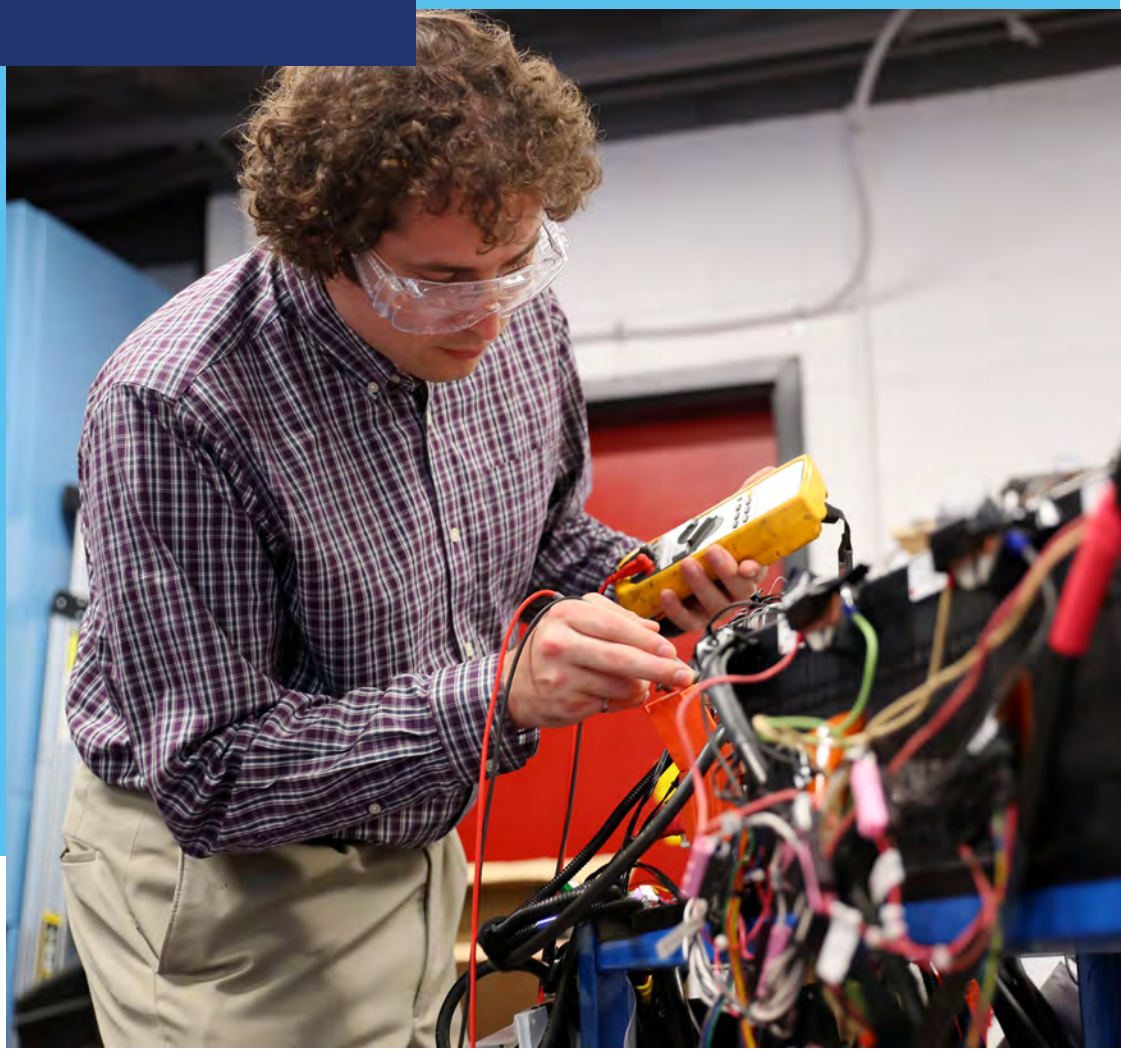
NSERC Energy Storage Technology Network

Year 2

Annual Report 2016-17



Ryerson University

Centre for Urban Energy

NSERC CRSNG

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1.0

INTRODUCTION

Ryerson University is proud to lead a five-year, $5 million pan-Canadian network of 15 universities and 26 industry and government partners focused on the future of energy storage (ES), an essential technology in the Canadian transition to clean energy.

Modern grid-scale ES is poised to transform the electricity system, bringing immense benefits to industries, utilities, governments and consumers. A confluence of factors is driving this surge of interest in Canada, including: advances in technology; environmental concerns leading to a renewed focus on renewable energy; aging electricity grid infrastructure that needs replacing; and the immense potential of smart grid systems that enable intelligent energy management.

Energy storage has been identified by the Natural Sciences and Engineering Research Council of Canada (NSERC) as a priority within its strategic target areas because Canada's capacity to store energy is currently seen as an underdeveloped component in its energy management capabilities. Early-stage Canadian companies and products are now entering a market that is on the verge of tremendous predicted growth with an international market opportunity estimated at $600 billion over 10 years according to Piper Jaffray (2009).

However, this global marketplace has multinational competition, and small and medium Canadian companies must be enabled to compete. A significant opportunity lies in positioning Canada to capitalize on the current momentum – similar to Denmark's capture of the first wave of the wind energy market – by developing a suite of technologies and systems to be commercialized by Canadian companies with trained, highly qualified personnel leading to employment and a robust economy.

The NSERC Energy Storage Technology Network (NESTNet) collaboratively explores many different types of ES, including flywheels, lithium-ion batteries and compressed air, while determining how best to integrate these technologies into electricity grids. In addition, researchers consider the implications arising from the increasing adoption of ES and how consumers will perceive, adopt and interact with these technologies. By partnering with the private sector, NESTNet enables directed progress – without duplication of efforts – towards a strong domestic Canadian ES industry that is also competitive in the global marketplace.

1.1 MISSION AND VISION

NESTNet's mission is to bring together leading academic, industry, utility and government stakeholders to develop, test, demonstrate and, ultimately, commercialize innovative ES technologies, products, processes and services through multidisciplinary and collaborative research and development.

To achieve its long-term vision of creating more reliable, environmentally friendly and efficient electric power systems, the network will work to increase the market penetration of Canadian-made ES technologies worldwide.

This mission and vision is directed at transformational change, and will be achieved by meeting goals critical to academic, public and private sector stakeholders over five years:

1. Generate fundamental ES knowledge.
2. Facilitate ES technology commercialization.
3. Train Canadian highly qualified personnel.
4. Strengthen and deepen existing research partnerships between Canadian organizations and academic researchers.

Mohamed Lachemi, President and Vice-Chancellor, Ryerson University.

