U.S. DEPARTMENT OF ENERGY

Electricity Delivery & Energy Reliability

American Recovery and Reinvestment Act of 2009

Using Smart Grid Technologies to Modernize Distribution Infrastructure in New York

Smart Grid Investment Grant Program

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RECOVERY ACT SMART GRID PROGRAMS

1. Summary

Consolidated Edison's (Con Edison) Smart Grid Investment Grant (SGIG) project focuses on the modernization of electric distribution systems, including subprojects on overhead and underground distribution switches, expansion of network transformer remote monitoring equipment, underground distribution loops, selected network sectionalizing, automated switching, advanced supervisory controls and data acquisition (SCADA) systems, sensing and measurement technologies, dynamic modeling, and automated controls for voltage and reactive power management.

Under the American Recovery and Reinvestment Act of 2009, the U.S. Department of Energy and the electricity industry have jointly invested over $7.9 billion in 99 cost-shared Smart Grid Investment Grant projects to modernize the electric grid, strengthen cybersecurity, improve interoperability, and collect an unprecedented level of data on smart grid and customer operations.

This case study presents results from Con Edison SGIG subproject that includes the deployment of smart grid technologies to modernize and improve the utilization of existing, overhead medium voltage distribution circuits. Through the deployment of advanced automated controls, sensing and measurement technologies, and advanced components, Con Edison has improved voltage management capabilities, enhanced power system measurement, reduced reactive power consumption, and improved asset utilization, capacity management, and energy efficiency.

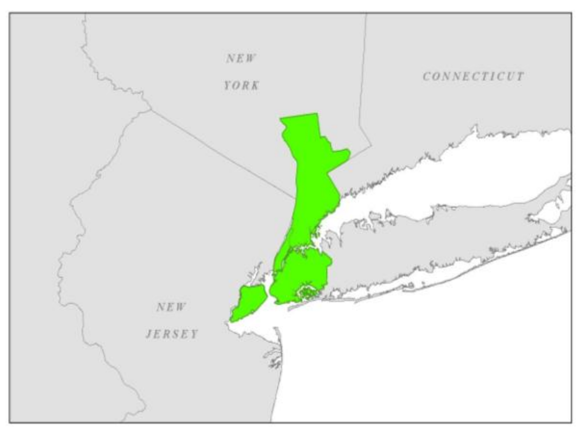
This subproject includes the installation of pole mounted distribution capacitors, load tap changer (LTC) controllers at 4kV unit substation transformers, power quality and battery monitoring systems, and development of 4kV grid models for enhanced load flow analysis. The aim is to optimize 4kV distribution grid performance, reduce electrical losses, enhance performance monitoring and analysis, and improve voltage control methods.

Table 1 summarizes the key results based on data through the end of 2013.

Table 1. Summary of Key Results	
Asset Utilization and Capacity Management	i. Increased 4kV unit substation capability by 31.1MVA or 2.8% under peak conditions with net savings of $15.7 million. ii. Reduced 4kV system primary losses by 2.3 percent under peak conditions.
Voltage Controls for Reactive Power Management and Energy Efficiency	iii. Reduced reactive power requirements at the aggregate level of 33 substations in Queens by about 12.3% and 9.9% over a one-year test period through the application of advanced LTC controls. iv. Increased power factor at these same substations by about 2% and 1% over the same one-year test period. v. Reduced annual system energy losses by 4,500 megawatt-hours (MWh) that saved an estimated $0.34 million in annual energy costs and reduced CO_2 emissions by about 340 metric tons.

2. Introduction

Con Edison serves about 3.3 million residential, commercial, and industrial customers in New York City and surrounding areas, operates more than 700 MW of electric generation, and manages an electric distribution system that is 86% underground. Con Edison's electric service territory includes a mix of high-density urban loads, such as those found in mid-town Manhattan, and moderate-density urban and suburban loads found in other boroughs and surrounding counties.



Con Edison serves 3.3 million customers and operates one of the largest underground electric distribution systems in the country.

Con Edison's SGIG project installed distribution automation technologies and systems to improve electric reliability, remote monitoring, operator decision support, asset utilization and capacity management, energy savings and efficiency, reactive power management, and power quality and substation battery monitoring.

