Long Island Rail Road (LIRR) High Speed Flywheel Demonstration[1]

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Abstract

A New York Power Authority (NYPA) led team proposes to install and demonstrate a high speed Flywheel Energy Storage System (FESS) at the Long Island Rail Road (LIRR) Deer Park station in Long Island, NY. The scope of the project is a turn key installation of a 2.5 MW FESS to provide traction power voltage support to LIRR to mitigate voltage sag problems, reduce power peak demand charges, and offset costly electric distribution upgrades.

Introduction

The LIRR is in the process of replacing existing trains with new technology trains that utilize an AC traction drive system with the regenerative braking. At this time, the LIRR is not planning to collect regenerative braking energy due to mixed train fleet issues but, the new trains draw more power and when fully adopted within the next five years will increase the peak demand on the system electrical distribution. Track voltage sags already results from physical limitations of the traction power supply. As the new trains are rolled out these problems will be exacerbated.

The FESS will provide third rail voltage sag correction and reduce traction peak power demand. In the event of a utility interruption the FESS will also be capable of providing backup power to allow a train loaded with passengers to proceed to the next station. By regulating the voltage and therefore reducing power demands on the system, the FESS will also defer the need for costly substation upgrades.

The FESS was chosen for this application over other energy storage devices due to its ability to meet the charge/discharge cycle demands of the application. The FESS also allows for indoor/outdoor applications, has a small footprint, can be remotely operated, has minimal maintenance, high efficiency, and is re-locatable and expandable. No emissions or hazardous materials are involved with the FESS. Altogether, the proposed project offers a broad range of benefits that are broadly applicable in the State and nationally.

About NYPA

The New York Power Authority (NYPA) is the largest state-owned power organization in the United States and provides some of the lowest-cost electricity in New York State, operating 18 generating facilities and more than 1,400 circuit-miles of transmission lines. NYPA was established in 1931 as a non-profit, public-benefit energy corporation and does not use any tax revenue or state credit. It finances construction of its projects through bond sales to private investors, repaying bondholders with proceeds from its operations. The Authority sells power to government agencies; to community-owned electric systems and rural electric cooperatives; to job-producing companies; to private utilities for resale—without profit—to their customers; and to neighboring states, under federal requirements. The Authority's low-cost power helps support more than 400,000 jobs statewide. Its business customers range from Fortune 100 giants competing in international markets to small manufacturing or service firms that are vital to local economies.

The Authority is also a national leader in promoting energy efficiency and the development of clean energy technologies and electric vehicles. NYPA commits $100 million a year to energy services and in 2006 its total investments in these programs surpassed $1 billion. As part of the Authority's long-standing commitment to the environment, it upgraded the energy efficiency of its administrative offices in White Plains and received a Gold rating for existing buildings in the LEED (Leadership in Energy and Environmental Design) certification process administered by the U.S. Green Building Council. NYPA is now incorporating "sustainability" into all of its day-to-day activities. More on NYPA can be found on NYPA's official website [1].

[1] This project is part of the Joint Energy Storage Initiative between the New York State Energy Research and Development Authority (NYSERDA) and the Energy Storage Systems Program of the U.S. Department of Energy (DOE/ESS), and managed by Sandia National Laboratories (SNL).

About LIRR

The Long Island Rail Road or LIRR (often referred to as the "L-I-double-R") is a commuter rail system serving the length of Long Island, New York, United States. It is the busiest commuter railroad in North America, servicing around 81 million passengers each year, and the oldest US railroad still operating under its original name. There are 124 stations on the LIRR, and more than 700 miles (1100 km) of track [2] on its two lines to the two forks of the island and eight major branches. Each weekday, the LIRR provides more than 282,410 rides to customers [3]. It is publicly owned by the Metropolitan Transportation Authority, which has styled it MTA Long Island Rail Road. The LIRR was bought by the Metropolitan Transportation Authority in 1966, whose headquarter is placed in Manhattan, NY.

The MTA is a public benefit corporation responsible for public transportation in the U.S. state of New York. The MTA has the responsibility for developing and implementing a unified mass transportation policy for The New York metropolitan area, including New York City and the suburban counties of Dutchess, Nassau, Orange, Putnam, Rockland, Suffolk, and Westchester, all of which together are the "Transportation District". Its agencies serve 14.6 million people spread over 5,000 square miles (13,000 km²) from New York City through southeastern New York State (including Long Island and the lower Hudson Valley), and Connecticut. MTA agencies now move nearly 2.4 billion rail and bus customers a year [4].