1.2 MESSAGE FROM THE BOARD CHAIR

Welcome to the second annual report of NESTNet. Led with purpose by our inimitable network director Bala Venkatesh, the progress made in year one has gathered pace.

In January and February of 2017, NESTNet winter schools took place in Toronto, Waterloo and Ottawa. These workshops gave students invaluable opportunities to work directly with industry professionals on ES challenges. In year three, our winter schools will head to Montreal and Halifax.

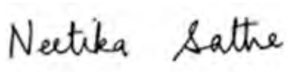
In April, the first Commercialization and Outreach Committee meeting took place. This group will help bring the network's innovative technologies – for which patents are already being filed – to market.

The reputation of the network now reaches beyond Canada. In May, I was invited to speak about the network at Smart Energy Systems Week in Vienna, Austria. During NESTNet Week in June, students and researchers from the U.K. travelled to Toronto to collaborate with their Canadian counterparts and share best practices.

As part of NESTNet Week, I had the pleasure of attending the Leading the Charge conference which brought together ES enthusiasts from many organizations across the industry. I also had the privilege of moderating a panel session encapsulating in microcosm the work of the network: government, utilities and technology providers convening to debate, discuss and deliver practical ES solutions that will ultimately benefit society.

I would like to applaud all of the research teams – made up of almost 100 undergraduate and postgraduate students – at universities across Canada for their outstanding work this year. I would also like to thank all of NESTNet's partners for their unwavering support for the network.

You are all contributing immeasurably to the success of the network and therefore playing an integral role in meeting today's energy and climate challenges head on.



Neetika Sathe
Vice President, Advanced Planning, Alectra Inc.

1.3 MESSAGE FROM THE NETWORK DIRECTOR

Building on the solid foundations laid in year one, I am delighted to say that the second year of NESTNet has seen it go from strength to strength. Year two has surpassed its annual targets and delivered significant progress on some far-reaching research projects. The network has also begun to build a global reputation, allowing us to bring together Canadian international ES experts with their international counterparts.

There have been a few changes this year to complement NESTNet's leadership and oversight committees. Steven Liss, the recently installed vice-president of research and innovation at Ryerson University, has joined the Board of Directors. Tom Chapman, senior manager of market design and development at Ontario's Independent Electricity System Operator, has moved from the Research Steering Committee to the Board of Directors. Christopher Jones, the acting director of the University of Sheffield's Centre for Doctoral Training in ES and its Applications, has joined the Research Steering Committee all the way from the U.K. Finally, Carmine Pizzurro, president of lithium-ion battery manufacturer eCAMION, Adam Tuck, program leader, ES for grid security and modernization at the National Research Council Canada, and Gary Thompson, lead, generation planning and system studies at Toronto Hydro, have joined the Commercialization and Outreach Committee. I warmly welcome these new additions who bring decades of experience and a wealth of expertise that will prove invaluable over the coming years.

In June of 2017, Ryerson University hosted a week of NESTNet events that brought together all the key stakeholders in the future of Canadian ES. Well over 100 people attended the week, which included a two-day summer school, a two-day technical conference and a one-day public conference, entitled Leading the Charge, which aimed to engage and inspire the wider community in ES matters. I was honoured to welcome a delegation from the U.K., including the aforementioned Chris Jones, a professor in psychology who spoke at the technical conference about the public attitudes towards large-scale ES technologies and the implications for planning policy.

Leading the Charge featured some lively panel discussions as well as keynote speeches from the Hon. Glen Murray, Ontario's minister of the environment and climate change, Bob Delaney, parliamentary assistant to the Ontario's minister of energy, and Mark Henderson, senior vice-president of energy solutions and services at Alectra, the second largest municipally owned utility in North America. A special thanks must also go to panelists Michel Losier, executive director of energy efficiency and customer engagement at NB Power, and Robert Wilhite, managing director of Navigant, who joined us from Fredericton, N.B. and Charlotte, N.C. respectively. We plan to invite more industry leaders from right across Canada and the United States to next year's event.

This network was set up as a collaborative and multidisciplinary endeavour and on that front I am excited to see project leaders collaborating more extensively with each other and our industry partners, as well as looking to best practices and expertise from overseas. This approach is delivering tangible results. Two projects are now completed: projects 1.6 (Design of a Pole-Top ES System) and 3.2 (Optimal Planning for ES in Distribution Systems Considering Feeder Investment Models). Two patents are filed or in progress: projects 1.6 and 2.1 (Modular Architecture and Functionality of ES Power Converter). There have been 25 journal and 32 conference papers published. Finally, the network has exceeded its annual target for training of highly qualified personnel: 90 versus 52.

I would like to thank everyone who has played their part in making year two such a success, including the esteemed theme leaders Miguel Anjos, Claudio Cañizares, Liuchen Chang and Handan Tezel; our board of directors and committee members; the 24 university research teams; our 26 industry and government partners; and NSERC. Last but not least, I would like to pay tribute to my colleagues at Ryerson – especially the network administrator Karen Ho-Cespedes – who have worked tirelessly to ensure the smooth running of the network and its numerous events and workshops.

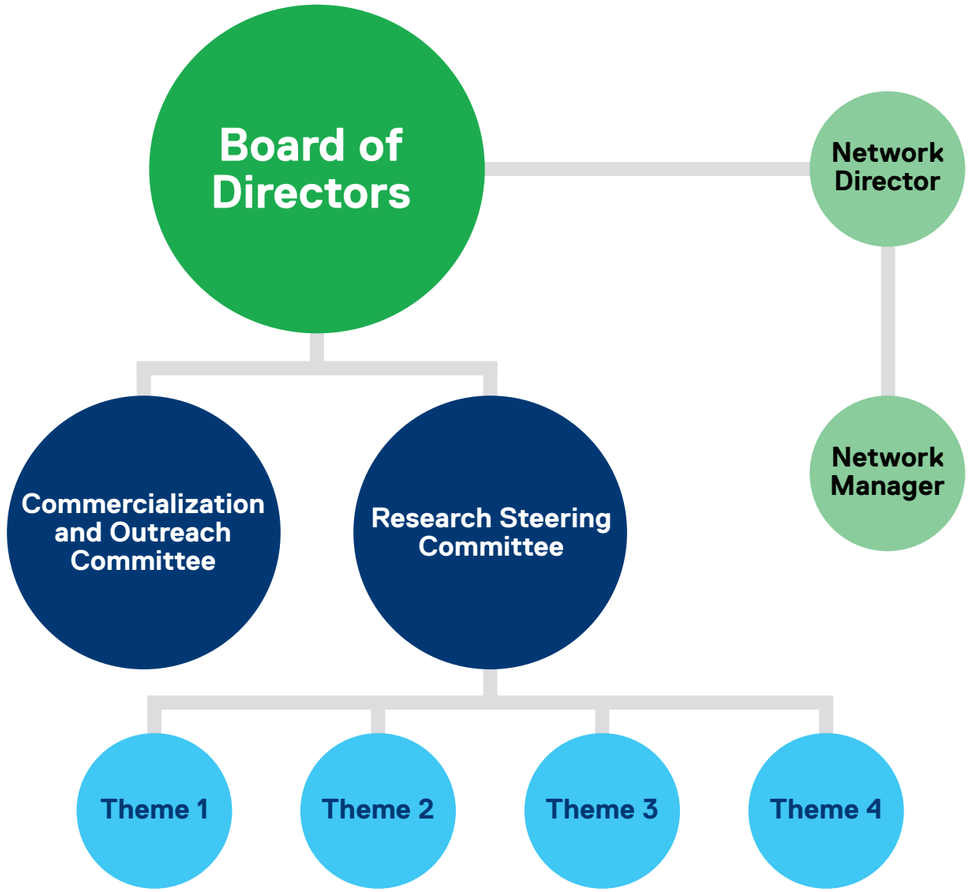
I look forward with anticipation to year three.