The total budget for the entire project is $272.3 million, including $136.2 million in SGIG funding from the U.S. Department of Energy (DOE) under the American Recovery and Reinvestment Act of 2009. The subproject in this case study involves 4kV grid modernization and includes installation of 449 pole mounted distribution capacitors; 111 digital LTCs; power quality and battery monitoring technologies; and development of a 4kV grid model for enhanced load flow analysis. The budget for this subproject is almost $20 million or about 7% to the project's total budget.

The portion of Con Edison's distribution system that uses 13kV and 27kV equipment has a greater percentage of substations and feeders currently equipped with automated digital controls and access to SCADA systems. In contrast, the 4kV grids use analog systems with electro-mechanical controls and typically serve areas where load growth has been modest. Replacing the 4kV grids with higher voltage systems is cost prohibitive in New York due in part to the high cost of real estate. Prevalent throughout the U.S. and other parts of the world, Con Edison's 4kV grids represent about 34% of distribution circuits, 16% of customers, and 11% of system peak demand.

Reduction in electrical line losses and reactive power management equates to less electrical generation required to supply system demand. System losses and poor reactive power management mean that power plants need to generate greater amounts of reactive power, which can cause higher fuel consumption and air emissions. Power factors on the 4kV grid can vary throughout the day as inductive loads, such as air conditioning, rise and fall. Deployment of automated capacitors provides local sources of reactive power and reduces the amount that would be needed overall.

Con Edison's 4kV grids are supplied by several unit substations[1] that are typically equipped with a single power transformer that, in some locations, experience circulating reactive power flows caused by voltage imbalances. These circulating flows are harmful to transformers, cause high internal heating, and result in de-ratings. To reduce these potentially damaging effects Con Edison has installed new digital load tap changer (LTC) controls at 111 of the 4kV unit

[1] Unlike other utilities, Con Edison's 4kV overhead distribution system is configured in a grid arrangement, with multiple 4kV feeders operating in parallel using closed-tie switches. Typically, 4kV feeders are connected to single transformer unit substations that step down voltage levels from higher voltage feeders. Because unit substation transformers effectively operate in parallel due to the closed-tie switches, the unit substation transformers experience circulating reactive power flows due to voltage imbalances. Having the ability to maintain similar voltages at the 4kV unit substations reduces circulating currents and improves power factors.

substations and implemented improved control methods. Distribution system operators can control each substation transformer LTC controllers through their SCADA system.

3. Improvements in Asset Utilization and Capacity Management

A large portion of Con Edison's overhead 4kV distribution grid will be modernized at the completion of this subproject, with many feeders equipped with capacitors and automated controls. Installations include a combination of fixed and switchable pole-mounted capacitors. Load flow models are being developed to enhance reliability analysis, improve system visualization, and integrate various sets of operating information to optimize the performance of these systems. Con Edison has installed 416 distribution capacitors on the 4 kV system (71.5 MVAR), and 33 distribution capacitors on the 13 KV system (10.5 MVAR).

Photo of a 4kV 150 kVAR, pole-mounted, switchable capacitor bank.

One of the benefits from operation of the capacitor banks are increases in the capacity of existing substations and the deferral of capital investments. Con Edison conducted analysis to determine the incremental increase in capabilities at the area station level due to capacitor installations under SGIG. The incremental increase in capability from the addition at the area level of 82 MVAR is 19.8 MW.

4. Improvements in Voltage Management

The intent of this sub project was to improve the 4kV unit station transformer load tap changer (LTC) control equipment, reduce circulating reactive power, and increase the power factor in Con Edison's 4kV grids. In the 4kV distribution system, the secondary sides of multiple unit station transformers are paralleled to supply customer load. Paralleled unit station transformers operating at significantly different secondary bus voltages produce currents that circulate between them. This circulating current is mostly reactive and increases the magnitude of reactive power in the system. A measurable impact of the additional reactive power is a lower system power factor. The goals of the project were satisfied by replacing existing analog and electromechanical controllers with microprocessor LTC controllers and implementing new control settings.

Analog and electromechanical LTC controllers were present in approximately half of the unit substations. A large number of these units did not allow for precise voltage control due to their age and high failure rate. Also, the existing analog units did not allow for true SCADA integration. Con Edison installed advanced tap changer controllers at 111 unit stations. In addition, the control settings at each of the stations were evaluated and modified to improve bus voltage regulation.

