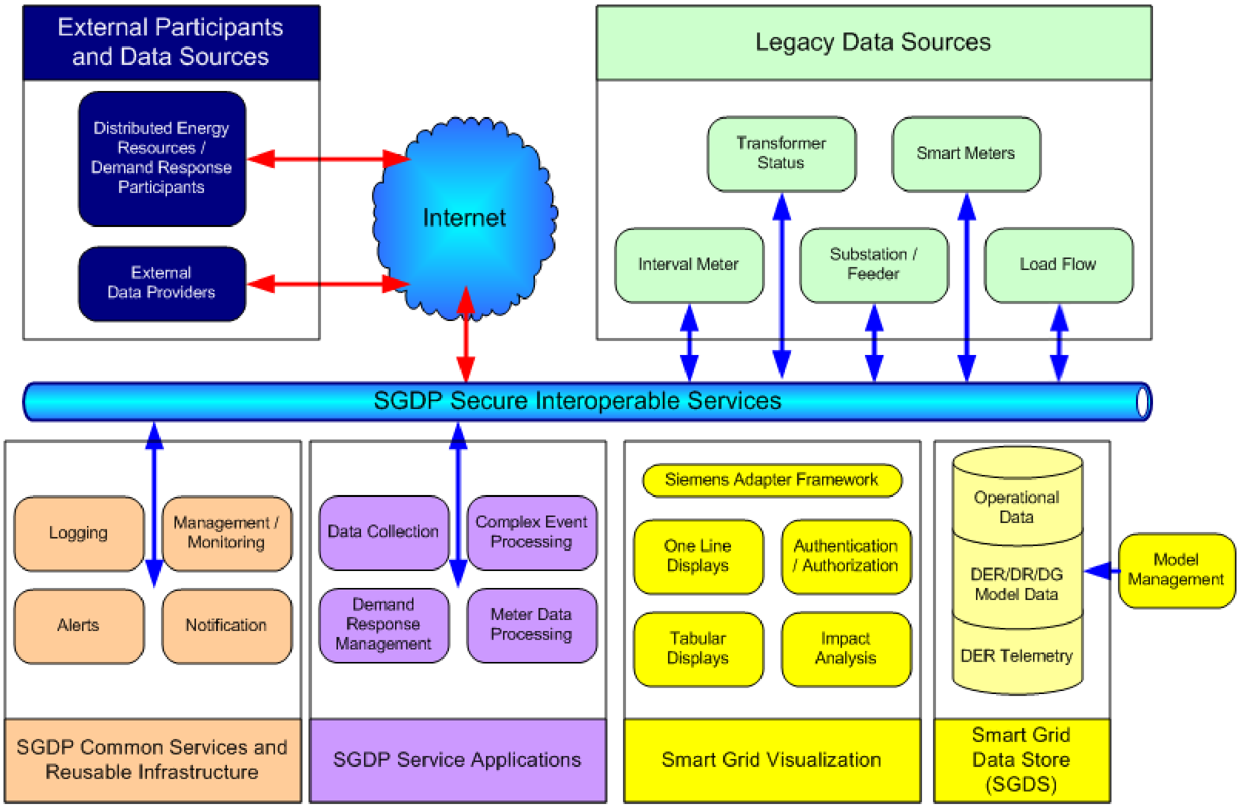
Siemens, its subcontractor TIBCO, and other partners were selected by Con Edison to deploy SG technologies to illustrate the impact of integrated and optimized DER on system efficiency and reliability, translating to improvements to the utility's business processes and underlying applications, as well as cost savings for the company and its customers.

Siemens designed DERMS to easily incorporate new technologies and standards while still integrating with legacy applications, with no replacement or redesign required. The solution is scalable and flexible, allowing Con Edison to implement both its mid-term and long-term SG roadmap, while efficiently navigating and managing any changes that may occur in the future.

The DERMS incorporates existing, off-the-shelf commercial products from both Siemens and TIBCO, alongside existing Con Edison legacy applications. The solution adheres to accepted industry standards (e.g., IEC and NIST) and architectural best practices proven across other large-scale utility projects. The use of standards and adapters within this Service-Oriented Architecture encourages reuse of libraries across multiple applications subject to integration, an especially critical distinction when integrating with external partners.

DERMS was designed from the outset to provide a means of integrating various existing software packages using a cyber-secure means of communication and to provide a means to visualize the state of the grid and the various assets of interest. The integration occurs using a commercial off-the-shelf Enterprise Service Bus from TIBCO. The data that is passed between these software packages is based on the IEC Common Information Model (CIM) standard and uses extensible markup language (XML) based messages. The software packages range from providing functionality to analyzing conditions on the grid to calling DR programs that communicate with loads and to controlling generation, all using web services and XML messages. This integration mechanism means that existing software packages and the investment in their development, configuration, maintenance, and know-how can be leveraged and used in the changing grid, while allowing the addition of newer software that adds value to the reliable and secure operation of the grid. A diagram of the software and systems integration architecture is provided in Figure 4-2.

Figure 4-2. DERMS Architecture Diagram



Using this standards-based, secure integration mechanism, DERMS provides the monitoring and control of a variety of DERs and DR resources, including solar, backup generation, DR aggregators, and others, from a variety of vendors.

The controls to and the responses from the various resources are collected by DERMS and are presented to the operator for visualization and to monitor conditions on the grid. The data is also used by software packages such as Load Flow Analysis to give operators the means to operate the grid more efficiently and to select what resources may be candidates for enrollment into the DR programs.

The DERMS architecture prioritizes security, taking into account existing Con Edison security layers and incorporating security standards and best practices that interface with non-Con Edison distributed energy and load resources, and DR providers, enabling the integration of new applications, existing legacy applications, and other third-party services.

The following are the primary objectives of the DERMS project:

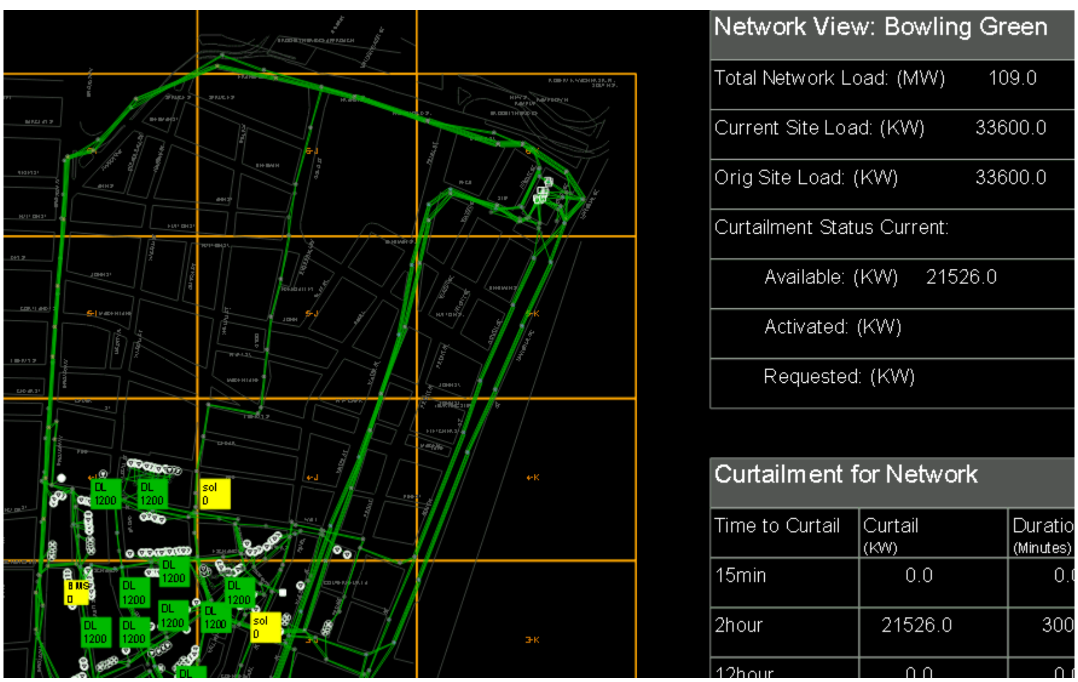
- Improve control capabilities of existing grid assets
- Minimize peak load growth and maximize EE savings throughout the electrical grid
- Provide world-class cyber-security for SG systems

- Demonstrate open standards and interoperability with vendors with commercially available products

Siemens' Model Driven Integration approach leverages the IEC CIM model as the Data/Domain Model within the Information layer to map and model data interface requirements. These requirements are driven by Functional Use Cases within the Function Layer, which in turn is influenced by Con Edison's Business Objectives and Processes within the Business Layer. Ultimately, the interfaces are implemented within the Communication Layer or the middleware, enabling interoperability between the various zones.

DERMS is an advanced software application that optimizes resource utilization in response to system operational events, environmental conditions, and equipment feedback. The platform provides visibility of and the capability to control a diverse portfolio of resources – for example, solar, wind, storage, and EVs – to address local complications, while flexibly addressing system-wide concerns. Visualization of the available resources allows the operator to simultaneously view the dynamic statuses of the resources and distribution grid components. A screenshot of the resource visualization interface is shown in Figure 4-3.

Figure 4-3. Visualization of Grid-Connected DR Resources



The conceptual purpose of a DERMS is to manage diverse DERs, to understand the unique status and capabilities of each, and present these capabilities to the Distribution Control Center Operator (DO) and other applications in a more useful and manageable way. This means aggregating the capabilities of individual devices, and transforming their settings and effects so that they become attributes at the circuit, feeder, or segment level.