Bala Venkatesh

2.0 NETWORK INFORMATION

2.1 GOVERNANCE

FIGURE 1: Governance Structure



As the network director, Bala Venkatesh coordinates network affairs and leads the overall implementation of project activities through his participation in research, dissemination and training of highly qualified personnel (HQP).

As the network manager, Karen Ho-Cespedes ensures the day-to-day operations of the network and supports the network director and the Research Steering Committee (RSC) in all responsibilities related to the network, including strategic planning and managing relationships.

The Board of Directors has overall responsibility for the governance of the network. It is comprised of the network director, representatives of network partners and independent representatives from academia, industry and government. Chaired by Neetika Sathe, the board provides strategic guidance, counsel and foresight, and administrative and financial guidance. The board oversees the NESTNet activities and approves the annual budget.

The research activities of the network are organized into four themes and led by Handan Tezel, Liuchen Chang, Claudio Cañizares and Miguel Anjos. The theme leaders are responsible for overseeing each theme's research projects and evaluating HQP research activities.

Board of Directors. Left to right: Eric Deschenes, vice-president, energy division, Schneider Electric Canada; Karen Ho-Cespedes, network manager; Claire McAneney, NSERC manager; Tom Chapman, senior manager, market design and development, Independent Electricity System Operator; Bala Venkatesh, network director; Sundar Venkataraman, director, GE Energy Consulting; Ken Nakahara, director, energy networks and partnerships, Ontario Ministry of Energy; Liuchen Chang, professor, Department of Electrical and Computer Engineering, University of New Brunswick; Steven Liss, vice-president, research and innovation, Ryerson University; Neetika Sathe, vice president, advanced planning, Alectra Inc. (Chair).

The RSC is comprised of the network director, theme leaders, partner representatives, and external academic experts to provide leadership and vision on the review and assessment of ongoing NESTNet research projects.

The purpose of the Commercialization and Outreach Committee (COC) is to identify potential technologies and intellectual property (IP) developed by network researchers for commercialization opportunities. The COC will be managing the technologies, focusing on technology transfer and commercialization, enabling and expediting demonstration opportunities, and promoting ES to the public.

Karen Ho-Cespedes, network manager, is a non-voting member of all committees.

Research Steering Committee. Left to right: Pratap Revuru, smart grid solution architect, Schneider Electric Canada; Claudio Cañizares, associate director, Waterloo Institute for Sustainable Energy; Bala Venkatesh, network director; Liuchen Chang, professor, Department of Electrical and Computer Engineering, University of New Brunswick; Handan Tezel, professor, Department of Chemical and Biological Engineering, University of Ottawa; Karen Ho-Cespedes, network manager; Miguel Anjos, Professor and Canada Research Chair, École Polytechnique de Montréal; Christopher Jones, acting director, Centre for Doctoral Training in Energy Storage and its Applications, University of Sheffield; Usman Syed, director, conservation and energy efficiency, Ontario Ministry of Energy; Adam Tuck, program leader, energy storage for grid security and modernization, NRC.

2.2 BOARD OF DIRECTORS

Neetika Sathe
Vice President, Advanced Planning, Alectra Inc. (Chair)

Bala Venkatesh
Academic Director, Centre for Urban Energy; Professor, Electrical and Computer Engineering, Ryerson University
(Network Director)

Jessica Bian
Technical Staff, Federal Energy Regulatory Commission

Liuchen Chang
Professor, Department of Electrical and Computer Engineering, University of New Brunswick
(Theme 2 Leader)

Tom Chapman
Senior Manager, Market Design and Development, Independent Electricity System Operator

Eric Deschenes
Vice-President, Energy Division, Schneider Electric Canada

Brian Hewson
Senior Manager, Strategic Policy, Ontario Energy Board

Steven Liss
Vice-President, Research and Innovation, Ryerson University

Ken Nakahara
Director, Energy Networks and Partnerships, Ontario Ministry of Energy

Sundar Venkataraman
Director, GE Energy Consulting

Claire McAneney
Manager, NSERC
(Non-Voting)

Karen Ho-Cespedes
Network Manager
(Non-Voting)

2.3 RESEARCH STEERING COMMITTEE

Bala Venkatesh
Academic Director, Centre for Urban Energy; Professor, Electrical and Computer Engineering, Ryerson University
(Network Director)

Handan Tezel
Professor, Department of Chemical and Biological Engineering, University of Ottawa
(Theme 1 Leader)

Liuchen Chang
Professor, Department of Electrical and Computer Engineering, University of New Brunswick
(Theme 2 Leader)

Claudio Cañizares
Associate Director, Waterloo Institute for Sustainable Energy
(Theme 3 Leader)

Miguel Anjos
Professor and Canada Research Chair, École Polytechnique de Montréal; Inria International Chair
(Theme 4 Leader)

Christopher Jones
Acting Director, Centre for Doctoral Training in Energy Storage and its Applications, University of Sheffield

Mohamed El-Hawary
Professor, Dalhousie University

Peter Hall
Professor, Energy Storage Engineering, University of Sheffield

Nelson Martins
Assistant to Director General and Research Consultant on Power System Analysis, Electrical Energy Research Center

Pratap Revuru
Smart Grid Solution Architect, Schneider Electric Canada

Usman Syed
Director, Conservation and Energy Efficiency, Ontario Ministry of Energy

Adam Tuck
Program Leader, Energy Storage for Grid Security and Modernization, National Research Council Canada

2.4 COMMERCIALIZATION AND OUTREACH COMMITTEE

Bala Venkatesh
Academic Director, Centre for Urban Energy; Professor, Electrical and Computer Engineering, Ryerson University
(Network Director)

Jennifer MacInnis
Senior Legal Counsel and Senior Director, Applied Research and Commercialization, Ryerson University

Geoff Osborne
Associate, NRStor

Carmine Pizzurro
President and CTO, eCAMION Inc.