The LIRR system is comprised of over 700 miles of track on 11 different branches, stretching from Montauk -- on the eastern tip of Long Island --to the refurbished Penn Station in the heart of Manhattan, approximately 120 miles away. Along the way, the LIRR serves 124 stations in Nassau, Suffolk, Queens, Brooklyn and Manhattan, providing service for some 82 million customers each year, taking them to and from jobs, homes, schools, sporting events, concerts, beaches, Broadway shows, and the multitude of other attractions around the New York metropolitan region. The LIRR operates 24-hours-a-day, 7-days-a-week, including all holidays, with service intervals varying by destination and time of day [3].

Figure 1. LIRR Rail Road Map [3]

Nearly 500 of the railroad's daily trains originate or terminate at Penn Station in Manhattan. Most of the remainder originate or terminate at Flatbush Avenue in Brooklyn, with a number of others originating or terminating at Hunterspoint Avenue and Long Island City in Queens. All of these terminals provide convenient connections to MTA New York City Transit subway service. All but one of the 11 branches pass through the important Jamaica hub, where customers may change trains to connect for other branches or terminals. Third-rail electric service is offered on the lines to Port Washington, Ronkonkoma, Babylon, Hempstead, Huntington, West Hempstead, Long Beach and Far Rockaway, and diesel service is provided on the lines to Oyster Bay, Port Jefferson, Montauk and Greenport.

Project Reasoning

The LIRR is in the process of upgrading its aging fleet with new AC drive trains and performing critical infrastructure assessments as part of its overall requirement to upgrade its railroad system to meet an ever increasing demand for commuter rail in the New York City and Long Island metropolitan regions. The assessment has shown that the new trains and the increased rail traffic presents two challenges for the traction power supply system:

Voltage levels need to be stabilized in order to minimize constraints on train power demands;
Substation capacities need to be upgraded to meet predicted power increases.

To meet these challenges, LIRR is planning to modernize and change the existing substation rectifiers with thyristor rectifiers, replace conventional third rail with aluminum and/or composite rail, built additional circuit breaker houses and substations. In addition to these conventional solutions, LIRR is exploring the possibility of incorporating energy storage systems throughout the system to meet the new demand and possibly avoid additional excessive energy cost and/or substation upgrades. Properly utilized, energy storage should reduce incremental peak power demands and stabilize voltage levels

Various energy storage systems have been evaluated, including the use of flywheels, batteries and electrochemical capacitor technology. New electrochemical capacitors, or so-called supercapacitors with high specific power and energy characteristics are well suited for hybrid traction systems to replace batteries or stand-alone storage systems. The shorter capacitor charging time represents a distinct advantage over batteries. However, several issues, including cycle life, charge/discharge duration and characteristics and hazardous material classifications need to be better understood and tested prior to adoption by the rail industry

A flywheel is a mechanical battery that uses an electric motor/generator to store energy by spinning a mass, and discharge energy by converting that rotational energy back electricity. Other than the material and physical differences from a chemical battery or supercapacitor, the life of the flywheel is not limited by the number of charge/discharge cycles it undergoes. It is also capable of producing high power output for medium term durations (1 –30 seconds), whereas a chemical battery is more suited to longer term cycles and a supercapacitor to shorter term cycles [5].

Flywheels have been developed for energy storage and power quality applications. The flywheel technology basics can be characterized as two general system design types. The first system is designed for low speed (1800 – 3600 rpm) operation, and consists of a high mass flywheel and optional power electronics for conversations between DC and AC voltages. The second type, the high-speed flywheel, can operate at speeds greater than 30,000 rpm, and relies on magnetic bearings, vacuum chambers and a permanent magnet motor/generator to provide high efficiency operation and high energy density storage capability.

A review of flywheel technologies and applications was performed to identify systems currently being manufactured for energy storage or power quality. Several companies were identified that offered medium speed/high mass and high-speed/low mass flywheel designs. One of the primary attractions to high-speed flywheels for the LIRR application is that they have a smaller footprint and provide more site flexibility for the rail properties which are often space limited. Locations, identified by LIRR as possible candidates for future flywheel installations, are usually within the LIRR existing infrastructure where space is at a premium, and physically smaller flywheel units of high-energy storage capacity are required. The high-speed flywheel system is also capable of being dispersed throughout a substation to utilize existing space; or be distributed around a station platform were space and loading is limited. Low-speed flywheels do not meet LIRR's long-term plan of implementing flywheels into their substations and later retrofitting them with higher capacity advanced flywheels as the technology improves.