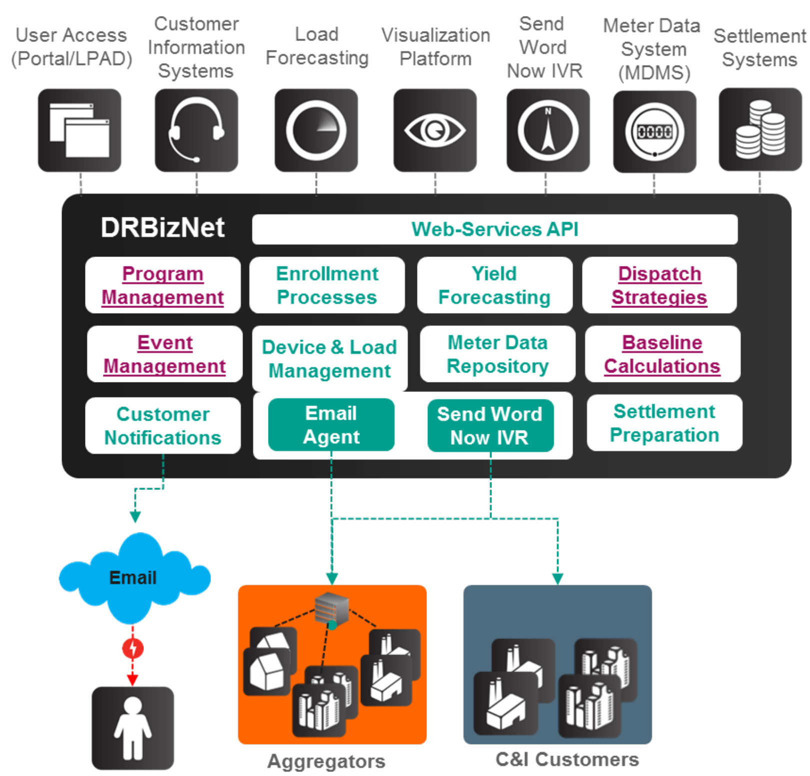
DERMS communicates with each DER controller to determine the operating status of each DER and to issue energy management control commands to reliably manage the stable integration of DER with the larger scale grid.

4-A.2. DRMS

The DRMS is a proven software technology platform that enables market operators and utilities to manage and implement the DR program through a single integrated management system. It can help reduce the imbalance between energy supply and demand. The DRMS software generally enables utilities to offer highly customized programs for its customers and to review real-time and historical outcome of DR programs to assess their effectiveness.

Alstom Grid's DRMS (see Figure 4-4) is a system that integrates commercial and industrial DR programs. The DRMS forecasts available load curtailment capacity and has been deployed at other utilities with the capability to send signals for automatic load control to aggregators or directly to devices such as air conditioners or water heaters, thus optimizing the use of electricity. It then calculates customers' normal electricity usage as a baseline, and then compares actual reduced usage to measure performance.

Figure 4-4. Diagram of the DRMS System



The DRMS is intended to be the system that manages all activities and data related to demand-side load resources for Con Edison's current and future programs. The DRMS can serve as the following:

- Single system of record for supporting DR Program Management and Operations
- A point of enrollment/registration for all DR programs including residential and C&I programs
- A command and control event management system
- Notification to DR customers of start of event
- Calculation engine to measure customer performance and calculate settlements using automated baseline calculations
- The system of record for all data and transactions related to DR programs and events

The scope of the DRMS project also included the following:

- Analyzing existing DR programs and business processes
- Gathering requirements for streamlining programs, processes, and DR performance measurement and calculations
- Configuring and implementing the DRMS
- Customizing baseline calculation options and control methods
- Migrating the existing DR programs, customers, resources, and related data to the new DRMS

4-A.3. ISM and Control Algorithms

The objective of the real-time control systems work performed at O&R was to demonstrate that a single, detailed, reusable model of the electric distribution system can be used in a secure, interoperable environment for multiple objectives, creating "model-centric"-type systems that can be used in real time for control applications such as fault isolation and restoration to improve system reliability, and to coordinate VVC to reduce system losses and energy consumption.

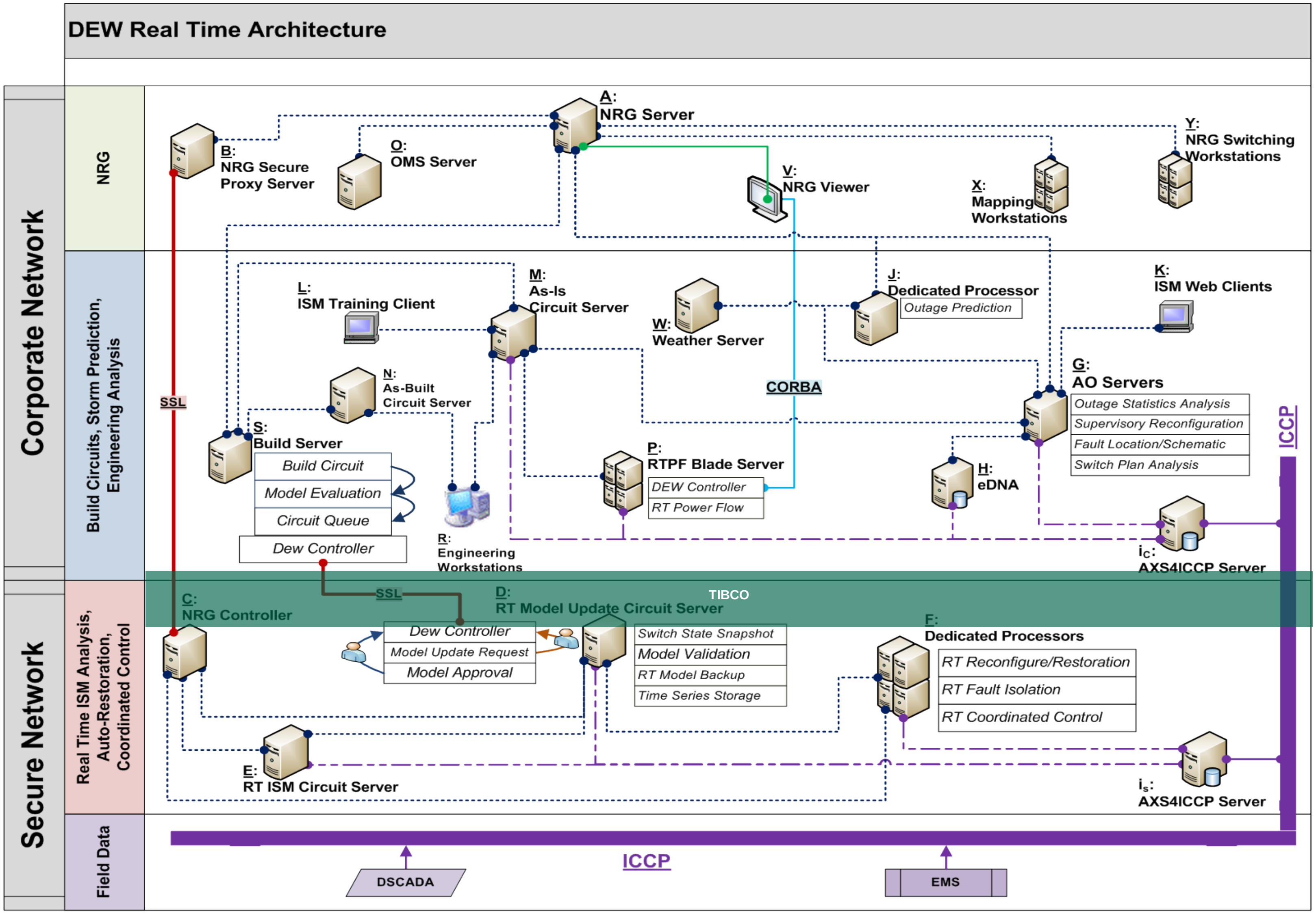
The second major objective was to develop and integrate a system into the interoperable environment that monitors weather conditions and the receipt of outage calls in real time to detect the beginning of storm events causing electric system outages and predicts the total number of outages that will be received, looking one hour and three hours ahead using a real-time feed-forward loop. Knowing the number of outage incidents that a storm will generate early in the storm allows the utility to right-size the restoration resource sooner, which reduces time to full restoration.

Prior to this project, O&R's system incorporated field devices such as reclosers and automated switches. The drawback to the previous configuration was that those devices could only respond automatically to preprogrammed scenarios; events outside those parameters could cause those devices to shut down. O&R's model-centric approach, built and tested on one circuit as part of this SGDP, provides real-time data from many points on the circuit, allowing more accurate depiction of power flows. This approach provides greater accuracy in understanding what is happening on the grid and allows more flexibility in adapting to non-normal operating conditions.

The work performed under this project integrated automated control systems with a detailed model of the electric distribution system known as the ISM and a fast, robust power flow analysis program known as Distributed Engineering Workstation (DEW) with a real-time Distribution Supervisory Control and

Data Acquisition (DSCADA) system to allow the fully integrated system to make and execute decisions in real time based on monitored and calculated electrical parameters and actual system conditions. Figure 4-5 shows how the ISM and control systems were integrated.

Figure 4-5. O&R ISM Architecture Diagram



New technology and equipment can easily be added to the ISM and controlled by the model-centric system through DSCADA. This allows for use of off-the-shelf equipment that does not require customization, is not limited by any proprietary protocols, and is not specific to any vendor, providing maximum flexibility.

Additionally, expansion of a model-centric control system requires minimal effort. Once the new equipment is installed in the field and communications with DSCADA have been established, setup of the control system requires only that the new device be added to the ISM. There is no scenario programming, thus simplifying the expansion process.

4-A.3.1. Auto Restoration Model-Centric Control System Demonstration

A demonstration of the auto restoration model-centric control system in a laboratory environment using ISM, DEW power flow analysis, DSCADA, and the auto restoration model-centric control system was performed. Actual recloser control hardware was set up in the lab in a configuration matching an actual open-loop distribution circuit. The fast fault isolation and customer restoration functions of the system were demonstrated on the laboratory arrangement. Two circuits configured in auto loop configuration with midpoint and tie reclosers for automatic fault clearing, and, with SCADA operable switches between the substation breakers and midpoint reclosers and between the midpoint reclosers and the tie reclosers, were represented. The demonstration used all of the production systems, such as the production DSCADA system, actual 220-megahertz) radio communications between the controls set up in the lab and a production master radio site for the DSCADA system, as well as the production back-haul communications to the DSCADA servers.

4-A.3.2. Model-Centric VVC System

The ISM is also used as part of a model-centric dynamic VVC system. The control system reduces energy consumption through continuous dynamic optimization of voltage levels and minimizes losses through dynamic var injection. This is done by real-time coordination of voltage-regulating devices, such as the substation Load Tap Changer and distribution line voltage regulators, with var injection equipment, such as switched shunt capacitors. Using the ISM, DEW runs power flows on the system as monitored voltage and currents change in real time. This provides voltage and var requirements across the entire system. The control system then uses these real-time and calculated system parameters to optimize var injections while maintaining acceptable voltage levels as close to minimally acceptable levels as possible to enable conservation voltage reduction. It then sends control commands to DSCADA to switch and adjust the appropriate devices. The system maintains voltage at the minimal acceptable levels while supplying the necessary vars, so that efficiency through loss reduction and energy reduction through conservation voltage reduction can both be realized.