Pratap Revuru
Smart Grid Solution Architect, Schneider Electric Canada

Hari Subramaniam
President, Carousel Development

Gary Thompson
Lead, Generation Planning and System Studies Engineering and Investment Planning, Toronto Hydro

Adam Tuck
Program Leader, Energy Storage for Grid Security and Modernization, National Research Council Canada

2.5 ACADEMIC PARTNERS

There are a total of 27 researchers from 15 universities across Canada participating in NESTNet.

FIGURE 2: University Locations

2.6 INDUSTRY AND GOVERNMENT PARTNERS

There are a total of 12 industrial, utility and government partners participating in NESTNet.

2.7 INDUSTRY AND GOVERNMENT ASSOCIATE MEMBERS

There are a total of 13 industrial, utility and government associate members and collaborators participating in NESTNet.

No logo included for one additional collaborator, Cowessess First Nation.


Project 4.6 – Social Acceptance of ES Systems
NSERC Energy Storage Technology Network

3.1 BY THE NUMBERS

NESTNet is committed to training the next generation to power the future of Canadian Energy Storage. During the second year of research, 90 highly qualified personnel (HQP) worked with NESTNet project leaders.

TABLE 1: Total HQP in Year Two

13	30	28	19
Postdoctoral fellows	**PhD students**	**MSc students**	**Undergraduate students**

TABLE 2: HQP by Theme in Year Two

20	22	25.5	22.5
Theme 1	**Theme 2**	**Theme 3**	**Theme 4**

In addition, NESTNet produced 25 journal articles, 32 conference papers and two patents (filed or in progress) through year two.

TABLE 3: Year Two Outputs	Theme 1	Theme 2	Theme 3	Theme 4	**Total**
Journal articles	9	4	7	5	**25**
Conference papers	15	10	5	2	**32**
Patents	1	1	0	0	**2**

3.2 FINANCES

For year two, NSERC provided a cash contribution of $996,200 to NESTNet. Partners (university and industry/government) provided a cash contribution of $943,353 over a 21-month period. These funds covered expenses related to network research projects across themes 1 to 4, as well costs associated with management of the network, hosting of NESTNet events, and internal and external communication and dissemination (central activities).

TABLE 4: Year Two NSERC Funding	Prorated budget (9 months)	Expenses (9 months)
Theme 1	$191,625	$240,483
Theme 2	$167,625	$201,379
Theme 3	$155,625	$214,583
Theme 4	$202,125	$238,050
Total: four research themes	$717,000	$894,495
Central activities	$60,900	$57,446
Total	**$777,900**	**$951,941**

TABLE 5: Year Two Industry / Government Partner Contributions	Prorated budget (9 months)	Expenses (9 months)
Theme 1	$172,397	$132,981
Theme 2	$0	$0
Theme 3	$202,500	$155,371
Theme 4	$0	$0
Total: four research themes	$374,897	$288,352
Central activities	$3,750	$0
Total	**$378,647**	**$288,352**

4.0 PROJECT THEMES AND HIGHLIGHTS

The 24 projects across four research themes comprising NESTNet are detailed in this section.

4.1 THEME 1 PROJECTS AND HIGHLIGHTS

Theme Leader: Handan Tezel, University of Ottawa

In this theme, research is focused on batteries (thermal management systems and innovative housing designs), flywheels (designs and modelling), compressed air energy storage (CAES) (underwater designs and operation), thermal storage (materials and system designs), and hybrid ES models.

Theme 1 at the Annual Technical Conference, June 22, 2017, including Pierre Mertiny (left), Handan Tezel (centre) and Bala Venkatesh (right).

Theme 1: Energy Storage Technologies

Project 1.1

Hybrid Multi-Level Grid-Scale Battery Thermal Management System

Project 1.2

Fabrication, Mathematical Modelling, Design and Testing of Flywheels for Grid-Scale ES

Project 1.3

Design and Testing of an Innovative Energy Accumulator for Underwater Compressed Air Energy Storage

Project 1.4

Thermal ES in Adsorbent Beds for Space Heating and Cooling

Project 1.5

Hybrid ES System Designs

Project 1.6

Design of Pole-Top ES

Project 1.1 – Hybrid Multi-Level Grid-Scale Battery Thermal Management System

Project Description: This project aims to develop a novel and custom-designed BTMS solution for thermal management of large-scale battery systems for grid applications that can maintain the temperature of the batteries within the recommended range under various loads and climate conditions. The BTMS should be compact, cost-effective, and reliable with minimal maintenance and packaging requirements. It must also promise low parasitic power requirements and be able to operate under variable climatic conditions.

Progress: The design of the cell-level thermal management system has begun. Battery characterization tests have been completed. The project team has studied heat performance of the battery, and designed, optimized and tested a cooling system at the cell level. Publications: 1 journal paper, 3 conference papers.

Project Leader:
Majid Bahrami, Simon Fraser University

Project Collaborators:
Handan Tezel, University of Ottawa
Liuchen Chang, University of New Brunswick

Highly Qualified Personnel:
Mehran Ahmadi (Postdoctoral fellow)
Martin Cermak (PhD)
Mina Rouhani (PhD)
Jason Wallace (Undergraduate)
Jerry Liu (Undergraduate)

Project 1.2 – Fabrication, Mathematical Modelling, Design and Testing of Flywheels for Grid-Scale ES

Project description: This project aims to develop mathematical models of flywheel systems considering energy losses, discrete design variables, rotor dynamic effects and novel material systems. A flywheel system with an energy capacity of 0.25 kWh will be fabricated, characterized and tested to validate and optimize models.

Progress: A flywheel testing enclosure has been constructed. Development of a composite flywheel system for 0.25 kWh has commenced. A flywheel numerical model and a comparative analysis of composite and metal flywheels were developed. Fabrication and testing of composite flywheel demonstrator are completed. Publications: 1 journal paper, 2 conference papers.

Project Leader:
Marc Secanell Gallart, University of Alberta

Project Collaborators:
Pierre Mertiny, University of Alberta
Liuchen Chang, University of New Brunswick
Magdy Salama, University of Waterloo

Highly Qualified Personnel:
Miles Skinner (MASc)
Vaishnavi Kale (MASc)

Project 1.3 – Design and Testing of an Innovative Energy Accumulator for Underwater Compressed Air Energy Storage (CAES)

Project Description: Research will focus on the development and testing of an innovatively simple and robust energy accumulator architecture based ultimately on prefabricated pipe elements. The experimental program will explore the fabrication, installation, operation, and recovery of this accumulator design.