As part of the project, the existing bus voltage control strategy and LTC control settings were modified. Con Edison's complex parallel grid configuration makes unit station bus voltage control using traditional approaches difficult. The new control settings adjusted the transformer tap changer to maintain unit station bus voltages within specified range. These settings were also applied to existing LTC controllers to ensure a consistent control approach at all unit stations and 4kV grids.

The impact of implementing the new equipment and control strategy on excess system circulating reactive power was evaluated in two 4kV grids in Queens. The study compared data obtained from Con Edison's unit station SCADA system during the same summer month prior to and post project implementation. For each grid, the reactive power (KVAR) was normalized to the total power (KVA) for each time period. In addition, the grid level power factor was calculated for each time period. The results are summarized in the Table 3.

Table 3. Impacts from LTC Controls on Reactive Power Consumption and Power Factors

	KVAR/KVA				Power Factor		
4kV Grid	**Sept. 2009**	**Sept. 2010**	**Reactive Power Reduction**		**Sept. 2009**	**Sept. 2010**	**Power Factor Increase**
Flushing	**0.34**	**0.30**	**12.3%**		**0.91**	**0.93**	**2.0%**
Jamaica	**0.25**	**0.22**	**9.90%**		**0.95**	**0.96**	**1.0%**

Overall, Con Edison estimates that the voltage and reactive power subproject has achieved annual reductions of about 4,500 megawatt-hours (MWh) in system energy losses from the operation of the 449 automated capacitors and 111 LTC controllers. This saved an estimated \$0.34 million in annual energy costs and reduced of CO_2 emissions by about 3,340 metric tons.

5. Conclusions

Con Edison has benefitted from the installation of local and automated capacitor controls on feeders where power factor correction is likely to yield the greatest demand reductions and where savings from reduced energy losses are highest. The replacement of older, analog LTC controls on transformers in substations with digital devices has improved load balancing in 4kV substations, where circulating reactive flows have caused transformer de-ratings due to excessive core heating.

Con Edison has deferred costly capacity upgrades due to improvements in voltage controls and power factor corrections, which have reduced needs for increase in electricity supplies. When operated properly the automated capacitors can produce near-unity power factor ratings, and thereby release capacity that distribution system planners and operators can use to defer capacity upgrades, manage capital expenditures, improve operating flexibility, and increase reliability. Using LTC controls to moderate the effects of circulating reactive flows have reduced de-ratings, extended the life of the transformers, and improved reliability through lower likelihood of equipment failures.

Efforts to apply automated controls for voltage and reactive power management on 4kV distribution systems are part of a broader Con Edison strategy to apply smart grid technologies on both the utility and customer sides of the meter to save energy and improve the reliability, efficiency, and affordability of electricity. Con Edison is showing that a more comprehensive set of tools are created for grid planners and operators when demand-side solutions like demand response and end-use efficiency are integrated with automated controls for voltage and reactive power management. Looking ahead, Con Edison plans to apply these techniques where appropriate to additional portions of their service area.

6. Where to Find More Information

To learn more about national efforts to modernize the electric grid, visit the Office of Electricity Delivery and Energy Reliability's website and www.smartgrid.gov. DOE has published several reports that contain findings on topics similar to those addressed in Con Edison's SGIG project and this case study. Web links to these reports are listed in Table 4.

Table 4. Web Links to Related DOE SGIG Reports and Case Studies		
SGIG program and progress	**i.**	**Progress Report II, October 2013**
	ii.	**Progress Report I, October 2012**
	iii.	**Con Edison SGIG Project Description**
	iv.	**SGIG Case Studies**
Recent Publications	**i.**	**Smart Meter Investments Yield Positive Results in Maine, January 2014**
	ii.	**Smart Meter Investments Benefit Rural Customers in Three Southern States, March 2014**
Voltage and Reactive Power Management	**iii.**	**Application of Automated Controls for Voltage and Reactive Power Management – Initial Results, December, 2012**
Distribution Automation	iv.	**Reliability Improvements from Application of Distribution Automation Technologies – Initial Results, December, 2012**