4-A.3.3. Storm Outage Detection and Prediction System

In addition to the real-time auto restoration and coordinated VVC systems, a Storm Outage Detection and Prediction application was developed and tested. The system is designed to determine, in real time, when a storm hits the service area by monitoring weather conditions and the receipt of outages in the

Outage Management System (OMS). It then uses this information to statistically predict the number of outage incidents that will be received, looking one hour ahead and three hours ahead.

The system continuously monitors OMS in real time and adjusts its predictions, which are then visualized on a web page. Quickly being able to understand how many outage incidents will be received allows the utility to right-size its restoration effort sooner, which can significantly reduce the time to completion. This is particularly useful for storms that have no specific track, such as severe afternoon summer thunderstorms that pop up over a geographical area.

4-A.4. Wireless Communication and MDM

In 2011, Con Edison's Itron MV-90xi system's hardware and software were upgraded for fast polling in support of DR data collection requirements. Even with this upgrade, the MV-90xi implementation was not capable of gathering the interval data from the meters fast enough for the DR program requirements.

Analysis done in December 2012 to evaluate MV-90xi system capabilities showed an inconsistent and limited rate of interval meter data collection and processing of 3,000 meters/hr. maximum. This rate would result in the system only being able to support reading about 700 meters every 15 minutes. Con Edison's current DR customer base includes a total of about 1,200 meters, which is far more than the current throughput capability. For this system to support the current 1,200 meters included in the DR program, it would need to be capable of consistently collecting and then exporting the data at a rate of no less than 4,800 meters/hr. (approximately 1,200 meters every 15 minutes). Any growth in the DR program would require even higher throughput rates.

To enhance the MV-90xi system, the plan and key tasks included the following:

- Rebalancing processing across workstations to increase workstation utilization and throughput
- Rebalancing modems across communications workstations to increase workstation utilization and throughput
- Reviewing the current population of meters and ensuring the right number and type of modems match the meter population
- Implementing a line-sharing function in support of daisy-chained meters and Selcom devices to prevent collisions in calling meters managed by these devices
- Implementing XML multi-threaded file transfers between MV-90xi and the MDM to increase throughput

The MDMS project exceeded the initial goals of the project. The MDMS project did the following:

- Converted from an Oracle database (DB) to SQL server
- Completed a version upgrade of Itron's MDMS software from V 7.0 to v 8.1, allowing the MDMS to benefit from using a 64- rather than 32-bit operating system and DB.
- Upgraded the hardware configuration, increasing the DB processing capability by 500% and memory by 400%. In addition, solid-state, rather than spinning drives, were used for temporary file processing,

These efforts resulted in dramatically improved performance.

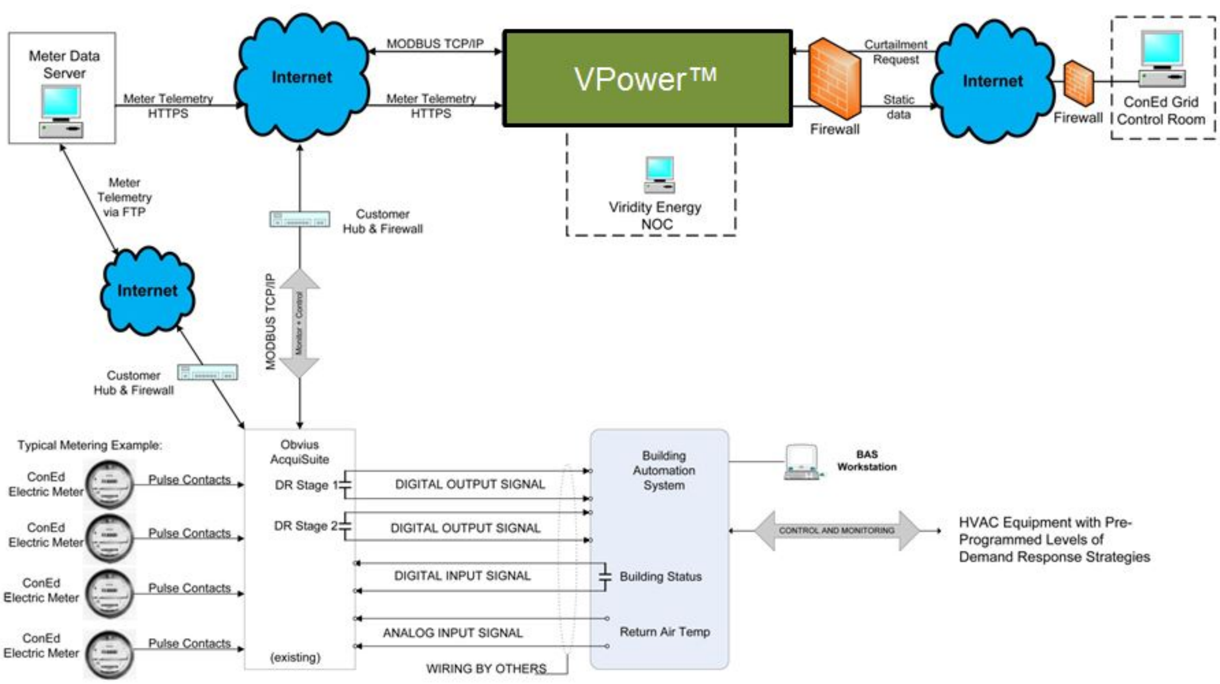
In addition, as part of the Wireless Communications project, 595 nodes have been installed to establish communications with 1055 meters. This will support the DRMS and DERMS projects.

4-B. DR and DG Connectivity

4-B.1. DR and BMS Integration

Through the VPower™ software platform, Viridity Energy provides a communication link between the participating customers and Con Edison's distribution system (see Figure 4-6). In addition, Viridity also provides a comprehensive analysis of the energy consumption patterns of Con Edison customers. This information can enable intelligent, responsible, and profitable changes in consumption behavior for participating customers.

Figure 4-6. Diagram of Viridity's VPower Implementation



The communication channel provided by Viridity allows Con Edison to manage the flow of electricity on its system to respond to emergencies as they arise, in order to maintain reliability on the system. The buildings that are participating in the project are programmed to be able to respond to calls for curtailment as needed by Con Edison, and are able to participate in energy and ancillary markets with the NYISO if they choose to do so.

The VPower™ optimizer determines an operating schedule which minimizes costs and maximizes revenue for optimal economic operational value. The VPower™ model is validated by comparing the business-as-usual (BAU) customer baseline load (CBL) produced by the model to the metered load from the building(s) for a historical period of time, typically 30 days. The model parameters are tuned to produce a best match between the BAU CBL and the building's/buildings' metered load. The best match is obtained when the average value of the absolute value of the BAU CBL relative error for the entire validation timeframe is minimized.

Table 4-1 lists resources that were selected for inclusion in a demonstration based on the relative size of controllable, curtailable loads and their general location on the Con Edison distribution network.

Table 4-1. DR Resources Integrated Using Viridity's System

Building	Vintage	Floors	Area (sq. ft.)
Avenue of Americas	1989	35	898,743
5th Avenue	1990	53	574,857
Broad Street	1968 (renovated: 1995)	30	400,000
Times Square	2001	32	855,000
Lexington	1959	22	232,000

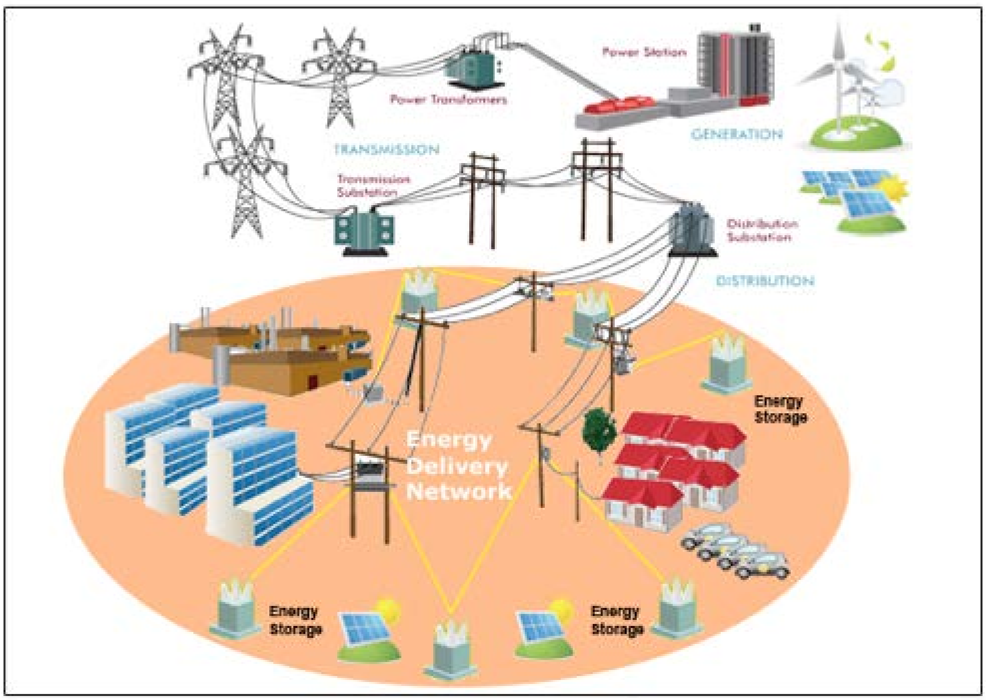
Above: A map showing building locations and a photo of the 5th Avenue building.

4-B.2. SSGUs

Current distribution systems typically have limited ability to absorb renewable energy. Increasing EV adoption and battery capacity will further stress distribution grids. A comprehensive, distributed system of "on-the-edge" generation and energy storage will help to ensure robust reliability as the grid grows larger, greener, and more complex. This on-the-edge system consists of multiple smart energy storage devices that are coupled with DG to augment normal grid power in an Energy Delivery Network (EDN) using SSGUs. Figure 4-7 provides schematic context for an EDN. Key features of EDNs include the following:

1. They can address isolated load pocket reliability-related issues while applying most of their capacity to peak shaving needs.
2. They can optimize DER potential in the distribution grid by modulating the intermittency of PV, effectively time-shifting supply to match peak demand. Instead of individual storage units acting in isolation, potentially increasing instability, EDNs can assist in coordinating all energy sources across the distribution grid.
3. EDNs have inherent real-time knowledge of the distribution-level energy mix which can enable shifting of discretionary load to match renewable energy supply.