Progress: The project team has completed Phase 1 of the Multiphase OpenFOAM model design and conducted first-ever Advanced Exergy Analysis on the underwater CAES. This research has begun collaborations with Claudio Cañizares of the University of Waterloo. Publications: 2 journal papers, 1 conference paper.

Project Leader:
Rupp Carriveau, University of Windsor

Project Collaborators:
David Ting, University of Windsor
Handan Tezel, University of Ottawa
Mark Winfield, York University
Ian Rowlands, University of Waterloo

Highly Qualified Personnel:
Maziar Mosavati (PhD)
Sara Alhasan (MASc)

Project 1.4 – Thermal ES in Adsorbent Beds for Space Heating and Cooling

Project Description: In this project, promising new adsorbent materials will be examined, modelled and optimized to increase energy density (by four to five times greater than current materials) in order to improve the economic viability of adsorption-based systems for space heating and cooling applications.

Progress: The experimental system has completed setup, testing and upgrading to include cooling experiments. Coding for modelling of the system has begun. Publications: 2 journal papers, 8 conference papers.

Project Leader:
Handan Tezel, University of Ottawa

Project Collaborators:
Tariq Iqbal, Memorial University
Miguel Anjos, École Polytechnique de Montréal
Majid Bahrami, Simon Fraser University

Highly Qualified Personnel:
Ye Hua (Postdoctoral fellow)
Tatum Alenko (MASc)
Amanda Godin (Undergraduate)
Elizabeth Miller (Undergraduate)
Michelle Denis (Undergraduate)

Project 1.5 – Hybrid ES System Designs

Project Description: This research aims to develop hybrid ES systems, where several types and sizes of ES systems are combined to provide a composite storage solution. The first objective is to develop an optimization solution that provides the optimal hybrid design of an ES system that combines two or more storage elements to provide certain performance metrics and features at the lowest cost, and with the longest life and highest reliability. The second objective of this research is to develop scheduling methods for the developed hybrid systems to deliver the required services, while maximizing asset life.

Progress: Analysis of various ES elements to determine their dynamic characteristics and development of mathematical models for the optimal design of the hybrid ES system have been completed.

Project Leader:
Bala Venkatesh, Ryerson University

Project Collaborators:
Bin Wu, Ryerson University
Reza Iravani, University of Toronto

Highly Qualified Personnel
Amr Adel (PhD)
Ayman Elkasrawy (PhD)
Kamran Masteri Farahani (PhD)
Christma Fernando (Undergraduate)

Project 1.6 – Design of Pole-Top ES

Project Description: Development and testing (both in the laboratory and in the partnering utility) of an ES solution that can be mounted on the utility pole, adjacent to pole-top transformers. The pole-top ES solution is housed in a cabinet containing the power converter and with lithium-ion batteries.

Progress: The two-year project has been completed. Results show acceptable performance of the unit for load curve smoothing and peak shaving of the distribution transformer. Installation of the unit on a Toronto Hydro utility pole was completed in August 2016 and successfully field tested until February 2017. Publications/patents: 3 journal papers, 1 conference paper, 1 patent in progress.

Project Leader:
Bala Venkatesh, Ryerson University

Project Collaborators:
Bin Wu, Ryerson University
David Xu, Ryerson University
Majid Bahrami, Simon Fraser University

Highly Qualified Personnel:
Mohamed Awadallah (Postdoctoral fellow)
Guilherme Mateus Franke (Undergraduate)

4.2 THEME 2 PROJECTS AND HIGHLIGHTS

Theme Leader: Liuchen Chang, University of New Brunswick

Research in this theme focuses on power electronic converters, including modular converters, digital controllers, supervisory controllers, supervisory control and data acquisition (SCADA) systems, and power electronics for repurposed electric vehicle batteries.

Theme 2 at the Annual Technical Conference, June 22, 2017, including Liuchen Chang (second from left), Tariq Iqbal (fourth from right) and Vijay Sood (third from right).

Theme 2: Power Electronics Converters

Project 2.1

Modular Architecture and Functionality of ES Power Converter

Project 2.2

Digital Control Systems of Power Converters for ES

Project 2.3

Coordinated Operation of Multiple Storage Units and Technologies

Project 2.4

SCADA Interface for ES Systems

Project 2.5

Control Systems for Second-Life Batteries for Grid-Scale ES

Project 2.1 – Modular Architecture and Functionality of ES Power Converters

Project Description: The objectives of this project are to 1) develop advanced power converter architectures for ES systems (battery and flywheel systems, etc.) with modular design, bi-directional power flow and embedded fault diagnosis algorithms, and 2) to develop enhanced grid support functions for power system operation (such as anti-islanding, voltage support, real power control, and black start, etc.).

Progress: The project team started investigating grid support functions of smart inverters for ES systems and completed onboard fault diagnosis algorithms to detect open circuit faults without additional voltage and current sensors. They have also completed power converter control algorithms and developed a communication module and tested it with a photovoltaic (PV) power converter. Collaborations began with WEICan and Vijay Sood, University of Ontario Institute of Technology (UOIT). Work has begun on modular inverter for ES. Publications/patents: 2 journal papers, 3 conference papers, 1 U.S. provisional patent filing.

Project Leader:
Liuchen Chang, University of New Brunswick

Project Collaborators:
David Xu, Ryerson University
Vijay Sood, UOIT
Saleh Saleh, University of New Brunswick
Bala Venkatesh, Ryerson University

Highly Qualified Personnel:
Xin Zhao (Postdoctoral fellow)
Guanhong Song (PhD)
Shuang Xu (PhD)
Katelin Spence (MASc candidate)
Majed Abdullah Shakir (Undergraduate)