The size of the commercial market for application similar to the one envisioned at LIRR is large, both within the New York City metropolitan area and throughout the world. Mass transportation continues to grow with increasing energy costs, traffic and the environmental challenges associated with vehicle usage. Railroad and subway system upgrades, particularly in metropolitan areas, are increasingly space constrained and peak demand charges for power are several reasons why the high-speed flywheel energy storage systems has broad market potential for rail line voltage support and peak shaving applications. Further insights to the high-speed flywheel market size in the State will be developed through and in parallel with the proposed demonstration Project.

Figure 2. The FEES Future Site Location

Project Objective

The project objective is to design, fabricate, install and evaluate a 2.5 MW Flywheel Energy Storage System (FESS) on the Long Island Rail Road (LIRR) Deer Park Station (north side of the tracks) to:

- regulate voltage on the West-End of Deer Park Station within 10% of the nominal voltage, subject to limitation of the device rating. The maximum output voltage shall not exceed 800 VDC in any condition, including nominal.
- demonstrate peak power shaving during train(s) acceleration,
- provide complete analysis and reporting on safety issues (such as harmonics, electromagnetic interference, flywheel failure, etc.),
- demonstrate the FESS technology viability and monitor the performance, characteristics, and benefits for a minimum period of 12 months,
- present an economic analysis of the installed system including an estimated cost/benefit ratio, and a plan to measure the actual cost/benefit ratio during the demonstration period.

Flywheel Energy System Storage Technical Requirements

The flywheel energy storage system should satisfy the following characteristics:

- Complete turnkey installation.
- High speed flywheel design.
- 2.5 MW continuous output for a minimum of 30 seconds.
- Rechargeable to full 2.5 MW in 30 seconds or less.
- Operating voltage is in the range of 500 VDC to 800 VDC.
- Response to train acceleration/breaking within 50 ms.

Control architecture to maintain operating setpoints despite voltage variations.
Modular design (independently operated units to sum up to 2.5 MW).
Units installed in a enclosure(s) suitable for trackside installation as well as relocation to other sites.
Embedded UPS for 24hr support for the control, vacuum and cooling systems.
Designed for a 20 year operating life
Capable of 10 charge/discharge cycles/hour over the life of the unit rated at 20 years
Capable of remotely monitoring the appropriate FESS data/parameters by a data acquisition system.

Project Participants

The FESS demonstration Project Team will be led NYPA and includes their customer, LIRR, plus an equipment supplier contractor to be determined through competitive bid. NYPA will be the overall project manager and be the prime contractor to NYSERDA. NYPA will issue a competitive solicitation for procurement of the FESS, including delivery, final connections, start-up and commissioning, as well as O&M and performance warrantee. Long Island RailRoad , a division of NY Metropolitan Transit Authority (MTA), is the customer/owner/operator of the unit. NYPA and LIRR jointly will be responsible for the project related civil and mechanical support services such as construction of the foundation for flywheel installation.

Project cofunding is provided by the US Department of Energy/New York State Energy Research Development Authority Energy Storage Initiative. Project data acquisition and storage will be performed by SANDIA National Labs.

NYPA

NYPA has extensive experience with the installation of a wide variety of distributed generation and energy storage projects. In 2000, NYPA took on the task of installing ten 44MW gas turbines in New York City within a one year time frame to offset expected utility demand shortages for the summer of 2001. NYPA was able to fulfill this mission: purchasing, installing and bringing up to full load all ten units on schedule.

Through one of the most active Distributed Energy Resources programs in the nation, NYPA has installed and is now operating twelve 200kW fuel cells. One of these fuel cells, in Yonkers, was the first in the world to operate on Anaerobic Digester Gas (ADG). NYPA has also installed eight additional ADG units at New York City facilities in partnership with the New York City Department of Environmental Protection and NYSERDA. A 250kW molten carbonate fuel cell was installed by NYPA at a New York State University campus in 2006.

In 2006 NYPA, working together with a variety of stakeholders, including NYSERDA and the DOE, initiated construction of a 1MW sodium sulfur battery energy storage project at a natural gas bus compression station owned and operated by Long Island Bus. The system will shift the electrical demand of the compressor station from peak to off peak utility demand periods. This project is in full operation since June, 2007. Additional activities of NYPA's Distributed Energy Resources program include:

Installation and operation of a 1MW flywheel energy storage system to provide voltage stability on a New York City subway dedicated third rail circuit.