Figure 4-7. Diagram of an EDN



Renewable Energy, Price and Reliabiity Optimization Engine

Provides:

1. Energy Storage on Edges Capacity and Command and Control
2. Balances System Needs for Reliability, Renewable Energy and Price
3. Incorporates required capability from Loan Pocket management System

The SSGUs, which enable the key functionality of an EDN, are relatively small (each providing anywhere between 27 and 300 kW). Their small footprint enables rapid site approvals and installations. SSGUs consist of four main components:

- EV charging system
- energy storage system

- PV system
- System controller

These four components and their interconnection are discussed in greater detail in Appendix A.

While distributed battery storage is beneficial in and of itself, this part sub-project strove to demonstrate that SSGUs connected in an intelligent EDN can provide additional value. GCN demonstrated that a network of SSGUs can operate in unison and respond to the utility in times of need. One example of this is the ability to curtail EV charging during DR events. GCN demonstrated that distributed energy storage can be centrally controlled by the utility, enabling targeted response to dynamic grid conditions.

4-B.3. DRCC

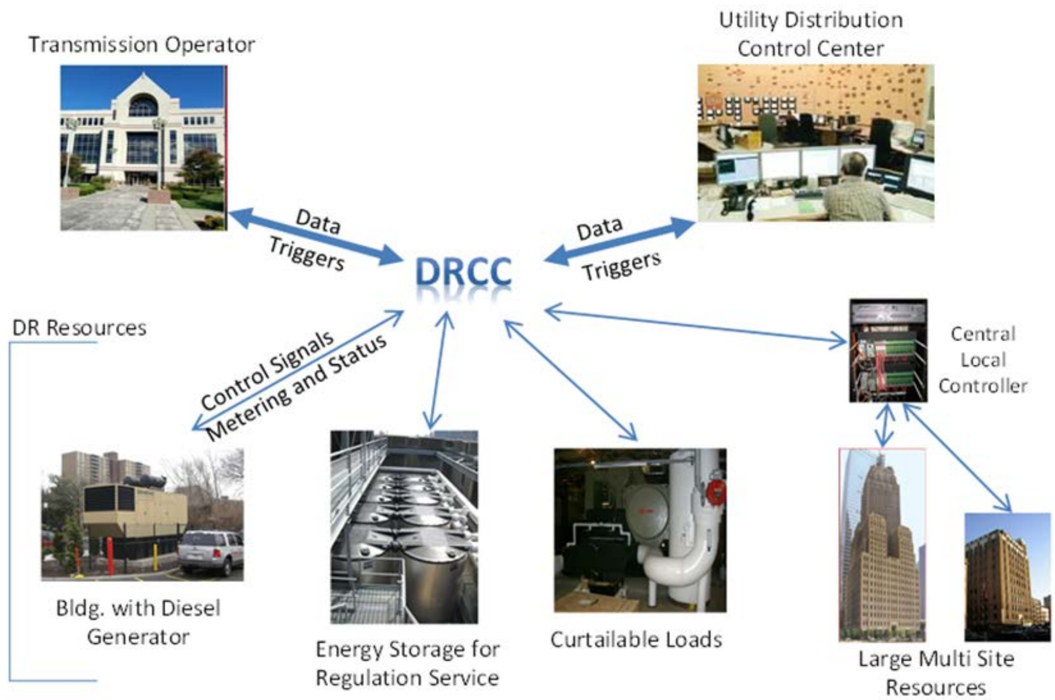
The objective of the DRCC sub-project was to develop and demonstrate methodologies to enhance the ability of customer-sited DR resources to integrate with electric delivery companies and RTOs.

This project was composed of the following two discrete components:

DRCC
The DRCC is designed to aggregate DR resources for activation in response to various conditions of the electric grid. This software was developed as part of an RDSI project, but a secure communications interface to the NOC was developed as part of the SGDP. This interface allowed DG to be integrated into the platform, and the functionality was tested many times throughout the project, demonstrating its technical effectiveness and ability to integrate with the broader platform. It will be utilized in a production environment to enable automatic DR for project resources. A total of 23 facilities and 20 MW of generation have been integrated into the DRCC. Figure 4-8 shows how the DRCC is positioned relative to the other grid components.

Virtual Generator (VirG)
A VirG is created by activating an aggregation of DR resources by the DRCC. This aggregated set of resources is able to supply virtual generation. A VirG is able to solve a capacity shortage on the transmission system as well as address system contingencies in electric distribution networks. Figure 4-8 illustrates the type of DR resources which may be dispatched by the DRCC. Backup power provided by standby generators is an excellent candidate to provide targeted, persistent load reduction to address network events by responding to dispatch signals from a grid operator within five minutes. In fact, the NYISO has included the concept of the VirG in its Reliability Needs Assessment as a potential solution to anticipated regional shortages of capacity.

Figure 4-8. Diagram of DRCC Configuration



4-B.4. PV, Battery Storage, and BMS Integration

The NYCEDC completed construction of a SG system at their BAT site, which integrated three main components: 1) a 100-kW solar PV array, 2) a BMS, and 3) a 720-kWh battery for on-site energy storage capable of delivering 100 kW for four hours. The project demonstrated the benefits of on-site renewable energy generation coupled with energy storage and management systems to reduce demand on the grid, offset energy costs, and advance the City's PlaNYC[3] sustainability objectives by reducing GHG emissions associated with energy generation and use. Additionally, the project findings will benefit the industry as a whole by sharing lessons learned and best practices to support acceleration across New York City.

Construction at the BAT began in January 2013. In addition to the installation of the PV and battery systems, a battery room was constructed to house the battery cells. The battery room was designed to meet fire code and building code requirements, provide structurally sufficient flooring, and to accommodate the valve-regulated lead-acid battery technology. The room features a Heating, Ventilating, and Air Conditioning (HVAC) system, hydrogen gas detection and alarm system linked to an outside exhaust system, fire-rated walls, structural improvements to the battery room floor, acid-resistant flooring, a pre-activated dry sprinkler system, and a tempered safety shower and eye bath. An on-site controller allows for direct control and programing of the battery inverter, which is also controlled through the BMS, located on the first floor in the building's operational offices. The solar PV

[3] PlaNYC is the NYC Office of Long-Term Planning and Sustainability's blueprint for resiliency and sustainability within NYC. For more information, see: http://www.nyc.gov/html/planyc/html/home/home.shtml

system was commissioned in August 2013, and has produced over 61 megawatt-hours of electricity through April 2014, averaging approximately 6.8 megawatt-hours per month. The integrated battery and BMS system was commissioned in October 2013.

4-B.5. Streamlined PV Design and Build

In 2013, Con Edison contracted Gehrlicher Solar to install a 40-kW alternating current (AC) solar PV installation at Con Edison's 4 Irving Place headquarters (Figure 4-9). Con Edison believes that by integrating this installation into the project, we gain hands-on experience with the process of installing equipment on NYC commercial building rooftops. This project was unique in that this behind-the-meter solar installation was completed atop a 19th-story roof of a NYC landmark building

Figure 4-9. PV Installation on Con Edison's Headquarters

The installation began in November of 2013 and was completed in January 2014. The main challenges included logistics and the weather. This building has a highly utilized loading dock. Extensive planning was necessary to reserve the loading dock, find adequate staging areas needed for the work location, and to plan the work to limit the amount of noise affecting building tenants. The harsh weather that NYC faced that year also added to the length of the project. Given those challenges, Con Edison believes that this was representative of a worst-case situation and yet, was still a successful installation.

- All permits and approvals were received from local authorities having jurisdiction (AHJs) including NYC Department of Buildings, Environmental Control Board (for electrical review and inspection), Landmarks Preservation Commission, and Con Edison’s DG department for utility interconnection.

- The PV system was successfully installed, inspected, and commissioned. It is currently operating at its full capacity.

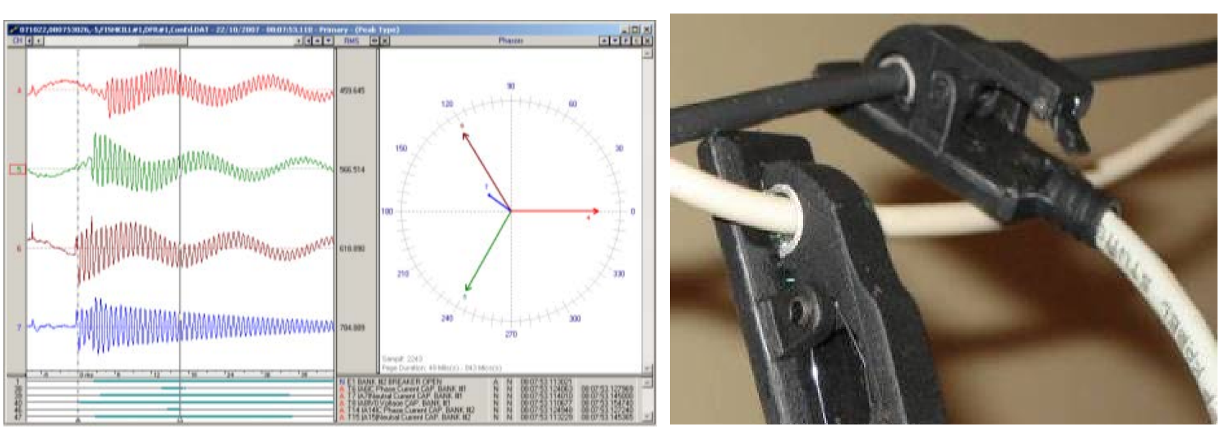
4-C. Optimization and Control

4-C.1. SGDM

Traditional power system disturbance monitors are effective but are costly to deploy (in and especially beyond the substation environment). The main reason is that traditional monitors are not deployable on live circuits. Utilities have to plan and schedule outages prior to deployment. To eliminate the need for such outages, a Con Edison, Softstuf collaborative effort resulted in the invention of low- cost, patent-protected monitoring technology that is just as effective as traditional methods but that can also be deployed on live circuits. The new technology uses small, non-intrusive sensors that clip on electrical circuits without disrupting equipment, which provides the added benefit of rapid deployment, thus allowing utilities to achieve timely compliance with regulatory requirements. A picture of sensor (right) and its output (left) is shown in Figure 4-10.

Furthermore, legacy protection relay systems do not provide sufficient data for fault analysis because they are mainly composed of analog devices (electro-mechanical). The lack of sufficient data limits the utility’s ability to determine root causes and mitigate risks of pending or actual failures. Most of the U.S. power grid, especially nuclear power plants, continues to be based on analog devices though a SG demands digital input for quick analysis and diagnosis. Utilities are therefore forced to replace their legacy relays with modern digital relays (even if the legacy relays still have useful life and do not require replacement). The new sensors offer an alternative solution that allows legacy relays to stay in place, while providing the additional monitoring capability featured in the latest digital relays. Supplementing legacy infrastructure with new, non-intrusive sensors can make legacy substations similar to modern substations with digital relays. The sensors help increase grid reliability and extend the lifetime of critical assets. Utilities may use these sensors to tune protection systems, extend maintenance and testing cycles, expose faulty wiring, and identify good/bad relay operations. The net balance is a more reliable grid at a lower operational cost.