Project 2.2 – Digital Control Systems of Power Converters for ES

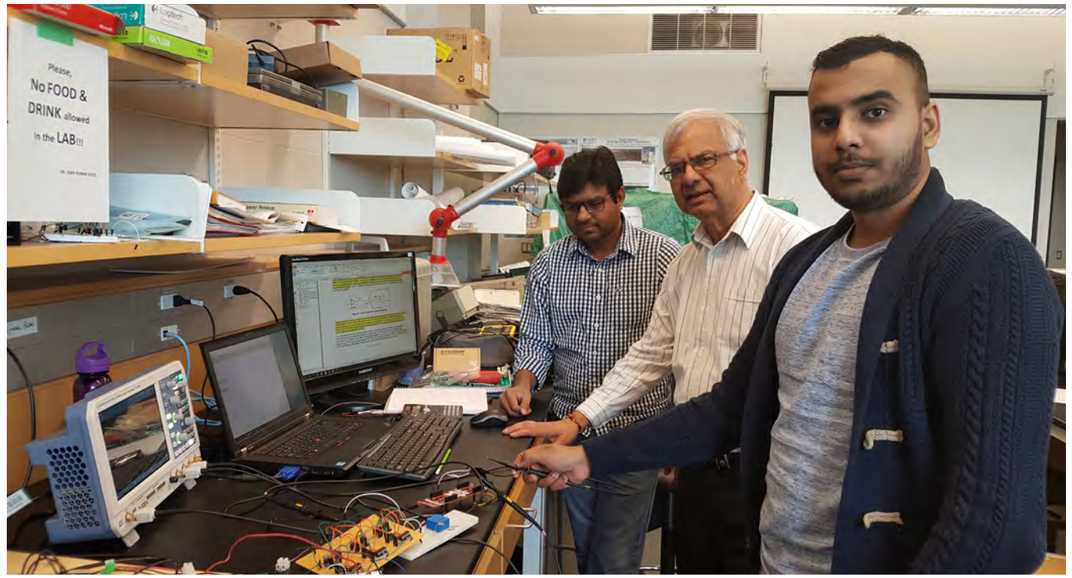
Project Description: The objectives of this project are to develop advanced digital control systems for power converters in ES applications, including fully digital control hardware and software; an upper-level energy management controller; and a communication system.

Progress: The project team is in the process of developing a digital controller based on TI Microcontroller F28069M Launchpad kit for a three-phase inverter and a control system.

Project Leader:
Vijay Sood, UOIT

Project Collaborators:
David Xu, Ryerson University
Tariq Iqbal, Memorial University
Liuchen Chang, University of New Brunswick

Highly Qualified Personnel:
Jigneshkumar Patel (PhD)
Mohammed Yasin Ali (Undergraduate)



Project 2.2, including Vijay Sood (centre).

Project 2.3 – Coordinated Operation of Multiple Storage Units and Technologies

Project Description: This project aims to develop supervisory-control and protection strategies and algorithms for 1) heterogeneous storage systems (i.e. battery and flywheel sub-units) and 2) for homogeneous storage systems (i.e. multiple battery storage units). The envisioned development serves as the interface between the utility command signals (Theme 3) and the required ES units' controls/operation (Projects 2.1 and 2.2), considering requirements of end users (Project 1.5).

Progress: The project team developed and is currently evaluating the developed system model under various faults and switching conditions in simulation in PSCAD. A study system for coordinated operation of multiple batteries with multi-microgrids and a microgrid simulation system for the application of battery and flywheel for autonomous microgrids have been established. Publications: 1 book, 1 journal paper and 1 conference paper.

Project Leader:
Reza Iravani, University of Toronto

Project Collaborators:
Liuchen Chang, University of New Brunswick
Vijay Sood, University of Ontario Institute of Technology
Amir Yazdani, Ryerson University

Highly Qualified Personnel:
Arman Ghasemi (PhD)
Sherif Helmy (PhD)
Mostafa Mohsen (PhD)
Hoda Youssef (MASc)
Mojtaba Ashourloo (MASc)
Zhi Zhong (Undergraduate)

Project 2.4 – SCADA Interface for ES Systems

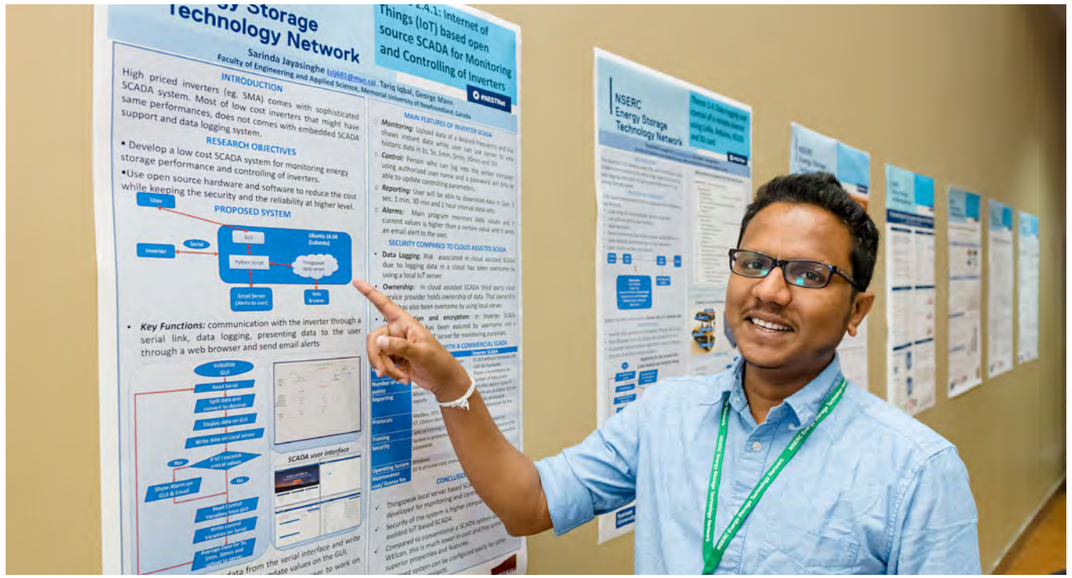
Project Description: Research aims to develop an innovative SCADA interface for smart grids that enables remote control of grid-tied converters for ES, and facilitates control and communication methods.

Progress: Design of a low-cost SCADA system based on internet of things (IoT) technology has been completed. The project team also demonstrated remote control and data logging of an inverter. A design of a SCADA system based on local open source server was demonstrated. Collaborations began with WEICan. Publications: 4 conference papers.

Project Leader:
Tariq Iqbal, Memorial University

Project Collaborators:
Liuchen Chang, University of New Brunswick
Vijay Sood, UOIT
Reza Iravani, University of Toronto

Highly Qualified Personnel:
Sarinda Jayasinghe (MASc)
Terashimla Kublathara (MASc)



Sarinda Jayasinghe, Memorial University, during poster session at the Technical Conference.