Installation and operation of a large solar electric demonstration program, with 576kW of installed capacity at 19 sites.

Installation of two ADG and one natural gas powered 30kW microturbines.

Design development for several multi-megawatt landfill gas projects in NYS.

NYPA has a long and successful history of conducting joint programs with NYSERDA in the areas of distributed generation, energy utilization, renewables, electric transportation, etc. In addition to the fuel cell, battery energy storage, microturbine and landfill projects described above, NYPA and NYSERDA have teamed up to fund 60kW of Building Integrated Photovoltaics in New York City.

Technology Benefit and Cost Assessment

The performance of LIRR's train based traction equipment is dependent on voltage levels. At or above 500 volts the train power demand can be fully satisfied while below 400 volts no power can be delivered to the train. The function of how much power can be delivered to the train is linear between 400 and 500 volts, i.e. at 450 volts approximately 50% of the traction power demand can be satisfied. Trains operating with third rail voltages below 500 volts will have difficulty meeting schedules. As train volumes increase, this problem is exacerbated. New trains being acquired by LIRR have the ability to provide regenerative breaking energy to the third rail. However, until voltage support and energy storage capabilities are added LIRR is suppressing this regenerative breaking feature. In addition, the new trains have larger traction loads than the older fleet, causing increased voltage sags on the LIRR third rail.

LIRR is embarking upon three part plan to enhance their traction power system and reduce voltage sags:

- Replacing conventional third rail with composite and/or aluminum rail
- Adding Circuit Breaker Houses (CBH) and performing CBH upgrades to substations
- Construction of new substations.

In addition, LIRR is also seeking new, less costly voltage support technologies. In 2003, LIRR participated in New York City Transit's 1 MW flywheel demonstration project and was planning to install similar equipment as part of their plan to introduce a new fleet of trains equipped with regenerative breaking capabilities. Unfortunately, the flywheel manufacturer for that demonstration, Urenco, pulled out of the business. The NYCT project, however, showed that high speed flywheel can maintain constant voltage during peak hours.

In addition to voltage support, the FESS will be able to provide sufficient emergency power to allow a train loaded with passengers to get to the next station on the line in the event of a utility interruption.

The FESS will save LIRR and New York State taxpayer's money by cutting down on the number of substations that will be needed to meet the already started system expansion and increased train throughput between Long Island and Penn Station in New York City.

NYPA and LIRR will develop methodology for cost and benefit calculations, and conduct lifecycle cost benefit analyses. The analyses will encompass a range of values that may be encountered in similar voltage support applications within New York State and elsewhere. In this manner, the experience gained from this project will be leveraged to provide insight to the broader market potential of FESS technology.

References

[1] NYPA's official website: http://www.nypa.gov
[2] Wikipedia website: http://en.wikipedia.org/wiki/Long_Island_Rail_Road
[3] LIRR's official website: http://www.mta.info/lirr/
[4] MTA's official website: http://www.mta.info/mta/network.htm
[5] EPRI-DOE Handbook of Energy Storage for Transmission and Distribution Application, Technical ReportDecember 2003

Biographies Edvina Uzunovic received her B.S.E.E. degree from the University of Sarajevo in 1990. After professional positions in Sarajevo, she joined the Department of Electrical and Computer Engineering at the University of Waterloo as a graduate student in 1993, where she completed her M.A.Sc degree in 1995, and her Ph.D. in 2001. In 1999, she joined the New York Power Authority as a Research and Technology Development Engineer. Her areas of interest are high power electronics controllers, stability and control of ac/dc power systems. She was a member of NYPA led team during New York City Transit's 1 MW flywheel demonstration project.

Guy Sliker is the Program Manager for Distributed Energy Resources and Energy Utilization in the Research and Technology Development group of the New York Power Authority, the nation's largest state-owned power organization. Mr. Sliker has been working with distributed generation and renewable energy R&D fields for 15 years, primarily with public and private electric utility companies. At his current position at the New York Power Authority Mr. Sliker is responsible for the implementation of the company's distributed energy resource, renewable energy and hydrogen energy programs. In addition, Mr. Sliker is responsible for the long term operation of distributed generation projects throughout New York State. Mr. Sliker has a BA in Economics and an MS in Mechanical Engineering, both from the University of Massachusetts.