Figure 4-10. Clip-on Sensor with Three-phase Disturbance Monitor Traces



The DOE SG funding through Con Edison supported the Softstuf task of producing and delivering a SGDM based on the new sensors technology. The SGDM is composed of over 4,000 sensors, a small array of concentrators powerful enough to process high-speed data (microsecond rate) from all of the sensors simultaneously, and an expert system smart enough to rank and report upon discovery of pending or incipient failures. Con Edison undertook the task of deployment of the SGDM at a major 345-kV substation to monitor performance of critical equipment under power system fault and disturbance conditions (such as transformers, breakers, and protective relay systems). Data from the deployed sensors is collected by the concentrators and analyzed at a central server using the expert system software. The performance of the SGDM during a number of real-life power system disturbances successfully demonstrated its effectiveness in discovery of events and cataloging of fault signatures based on targets, fault magnitude, and duration. The disturbances included reporting on a major 345-kV transformer event, a phase angle regulator fire, and Hurricane Sandy.

The project activities were multifold and proceeded in parallel. The main focus was on building the simulator, delivering the sensors and supporting hardware, and installing the SGDM software on the central server.

4-C.1.1. Simulator

The simulator, representing a substation with three feeders, was designed and assembled at the Softstuf Lab at 333 Bainbridge Street in Philadelphia. The feeders are a ring bus mimic two analog schemes (electromechanical protection) and one digital scheme (numeric relay). The simulator is equipped with a state-of-the-art, three-phase current/voltage injection test set and includes sensors, concentrators, a server with the SGDM software, and a breaker simulator mounted in a panel to mimic a substation control board.

The simulator and test set were used for application of various types of fault and disturbance conditions including balanced and unbalanced faults (phase-to-phase and phase-to-ground faults) designed to challenge both the sensors and the developed software. The simulator and test set were invaluable in demonstrating the features of the SGDM, which are not easily done on service equipment because fault occurrences are unpredictable by nature.

4-C.1.2. Sensors and Infrastructure

Sensors were produced and delivered to Con Edison within the first three months of the project start. The required infrastructure was also procured and delivered along with the sensors. The required infrastructure included 100 sampling units, 40 network switches, four data concentrators, and other supporting components such as cables, connectors, and power supplies.

The sensors connect to the sampling units, which broadcast their measurements through the switches to the data concentrators. The data concentrators process the incoming measurements at the microsecond level and generate waveform captures of any detected fault or disturbance signatures. The captures include both pre- and post-fault measurements and are transmitted to the central server upon occurrence (report by exception).

4-C.1.3. Central Server

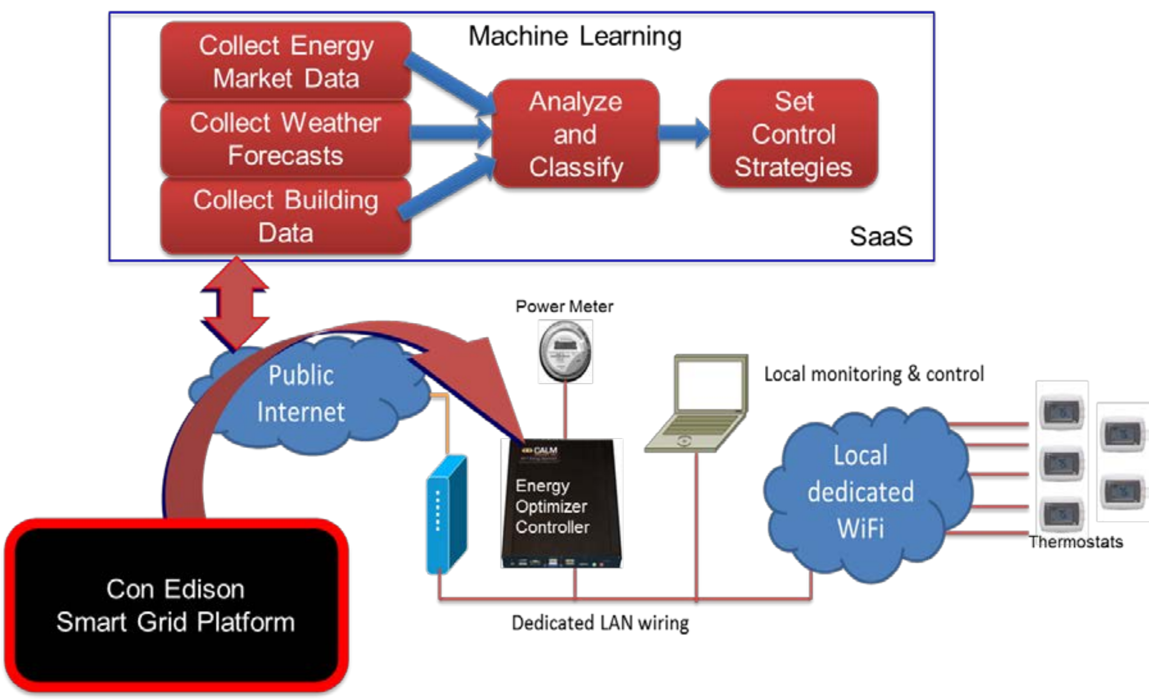
The server was provided by Con Edison and Softstuf was given secure access to remotely deploy, monitor, and refine the performance of the software. The software was successfully deployed, the performance was monitored for an extended period, and the software was then refined accordingly. The software receives sensor data captures from the concentrators in the field and includes an expert module designed to organize the sensor data based on monitored circuits and time of fault occurrence. The software also includes an adaptive engine that processes and ranks the data captures based on fault magnitude, duration, and targets. A number of additional interfaces are also provided for manual diagnostics and visual purposes, including sequence-of-events reports and three-phase metering displays.

4-C.2. Energy Optimizer Controller and ISM

The business case for deployment of the CALM ISM Decision Aid platform was to help prevent cascading area station or sub-transmission feeder incidents. The ISM Decision Aid supports this incident prevention by predicting in advance vulnerabilities of overloaded equipment and providing recommended preemptive, targeted actions to take, like DR, to mitigate the potential incident.

The specific goal for the CALM sub-project was to develop and demonstrate the ISM decision aid platform. The objective was to then validate its value in a real-world electric grid operational environment. The ISM Decision Aid platform was not connected to the Con Edison SG DERMS platform. It was successfully developed and demonstrated using offline data.

Figure 4-11. Diagram of the Energy Optimizer Controller Built by CALM



CALM's demonstrated technology included the following:

- ISM Decision Aid platform for use by T&D control center operators
- Building smart node energy optimization controller

4-C.3. DTC and LSOC

CCLS was responsible for developing ASCs to assist distribution system operations in optimizing decisions about maintenance actions. The ASC used a sophisticated set of algorithms to determine the optimal action.

An alpha version of the DTC was developed to provide recommendations for which operator actions should be implemented. For example, actions on the secondary grid to improve reliability could include repair of open mains or closure of network protector switches. Colombia also developed various visualization tools to inform operators of recommended actions.

The LSOC was intended to provide real-time recommendations for curtailing load when the grid is stressed in order to drive the SG to fewer failures and more efficient delivery of power. Additionally, feedback would be provided to the LSOC of constantly changing grid conditions so that the LSOC could continually simulate multiple future variants and select optimal recommendations to the operator. These algorithms incorporate disparate data, such as pricing information, system loads, weather, and the impact of proposed actions on future flexibility to respond to system conditions.

The LSOC was an approach to recommending curtailable loads to DOs. It aimed to achieve more precise, targeted curtailment of customers considering most likely events and not just worst events. It does so by optimizing a load balancing objective function across hundreds of possible future situations (with their power flows) whose possibilities are delineated by the uncertainties in load and feeder failure rates 19 hours into the future. The curtailment policy (set of customers to be curtailed) it suggests is robust in that it attempts to cover many possible situations with its prioritization of customers to curtail.

The LSOC optimizes the curtailment recommendations given to the operator. It optimizes these recommendations based on a future looking 19 hours ahead considering what might happen in the network based on load being driven by weather forecast, and also based on forecast on the feeder failure rates. It displays these recommendations sorted (descending) by curtailable amount and highlighted along with all the possible curtailable customers in the network to the DO and gives the operator the choice to select those or entertain other possible selections. The DO is presented with charts that describe the performance of the choices compared to a simple selection of all possible curtailable loads (baseline). Auxiliary screens present details of cable sections and transformers that are overloaded. A demonstration of the LSOC was conducted in March, 2012.

4-C.4. IDSM Potential Model

Since 2004, Con Edison has operated the TDSM program focused on deploying customer sided EE for demand reductions in constrained electric networks. With a focus on system and cost management, along with the growth in EE and DSM technology and associated customer strategies, Con Edison recognized the need for increased visibility into customer and technology potential and economics on the demand side. To address this need, Con Edison, along with E3 and Navigant, have created the IDSM

Potential Model, a dynamic, geographically specific, and technology-integrated analysis tool to assess the market potential and economics of EE and DSM for cost-effective deferral or avoidance of capital expenditures required to meet growing customer demand.

The IDSM model was developed to evaluate Con Edison electric networks for demand-side market potential and economics. The model can evaluate individual electric networks, groups of networks, whole boroughs/counties, and the entire system, depending on the needs of the company. The initial model contains eight of Con Edison's 82 networks/load areas, and will be scaled up to include all networks over time (starting with the most near-term constrained networks). Flexibility and usability have been built into the model via standardized input data templates, which will enable easy updates as new customer, technology, and market data are developed or gathered. The model will allow for better and more detailed customer engagement by outputting EE and DSM potential at the technology and customer segment level, specific to the geographic areas in question. Model outputs also include cost-effectiveness testing based on user selections to ensure solution cost-effectiveness. The model outputs will be evaluated by EE and DSM staff to assess the feasibility of deploying TDSM to defer specific capital infrastructure needs and inform go-to-market strategies (e.g., evaluation of vendor proposals via competitive Requests for Information [RFIs] and Requests for Proposals [RFPs]). Con Edison will be using the project model immediately following its completion (September 2014) to evaluate market-proposed TDSM solutions aimed at relieving electric constraints in Brooklyn and Queens.