Project 2.5 – Control Systems for Second-Life Batteries for Grid-Scale ES

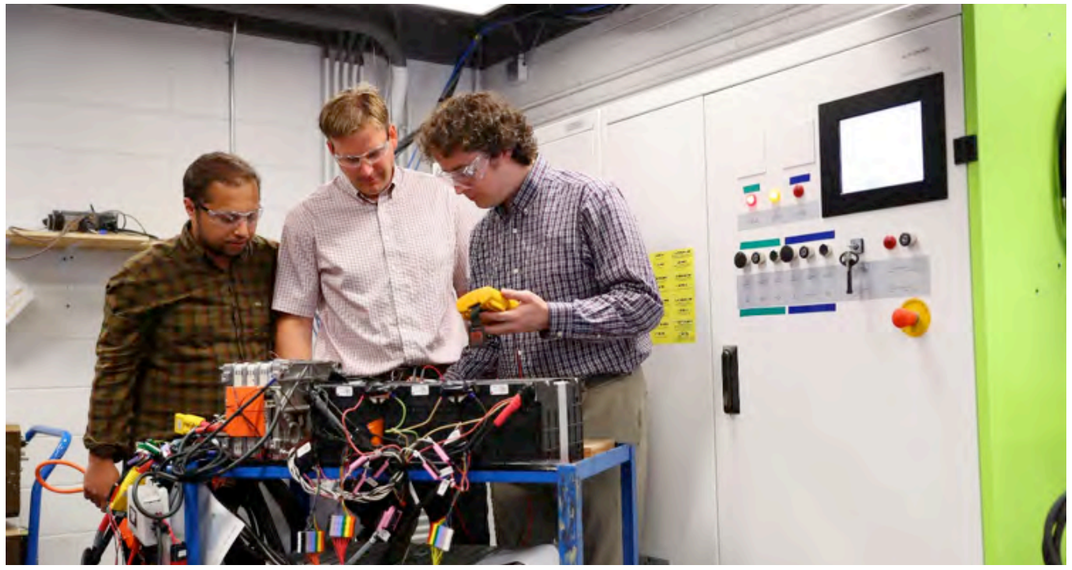
Project Description: A new concept is to repurpose various electric vehicle (EV) batteries by separately connecting them to a multi-channel power converter, which is able to handle various used batteries of differing capabilities. With this project, the principal research objective is to develop a new control strategy to utilize the best EV battery packs depending upon the specific electricity grid service requirements. New map matrix has been created for each of three battery types (LMO, NMC, NCA), two pack types (high power, high voltage), and the range of PNNL test standards for grid storage services.

Progress: The project team completed a mixed battery array concept and acquired a thermal chamber for the safe testing of batteries. They also acquired training and batteries for testing, began advanced testing of batteries (i.e. baseline performance testing of different batteries); and added a new high-power cycler and water cooling system to batteries. Publications: 2 conference papers.

Project Leader:
Lukas Swan, Dalhousie University

Project Collaborators:
Vijay Sood, UOIT
Tariq Iqbal, Memorial University
Saleh Saleh, University of New Brunswick

Highly Qualified Personnel:
Nathaniel Pearre (Postdoctoral fellow)
Blenson Paul (PhD)
Ben Thompson (MASc)
Bryan Ellis (Undergraduate)
Chad LeRue (Undergraduate)
Cohen Poirier (Undergraduate)



Left to right: *Blenson Paul; Lukas Swan; Ben Thompson.*

4.3 THEME 3 PROJECTS AND HIGHLIGHTS

Theme Leader: Claudio Cañizares, University of Waterloo

Research in this theme will enable the seamless integration of energy storage into power systems by developing planning tools, operational tools, protection systems, power quality mitigation solutions, and reliability benchmarks.

Theme 3 at the Annual Technical Conference, June 22, 2017, including Bala Venkatesh (left) and Rajesh Karki (second from left).

Theme 3: Power Systems Integration

Project 3.1

Optimal Planning for ES Facilities in Transmission Systems

Project 3.2

Optimal Planning of ES in Distribution Systems Considering Feeder Investment Model

Project 3.3

ES Device Protection

Project 3.4

Integration of ES for Improving Power Quality (PQ) of Smart Distribution Systems

Project 3.5

Operation and Control of Power Systems with ES Systems

Project 3.6

Reliability Modelling and Assessment of Power Systems with ES Systems

Project 3.7

Integration of ES for Improving Power Quality of Smart Distribution Systems

Project 3.1 – Optimal Planning for ES Facilities in Transmission Systems

Project Description: Deterministic co-optimization models will be built for sizing and siting of ES facilities, considering many services and technologies. The models will be built for both utility-owned ES facilities as well as investor-owned merchant facilities. The deterministic models will then be extended to include sources of uncertainty in power systems operation and planning. Stochastic versions of the deterministic models will be developed using techniques such as robust optimization or approximate chance-constrained optimization that make use of convexity and hence can be solved efficiently.

Progress: The project team is currently creating a model for co-simulation optimization with an ES model and working on the deterministic model for ES planning. Also, a literature review of ES technologies was completed. Publications: 2 journal papers, 1 conference paper, and 1 tutorial.

Project Leader:
Hamid Zareipour, University of Calgary

Project Collaborators:
Miguel Anjos, École Polytechnique de Montréal
Amit Kumar, University of Alberta
William Rosehart, University of Calgary
Andrew Knight, University of Calgary
Patrice Marcotte, Université de Montréal

Highly Qualified Personnel:
Ahmed Chaouachi (PhD)
Ehsan Nasrolahpour (PhD)
Juan A. Gomez (PhD)
Shubhrajit Bhattacharjee (PhD)
Benjamin Thomas (Undergraduate)

Project 3.2 – Optimal Planning of ES in Distribution Systems Considering Feeder Investment Model

Project Description: Research will focus on the development of a new algorithm for the feeder investment model for distribution systems, including optimal location and size of ES systems. The algorithm will ensure that all customer loads and renewables are fully connected and reliably serviced over the plan period. The algorithm will minimize the annual amortized cost of investment for the utility considering both purchases of feeders and ES units.

Progress: The two-year project has been completed and includes feeder investment model for distribution systems analysis; study of battery ES system (BESS) and its market price projections; feeding investment model with BESS. Publications: 2 journal papers, 3 technical reports.

Project Leader:
Bala Venkatesh, Ryerson University

Project Collaborators:
Bob Singh, Ryerson University
Claudio Cañizares, University of Waterloo
Amit Kumar, University of Alberta

Highly Qualified Personnel:
Peng Yu (Postdoctoral fellow)
Jonathan Nikodem (Undergraduate)
Michael Santorelli (Undergraduate)
Sara Azimi (Undergraduate)

Project 3.3 – ES Device Protection

Project Description: This research will develop and test new protection architectures for ES systems, digitally implemented to be embedded within the main ES systems controller. This architecture is required for development of fault detection and classification methods based on signature extraction, rather than magnitudes of voltages or currents. The desired fault detection and classification methods will be based on processing current signals obtained from the main ES system controller to facilitate full embedding.

Progress: The project team is implementing the phaselet filter bank to process currents collected from lab-scale 5 kW storage system and testing the responses of the developed phaselet-based protection for different types of storage systems. They have completed selection of wavelet and phaselet basic functions that generate filter banks to process currents for fault detection. Publications: 1 journal paper, 3 conference papers.