5. Conclusions

The Con Edison SGDP provides the fundamental building blocks for Con Edison to efficiently and flexibly respond to current and future reliability, environmental, and regulatory drivers. This section summarizes the major accomplishments of the project, the key takeaways, and the implications that the project's learnings and accomplishments have for future operations of Con Edison's system, as well as other electricity delivery systems across the country.

5.1 Major Accomplishments

The SGDP successfully demonstrated that the secure integration of enhanced monitoring and control capabilities with intelligent analytical tools can improve the management of the distribution grid and enable greater deployment of renewable energy resources and SG technologies.

In this project, Con Edison worked on SG technology that can improve the management of the Distribution Grid through a combination of enhanced monitoring and control capabilities along with intelligent analytical tools. Con Edison demonstrated that it can integrate a number of existing legacy control and data systems along with new SG applications in a common, cyber-secure, interoperable control platform. This enabled Con Edison to demonstrate seamless integration and control of renewable energy resources and SG technologies, such as EV charging stations, DG, and BMS.

The successful integration of the underlying technologies was verified through a series of live demonstrations conducted by Con Edison and its partners. A DERMS was developed which includes a visualization platform that provides DOs with a wide-area situational view of the interconnected SG distributed resources and displays available resources within a network that can be utilized to relieve specific grid load constraints. The DERMS platform was integrated with third-party control centers.

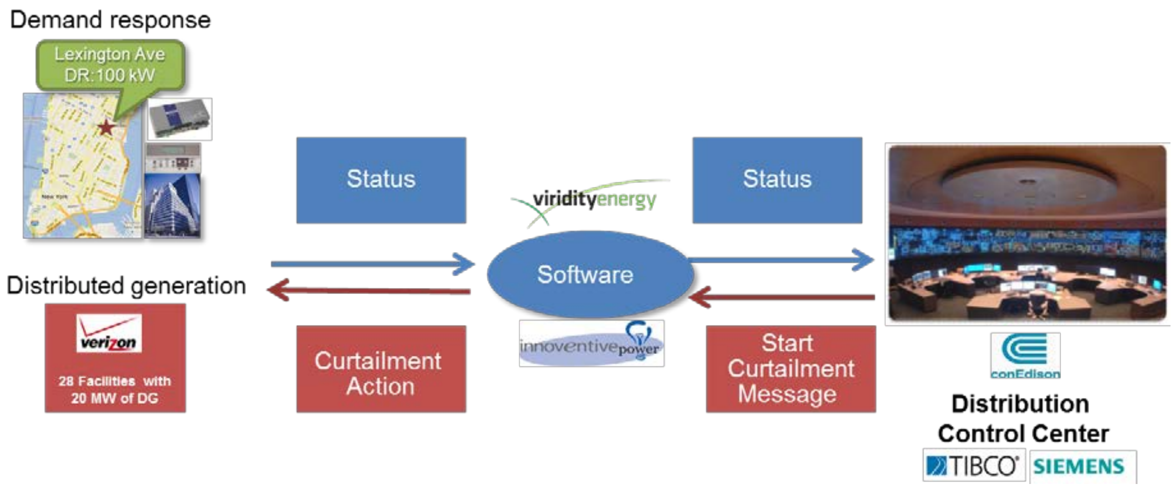
These third-party control systems have the ability to manage specified customer equipment, allowing for things such as load reduction using existing BMS or starting customer-sited DG to relieve localized system needs. From the DERMS platform, operators have the capability of visualizing near real-time customer load information associated and curtailment capacity available from customer-sited distributed and DR resources. The platform was developed with an integrated decision aid tool that can make recommendations as to which demand resources can meet the need of a specific constraint. The tool also enables the DO to see the near real-time impact of a DR resource once it has been activated. The integration of the decision aid tools enables targeted DR.

Targeted DR allows DO to alleviate a particular distribution feeder overload condition by calling upon the distributed resources that can effectively reduce the overload, thus improving overall grid reliability.

In addition to the DERMS platform, a DRMS was implemented as part of the project to more efficiently manage the enrollment, event notification, settlement, and reporting processes associated with Con Edison's DR programs. The DRMS will automate many of these processes, enabling them to be completed more efficiently and at lower cost.

The DERMS and DRMS platforms are two parts of the SGDP that will help Con Edison manage the integration of DR resources.

Figure 5-1. Increased Visibility of DR and DG through Systems Integration



Integration of SG Applications and Resources: As a result of the SGDP, Con Edison is now capable of monitoring and communicating with a variety of SG resources, including the following:

- BMS
- DG
- EV Charging Stations
- Aggregator Network Operation Centers

The DERMS visualization platform also provides DOs with a wide-area situational view of the interconnected SG distributed resources and their availability to relieve specific grid load constraints. To date, the following have been mapped to the visualization platform:

- All 64 networks in Con Edison's service territory
- All 774 enrolled distribution load relief DR program sites and an additional 400 SG DER sites (including solar sites)
- Ongoing effort to include additional DR sites and EV charging sites

Additionally, approximately 500 Digi and 15 Ambient nodes were deployed to support the enhancement of communications between interval meters and Con Edison's MV-90 and MDMS.

The project team developed and implemented protocols for integrating project-related resources and applications in a cyber-secure manner. This approach will be replicated when integrating resources and applications in the future.

Additions to Project Scope: Over the course of the project and with appropriate approval from the DOE, Con Edison took advantage of opportunities to enhance or improve upon the original scope of the project in the following ways:

- Viridity expanded their scope from the integration of five buildings to 23 buildings, due to their early success in the project.
- The DRMS sub-project, provided by Alstom Grid, was added in order to provide DR program management and customer visibility.
- Con Edison added an IDSM Potential Study which will serve as a comprehensive platform to expand Con Edison's TDSM program, improve capital decision-making, support ongoing efforts to further build DR capability, and establish a set of new programs to maximize both system and customer benefits by network, segment, and building type.
- The Wireless Communications and MDM project was added as an essential element for success of the DRMS project.
- Additional GCN battery storage units at Walgreens and UPS
- 40-kW solar panel installation at 4 Irving Place
- Mapping and integration of DR and DG resources across entire distribution network with the DERMS system

Realization of Project Objectives: The SGDP accomplished each of the project objectives outlined in Section 2.2 and demonstrated these capabilities through six iterative and cumulative demonstrations performed over the course of the SGDP. These six demonstrations built upon the learnings of the previous demonstrations to ultimately accomplish all project objectives, and culminated in a final capstone demonstration performed by Con Edison for the DOE on July 15, 2013.

Table 5-1 gives examples of how each project objective was realized, by which sub-project and which demonstration.

Table 5-1. Completion and Demonstration of the Project Objectives

Project Objective	Objective Achieved by:	Demonstration						Sub-project												
		1	2	3	4	5	6	A.1	A.2	A.3	A.4	B.1	B.2	B.3	B.4	B.5	C.1	C.2	C.3	C.4
1. Improve control capabilities for existing grid assets	DERMS visualization functionality	x		x	x	x	x	x	x	x		x		x			x	x	x	
2. Determine how to best apply newly developing technologies	Architecture, technology, and systems integration in conjunction with industry standards	x	x	x		x	x	x	x		x	x	x	x	x	x	x			x
3. Minimize peak load growth	DERMS visualization, customer site system monitoring, and third-party service provider NOCs	x		x		x	x	x	x			x	x	x						x
4. Improve grid reliability	DERMS interoperability between distribution system operations and DERs	x	x	x	x	x	x	x		x		x	x	x			x	x	x	x
5. Provide customers with greater visibility, flexibility, and value	Third-party service providers	x		x		x	x					x	x	x						
6. Leverage controllable field assets that provide targeted load reductions, such as:	Third-party service providers	x		x	x	x	x		x			x	x	x						
curtailable customers	SGDP curtailment functions, third-party service NOC, customer sites	x		x	x	x	x	x	x			x		x						
customer-owned switches	Third-party service providers and control interfacing		x				x							x						
DG	SGDP technology services framework, visualization, engineering analysis, load flow extension			x	x	x	x							x						
battery storage	Customer battery storage monitoring	x		x	x	x	x						x		x					
EV charging stations	Third-party service providers and control interfacing	x		x	x	x	x							x						

Project Objective	Objective Achieved by:	Demonstration						Sub-project														
BMS	Third-party service providers and control interfacing			x	x	x	x					x								
HANs	Third-party service providers and control interfacing			x	x		x	x												
high-voltage monitoring	SGDP integration with high-voltage meters				x		x	x												
AMI	SGDP Services and improve MDMS			x			x	x			x									
7. Decision Aids	Modeling and control decision aides and DERMS visualization	x		x		x	x			x							x	x	x	x
8. Integrate legacy applications, sensory data, and decision aids to the middleware	DERMS and TIBCO middleware	x	x	x	x	x	x	x		x										
9. Integrate data from system sensors and control functionality with the middleware	DERMS and TIBCO middleware	x	x	x	x	x	x	x		x	x									
10. Conduct an Operational Readiness Review prior to each demonstration	*completed prior to each demonstration*	x	x	x	x	x	x													
		1	2	3	4	5	6	A.1	A.2	A.3	A.4	B.1	B.2	B.3	B.4	B.5	C.1	C.2	C.3	C.4

Public Outreach: Con Edison leveraged the SGDP as a platform for raising public awareness of the SG and its implications for utility customers. Con Edison's Public Affairs department worked with the Smart Grid Implementation Group to create public awareness of SG in Con Edison's service area through broadly disseminated communications and messaging, as well as targeted communications to the communities most affected by visible installations. Con Edison's outreach efforts are cited and linked below:

Community Engagement

- Developed a clean-tech curriculum as part of a Solar1 initiative that includes SG technologies. (Independent of the SGDP)
- Young Men's Christian Association (YMCA) presentation by R&D – SG model for high school students
- Video of Solar Project at 4 Irving Place- and press releases
- SG animation on YouTube (more than 20,000 views) https://www.youtube.com/watch?v=QPWCCz_OTGU

Press Releases

- Con Edison Releases SG Animation: http://www.coned.com/newsroom/news/pr20100701.asp
- Additional $45 Million in SG Stimulus Funding: http://www.coned.com/newsroom/news/pr20091124_2.asp
- $136 Million in SG Stimulus Funding http://www.coned.com/newsroom/news/pr20091027.asp
- Senator Gillibrand Pushes For SG Funding: http://www.gillibrand.senate.gov/newsroom/press/release/gillibrand-pushes-for-smart-electric-grid-funding-for-new-york-federal-dollars-would-lower-energy-costs-in-hudson-valley
- NYISO Press Release – Phasor Measurement Unit (PMU) Project attended by P. Hoffman October 2012
- Con Edison Installs PV Panels on Historic NYC Headquarters http://www.coned.com/newsroom/news/pr20140421.asp
- Con Edison SG Initiative http://www.coned.com/publicissues/smartgrid.asp

Media Coverage

- US Electricity blackouts skyrocketing http://www.cnn.com/2010/TECH/innovation/08/09/smart.grid/index.html
- "They'll rays the roof in B'klyn" http://nypost.com/2010/11/22/theyll-rays-the-roof-in-bklyn/
- SG Illuminates New York's Underground http://www.smartplanet.com/blog/intelligent-energy/smart-grid-illuminates-new-yorks-underground/
- Con Ed Tests a SG in Queens http://cityroom.blogs.nytimes.com/2009/08/05/con-ed-tests-a-smart-grid-in-queens/
- Con Ed testing a $6 million pilot SG program in Queens neighborhoods hit by blackout http://www.nydailynews.com/new-york/ed-testing-6-million-pilot-smart-grid-program-queens-neighborhoods-hit-blackout-article-1.394171

Professional Conferences and Events

- Con Edison recognized at the 4th Annual Network Grid Event as being among the top 10 Distribution Automation projects in the country
- Presentations at GridWeek in 2011 and 2012

- Presentation on Demonstration and Investment Grant Projects at Distributech 2012
- Institute for Electric Efficiency (IEE) – March 2011- SG Model Display and Smart Grid Investment Grant (SGIG)/ Demonstration Project Overview (SG-Powering the People Innovations)
- American Association for Blacks in Engineering (AABE) conference in Jersey City –April 2011 -SG Model Display and SGIG/Demonstration Project Overview
- Mid-Atlantic Conference for Regulatory Utilities (MACRUC) - Utility Commissioner event – SG Model Display and Project Overview Hershey Penn- June 2011
- Edison Electric Institute (EEI) Board Meeting at Waldorf Astoria Conference (Sept. 6 – Sept. 8, 2011)

Institute of Electrical and Electronics Engineers (IEEE) Presentation (2-25-2012, Washington, DC)

- SG Peer Review (6-8-2012, San Diego, CA)
- Electric Utility Consultants, Inc. (EUCI) Conference (9-19-2012 – Philadelphia, PA)
- SICA (Atlanta, GA Spring 2013)
- Technically Speaking Seminar Presentations August 2011 and August 2013. Continuing Education Credits received by attendees.
- Stevens Institute/ Burns & Roe employee Presentation – SGIG and Demonstration Projects - March 2014 for Continuing Education Credits
- EEI Building Integration Conference – Presentation on SGIG projects and Demonstration Projects (June 2013)
- Advanced Energy Conference April SG Projects (April 2013 and May 2014)
- DOE Demonstrations attended by the DOE (March 27, 2012 and July 15, 2013)
- Partnership to Advance Clean Energy – Development (PACE-D) delegation from India (1-21-2014 – Con Edison Headquarters)
- IEEE Presentation with Hank Kenchington (Feb. 2014, Washington, DC)
- DR National Forum Presentation on DERMS/DRMS (May 2014)
- DERMS/DRMS Project presentation – Public Service Commission (Albany, NY - May 2014)
- REV at Public Service Commission (5-28-2014 – Albany, NY)

5.2 Project Benefits

Table 5-2 summarizes the overall benefits realized by Con Edison through the SGDP, as a result of the project's accomplishments described above. These benefits were demonstrated throughout the project performance period and, more importantly, will continue to develop in the future as Con Edison capitalizes on the groundwork developed through the SGDP.

Table 5-2. Summary of Project Benefits

Benefit	Category	Subcategory	Description of Benefit Achievement
Capacity, Arbitrage, and Ancillary Service Revenue	Economic	Market Revenue	Viridity estimates that $1.1 million and Innoventive estimates that $3.7 million in additional annual income may be available to market participants as a result of the DR resources deployed through this project. Additional market revenues will likely be possible in the future as a result of this project.
Optimized Generator Operation, Deferred Generation Capacity Investments, Reduced Ancillary Service Cost, and Reduced Congestion Cost	Economic	Improved Asset Utilization	Although the DR and DG systems that were installed as part of this project have a relatively small impact on system generation optimization, capacity investments, and congestion costs, the supporting platforms developed during this project will ultimately enable integration of additional DERs that will improve asset utilization.
Deferred T&D Capacity Investments	Economic	Distribution Capital Savings	Integration of DR and DG resources and the associated control and visualization systems will allow Con Edison to defer distribution capacity investments.
Reduced Equipment Failures	Economic	Distribution Capital Savings	Through load reduction using targeted DR and advanced equipment failure monitoring, Con Edison can minimize potential failures and damage associated with transformer and feeder overloads.
Reduced Meter-Reading Costs	Economic	Distribution O&M Savings	The wireless metering project has improved communication for meter reading on over 1,000 meters, resulting in approximately $2 million dollars per year of operational savings.
Reduced Electricity Losses	Economic	Energy Efficiency	Integration of DERs using the DERMS and DRMS platforms has reduced line losses, resulting in energy savings.
Reduced Electricity Cost	Economic	Electricity Cost Savings	Customer-sited generation and storage units reduced customer peak capacity payments.
Reduced Sustained Outages	Reliability	Power Interruptions	Enabling DR and DG using DERMS will lead to fewer sustained outages.

Benefit	Category	Subcategory	Description of Benefit Achievement
Reduced Major Outages	Reliability	Power Interruptions	The enhanced O&R distribution equipment controls will reduce the number and frequency of major outages.
Reduced Restoration Cost	Reliability	Power Interruptions	Root cause and equipment failure analysis systems implemented by Softstuf will reduce overall restoration costs.
Reduced CO_2, SO_x, NO_x, and PM -2.5 Emissions	Environmental	Air Emissions	Enabling renewables, reducing reliance on emissions-intense peaking generators, and reducing the number of truck rolls and labor for meter reading all have reduced emissions.
Reduced Oil Usage	Environmental	Security	The immediate impact of this project on oil usage has been minimal, but the platforms developed and implemented will ultimately allow for increased renewables integration and oil usage reduction.

5.3 *Key Takeaways*

The SGDP has provided a number of key takeaways that can be leveraged to the benefit of future projects as some of the technologies and approaches move towards commercialization and broader deployment. The key takeaways come in the form of *challenges* encountered and *lessons learned*. Some of these takeaways pertain to the entire project, while others are specific to sub-projects. Thus, they have been organized into overall project and sub-project specific sections below.

5.3.1 Overall Project

Overall project takeaways rise to the level of importance across the entire project, spanning all sub-projects, and thus can be thought of as the "meta-lessons" from the overall SGDP. These takeaways fall into the areas of project management, technical, and customer engagement.

Project Management: SG projects by definition involve a complex set of technologies, functions, and stakeholders. The complex planning and interplay between the parties leads to project management challenges.

- *Challenge*: Establishing and maintaining a focused strategy with achievable and measureable goals, is a complex undertaking that should not be underestimated.
    - *Lesson Learned:* Detailed scope of work and requirements are critical to successful integration projects. This may seem obvious, but it cannot be emphasized enough.
- *Challenge*: Keeping the project on track despite the replacement of the proposed middleware provider/system integrator. The middleware provider/system integrator did not start work until August 2011, approximately 20 months following project kick-off.

  - *Lesson Learned:* Unexpected events or changes can and will affect project schedules and outcomes, and a project management approach must be in place to deal with the unexpected.
- *Challenge*: Enforcing compliance with technical standards that are constantly evolving can be difficult and cause ripple effects across project components.
  - *Lesson Learned:* Project plans should allow for monitoring of key standards and should build in flexibility to accommodate evolving standards.

Technical: Integrating disparate technologies, both new and legacy, creates multiple challenges that must be overcome. It also presented certain opportunities.

- *Challenge:* Integrating equipment into Con Edison's operations required a great deal of flexibility. Despite vendors' claims, their equipment and software do not always work exactly as described.
  - *Lesson Learned:* Laboratory testing of vendors' products is critical to the success of the project. On-site laboratory testing has found and eliminated a number of undisclosed issues that would have prevented successful operations.
- *Challenge*: Identifying and integrating data from multiple systems and sources within the enterprise is complicated. In most cases, data resides within silos and bringing these silos together requires a clear understanding of the data as well as the purpose for integrating the data.
  - *Lesson Learned:* Integrating this disparate data requires access to SMEs of the disparate system and an overarching understanding of how to bring this data together to present in a unified manner.
- *Opportunity*: As a demonstration project, the objectives included learning about the barriers that private-sector project developers would face in leveraging new technologies. In particular, integrating storage was a key goal.
  - *Lesson Learned:* Among those identified is that particular battery chemistries do not yet have local permitting guidelines, so project developers must consider both performance and regulatory readiness in selecting technologies.
  - *Lesson Learned:* Existing power system design specifications do not readily allow battery generation. For example, integrating battery storage required the use of a reverse power relay for safe operation, which was not anticipated initially.

Business: Business and financial challenges continue to exist, even though the American Recovery and Reinvestment Act of 2009 (ARRA) funding provided a significant boost in these areas.

- *Challenge:* The cost and overhead required for project compliance was significant, and should not be underestimated. Significant cost-share commitments often hamstring small businesses.
  - *Lessons Learned*: Fortune 500 companies are interested in reducing energy costs and GHGs. 7-Eleven, Avis, and Whole Foods all committed significant money ($250,000+ each), time, and resources to partner with GCN on this ARRA project. These companies are interested in being on the forefront of the energy revolution.

- *Challenge*: Existing DR programs do not readily measure the impact response, as well as other limitations.
    - *Lessons Learned*: DR programs can be significantly enhanced through application of new SG technologies, as illustrated in Table 5-3.

Table 5-3. Potential Enhancements to Con Edison's DR Capabilities

	Current Demand Response	Demonstration
Visibility into location on network	• Limited	• High
Magnitude	• Discounted for uncertainty	• Higher real-time availability
Timing	• Two hours to day-ahead	• Close to real-time (under five minutes)
Security	• Not applicable	• Added layer of cyber security
Customer experience	• Manual intervention	• Automated and seamless

The takeaways above will be leveraged in the continued SG development efforts by Con Edison, and should be leveraged by other utilities and SG technology providers as inputs into SG project planning efforts.

5.3.2 Sub-project Specific

Individual subprojects also encountered challenges and developed key learnings during the process of developing their specific, agreed deliverables. The challenge areas and lessons learned, in addition to the overall SGDP lessons above, can be instrumental in informing future work that leverages and builds on the work performed as part of this project. Table 5-4 reviews these key challenges and lessons learned for selected sub-projects whose lessons learned were specific to the activities of that sub-project.

Table 5-4. Challenges and Lessons Learned by Sub-project

Sub-project	Deliverable	Challenges	Lessons Learned
A1. DERMs (Siemens, TIBCO)	Meeting the demonstration timeline and scheduled dates	Communicating with project partners to achieve objectives across multiple participants	Documentation, communication, and up-front scope agreement are critical to timely success.
	Data integration of legacy and SG systems	Accessing subject matter experts, presenting data in unified manner, and leveraging data residing within silos – must facilitate bringing these silos together	Must understand technical capabilities of diverse group of partners during system integration activities
	Cyber-security implementation	Integrating legacy systems that weren't necessarily designed with cyber-security in mind	Utility and Third Party systems have cyber- security challenges that require advance planning and careful implementation.
A.3 ISM (O&R)	Developing a cyber-secure & interoperable system	Integrating *real-time* command and control systems that reside on cyber-secure network with corporate network systems	Solve problems in laboratory environment before trying to solve in the field
		Data communications (inter-control center communications protocol (ICCP), OPC, Secure Sockets)—getting these communications to work in realistic environment	Use real-time logic simulator with production software and actual communications during the testing process
		Managing last-mile radio communications	End-to-end system testing using production systems, actual data communication systems, last-mile radio communication, and field hardware setup in a laboratory environment identified problems that would not have been discovered until the system failed in the field.
	Developing ISM	Micro Corba software used for control room displays, Open Platform Communications client software used for DSCADA interfaces	ISM approach can identify/provide solutions to problems that were not envisioned at beginning.
		Identifying start of storm	Identified need and is providing

Sub-project	Deliverable	Challenges	Lessons Learned
		from weather and incoming outage data	solution for radio bandwidth management issues
B.1 DR and BMS Integration (Viridity)	Building and resource models	Buildings not yielding meaningful DR	Developed screening methods to target high-potential sites
		NYC commercial building culture and configuration presented a learning curve.	Must refine approach to targeting and acquiring sites
		Scope dependent on actual site acquisition (sales of a sort) leading to some missed expectations	Target, but not commit to, specific sites unless contracts are in place – use risk-based planning
	Con Edison interface	Middleware provider established 20 months into project	Develop requirements and design to greatest extent possible, as done with the Con Edison – VPower™ messaging interface
	NYISO interface	First operational exposure to NYISO market rules	Trained the NOC resources appropriately and adjusted strategy
		NYISO price forecasting tools somewhat unreliable	Augmented with an external pricing feed
	Other	Hurricane Sandy flooded several sites which remain inactive.	Consider risk in site-assessment and equipment location
B.2 SSGU (GCN)	Installing energy storage units	Department of Transportation, safety, and space concerns must be addressed for mobile energy storage.	Mobile energy storage may not yet be ready for full-scale deployment.
	Integrating software	Integration of battery storage, PV, and EV storage at small commercial customer sites has no precedent.	The control software is the key behind effective customer side of the meter energy storage.

Sub-project	Deliverable	Challenges	Lessons Learned
B.3 DRCC (Innoventive)	Software developments	Integration of many moving parts developed by various teams is a management challenge. In this project, software was developed by four different organizations with requirements driven by three different entities.	Precise management of requirements and schedules is required upfront.
	DRCC	Technology changes rapidly and designs must be able to accommodate these changes (DRCC, Metering, Frame relay vs. Multiprotocol Label Switching [MPLS]).	Must remain flexible
	Program participation	Market rules and regulations must be carefully monitored and influenced, if possible, to get the most value out of the software (NYISO Direct Communications, Demand-Side Ancillary Service Program Aggregation, and Distribution Load Relief Program).	Do not underestimate the effort needed to change or create new markets
	Continuity	Hurricane Sandy	Redesigning and rethinking can be essential to project success.
	Development of SGDM	Synchronizing data files	Utilize a simulator for testing/verification prior to field deployment
C.2 Energy Optimizer Controller (CALM)	Software development	Retrieving data for design and testing can be challenging.	Must maintain a flexible and innovative design process
	Administrative	Reporting and documentation requirements	Administrative functions can be exhaustive for a small government contract.
	Other	Managing large number of data files	Large data files require additional effort.

5.4 Implications for the Future

Con Edison is dedicated to lowering costs, improving reliability and customer service, and reducing its impact on the environment for its customers. These objectives also align with the policy objectives of New York State, as a whole. As part of this strategy, Con Edison's long-term vision for the distribution grid relies on the successful integration and control of a growing penetration of distributed resources, including DR resources, battery storage units, DG, and EV charging stations. For example, as shown previously in Figure 2-4, Con Edison is expecting significant long-term growth of DG. The SGDP enables the seamless integration of these disparate resources and lays the architectural foundations for future scalability.

5.4.1 Future Commercialization and Scalability

The SGDP began as a demonstration project for the DOE with two boroughs, two distribution networks, and one substation, as well as O&R. The platform is extremely flexible and scalable, and has been expanded to encompass the entire Con Edison distribution network (five boroughs, Westchester County and 64 networks), which will enable the growth expected for DER and DR across Con Edison's territory. Currently, the SGDP platform includes all enrolled (774) distribution load relief program sites and an additional 400 SG DER sites (including solar sites). The effort is ongoing to include additional DR sites and EV charging sites.

With the DERMS visualization layering capability, it is possible to include as many sites as required for monitoring the availability and accessing the condition of the distribution network.

In addition to the DERMS platform, a DRMS was implemented to more efficiently manage the enrollment, event notification, settlement, and reporting processes associated with Con Edison's DR programs. The DRMS automates many of these processes, enabling them to be completed more efficiently and at lower cost.

Over the course of the project, Viridity Energy commercialized a total of 31 SGDP-related sites by operating them in both NYISO and Con Edison DR (capacity) programs in parallel to project participation. Leveraging the project investment in ongoing commercialization, Viridity entered 2014 summer program operations representing 32.85 MW at \$8.7M estimated economic value (revenue from NYISO/Con Edison), as shown in Figure 5-2. These results and the implied benefit to economic and environmental sustainability are directly attributable to Viridity's partnership with Con Edison, made possible by the DOE project funding.

Figure 5-2. Commercialization of Viridity Energy DR Resources

	Grant Related Commercialization Progression						Capture Improvement	
	MW Value	Grant Sites	Last Reported	Current	Extension	Combined	Value	%
Site Count		**23**	**5**	**16**	**15**	**31**	**26**	**520%**
Curtailable Load (SCR) *MW*	---	---	5.154	7.45	3.90	11.35	6.20	120%
Curtailable Load (DLRP) *MW*	---	---	3.402	7.05	3.90	10.95	7.55	222%
Curtailable Load (CSRP) *MW*	---	---	3.894	7.05	3.50	10.55	6.66	171%
Total Curtailable Load	---	---	**12.45**	**21.55**	**11.30**	**32.85**	**20.40**	**164%**
Est. Economic Annual Value	**\$265,100**	---	**\$3,300,495**	**\$5,712,905**	**\$2,995,630**	**\$8,708,535**	**\$5,408,040**	**164%**
viridityenergy power economics redefined	Conservative average annual value of 1 MW of curtailable load across these non-exclusive DR programs	Total number of sites that participated in the program / grant with Viridity	Initially commercialized with 5 of 23 sites as reported in the 2013 technical review in WV	Improved commercialization to 16 of 23 sites participating in program	Extended commercial terms to 15 additional sites of real estate portfolio managers benefitting from program / grant	Total sites commercialized as direct result of program / grant	Realized improvement in commercialization in the past 12 months stemming from program / grant, related NYSERDA programs, ConEdison DR incentives, and Viridity Market Strategy	

The DOE SG funding through Con Edison also supported the Softstuf task of producing and delivering a SGDM based on a new sensor technology. Softstuf is actively working to make SGDMs commercially available in whole and in part by packaging, advertising, and soliciting investment capital. The ongoing process of commercialization was initiated by Softstuf during the project.

5.4.2 Alignment with New York State REV Process

In December of 2013, the NYPSC announced that it would comprehensively consider how the regulatory paradigm and retail and wholesale market designs effectuate or impede progress toward achieving the policy objectives underlying system benefits programs and regulation of electric distribution utilities. As of April 24, 2014, the NYPSC outlined these objectives in its strategic report, "REV".[4] Today these policy objectives are stated as follows:

- Enhanced customer knowledge and tools to manage the energy bill
- Market animation and leveraging customer contributions
- System–wide efficiency
- Fuel and resource diversity
- System reliability and resiliency
- Reduction of carbon emissions

Con Edison recognizes that significant investment will be needed to: (1) meet these new policy objectives, (2) provide customers with the level of service they desire, and (3) compensate the customers in partnership for the level of service they may also provide to the system. Future investments in generation, transmission, and distribution facilities will be more effectively coordinated with demand-side resources, IT, and communication infrastructure, some of which will enable and integrate customer and third-party investment in DERs. The policy objectives actively promote EE and renewable generation to further reduce customer GHG emissions. Energy produced by customer-sited renewables offsets procured energy, thereby reducing the overall level of non-renewable energy consumed.

The SGDP lays the groundwork for implementing several of the policy objectives laid out by the NYPSC in the REV proceeding. Additional investments will be necessary to meet the requirements of the DSP. This project has deployed technologies that will improve system visibility, enhance control, and support analytics that can help achieve objectives described in REV. Specifically, the DERMS and DRMS deployed through this project will facilitate integration with DER components and control center operations, provide communication options and secure messaging, and enhance the overall DR implementation process. This will allow Con Edison to align with REV in the following ways:

- Engage, educate, and empower customers through increased options for customer-sited solutions and energy management tools
- Better enable DR and DER penetration through enhanced visibility and control of these distributed resources to do the following:
  - Increase system-wide efficiency
  - Reshape the load curve
  - Provide greater reliability and resiliency
  - Provide fuel and resource diversity, while reducing carbon emissions

[4] Reforming the Energy Vision, NYS Department of Public Service Staff Report and Proposal, April 24, 2014.

Overall, the approach and results of the SGDP are consistent with the NYPSC's and Con Edison's shared objectives for increasing the reliability of Con Edison's distribution services at improved costs, while leveraging DER to complement centralized generation plants.

Appendix A. Final Technical Reports

[Please see separate attachment]