Project Leader:
Saleh Saleh, University of New Brunswick

Project Collaborators:
Eduardo Castillo Guerra, University of New Brunswick
Liuchen Chang, University of New Brunswick
Reza Iravani, University of Toronto

Highly Qualified Personnel:
Christiane Richard (MASc)
Ryan McSheffery (MASc)
Ryan Meng (MASc)

Project 3.4 – Integration of ES for Improving Power Quality of Smart Distribution Systems

Project Description: Research will develop novel solutions to overcome PQ issues (due to switching, load cycling or intermittency of renewables) using ES systems. Another goal is to study the impact of integrating different ES technologies (dedicated for grid-related PQ issues) on smart grid; under low- or high-loading conditions.

Progress: The project team is preparing a comprehensive list of PQ problems that could be mitigated by specific ES technologies, as well as ES modelling techniques. Also, researchers have begun development of the required methodologies to incorporate the ES-developed model and to assess the effect of ES integration on power quality problems and indices. Publications: 2 journal papers.

Project Leader:
Magdy Salama, University of Waterloo

Project Collaborators:
Tarek El-Fouly, CanmetENERGY and University of Waterloo
Saleh Saleh, University of New Brunswick
Liuchen Chang, University of New Brunswick
Ahmed Awad, CanmetENERGY
Mohamed Ahmed, SNC-Lavalin and University of Waterloo

Highly Qualified Personnel:
Ahmed Mustafa (PhD)
Mohamed Hamouda (PhD)
Haytham Rafaat Ibrahim (MASc)

Project 3.5 – Operation and Control of Power Systems with ES Systems

Project Description: In this research, mathematical models of ES systems will be developed that account for operational features and constraints, and be combined with power systems optimization algorithms meant for daily operations. Such ES system models will be integrated into existing optimization models and simulation tools for power systems operation and control. These models will be used to evaluate the contribution and impact of ES systems on the overall power system operation. At the distribution system level, optimal operation will examine and derive benefits from ES systems to manage increased renewable integration, feeder loading management, arbitrage, etc. At the transmission level, optimal operation will examine the use of ES for frequency regulation, energy arbitrage, etc.

Progress: The project team is currently modelling flywheel, battery and CAES technology. Collaboration began with IESO and NESTNet partners to analyze ES potential in regulation services. The group conducted 4 seminar/ workshops.

Project Leader:
Claudio Cañizares, University of Waterloo

Project Collaborators:
Kankar Bhattacharya, University of Waterloo
Bala Venkatesh, Ryerson University
Miguel Anjos, École Polytechnique de Montréal
Rupp Carriveau, University of Windsor

Highly Qualified Personnel:
Mariano Arriaga (Postdoctoral fellow)
Chioma Anierobi (PhD)
Fabian Calero (PhD)
Ivan Calero (PhD)
Noela Sofia Guzman (PhD)
Dario Peralta (MASc)

***Visit to Compass Minerals, Goderich, Ontario**. Left to right: Eric Tharumalingam, Elaine Lord, Chioma Anierobi, Fraser Lord.*

Project 3.6 – Reliability Modelling and Assessment of Power Systems with ES Systems

Project Description: New reliability models will be developed for battery, CAES, flywheel and thermal ES systems. Probabilistic techniques will be developed to incorporate market scenarios and operating strategies in quantifying adequacy benefits of ES systems with large-scale renewables penetration. Value-based reliability of different ES technologies and capacity credit increments of renewables due to ES systems will be analyzed, providing invaluable investment decision information. New methodologies will be proposed to incorporate the aforementioned factors, assess the implications of operating reserve requirements and response capabilities, and quantify the impact and worth of ES systems.

Progress: Modelling of the flywheel and power system adequacy has begun, considering CAES. The project team is currently reviewing available power systems, renewable energy and reliability concepts.

Project Leader:
Rajesh Karki, University of Saskatchewan

Project Collaborators:
Handan Tezel, University of Ottawa
Bala Venkatesh, Ryerson University
Rupp Carriveau, University of Windsor

Highly Qualified Personnel:
Nava Raj Karki (Postdoctoral fellow)
Prajjwal Gautam (MASc)
Safal Adhikari (MASc)
Saket Adhikari (MASc)

Project 3.7 – Capacity Markets for ES – Design and Implementation

Project Description: Research aims to analyze the potential of ES to provide services such as demand response, ramping, frequency regulation, etc., given that ES can act as both a load and a generator. With knowledge of the potential of ES solutions, this research will examine and develop capacity markets for ES considering various services.

Progress: Work has begun on both the capacity market model and the overall capacity market auction model, in addition to the general economic model of ES for operations in electricity markets. The literature review of ES has been completed. Publications: 4 technical reports, 1 conference paper.

Project Leader:
Bala Venkatesh, Ryerson University

Project Collaborators:
Kankar Bhattacharya, University of Waterloo
Handan Tezel, University of Ottawa
Rupp Carriveau, University of Windsor
Amit Kumar, University of Alberta

Highly Qualified Personnel:
Chandrabhanu Opathella (Postdoctoral fellow)
Shriram Shukla (MASc)

4.4 THEME 4 PROJECTS AND HIGHLIGHTS

Theme Leader: Miguel Anjos, École Polytechnique de Montréal

This theme investigates and provides solutions for techno-economic challenges in the successful integration of ES into power systems. In addition, it examines policy, regulatory and social challenges faced by storage solutions to enable successful uptake by utilities and societies.

Theme 4 at the Annual Technical Conference, June 22, 2017, including Mark Winfield (left), Miguel Anjos (fourth from left), Kankar Bhattacharya (fifth from left) and Ian Rowlands (fourth from right).

Theme 4: Economics and Policy

Project 4.1
Development of Life Cycle Net Energy Ratio of ES Technologies

Project 4.2
Modelling Electricity Market Prices Considering Large-Scale ES Penetration

Project 4.3
Provision of Ancillary Services by ES Systems

Project 4.4
Optimal Brokerage Models for the Grid Integration of ES

Project 4.5
Towards Federal and Provincial ES Policy Frameworks for Canada

Project 4.6
Social Acceptance of ES Systems

Project 4.1 – Development of Life Cycle Net Energy Ratio of ES Technologies

Project Description: This project aims to assess ES pathways in terms of the ratio of energy input to output to calculate how much energy is required over a life cycle to store a unit of energy from a particular energy source. The ratio of energy input to energy output through a particular pathway is referred to as net energy ratio (NER). First, a life cycle assessment (LCA) framework of ES technologies specific to Canada will be developed and used to create LCA models for the various storage solutions. Then a comparative assessment of NER and greenhouse gas (GHG) emissions for ES technologies will be undertaken.

Progress: The project team has developed a bottom-up data intensive techno-economic model to assess the cost of the ES in the CAES system, thermal ES and pumped hydro storage systems. The literature review of ES systems with focus on mechanical and thermal storage systems has been completed.

Project Leader:
Amit Kumar, University of Alberta

Project Collaborators:
Bala Venkatesh, Ryerson University
Rajesh Karki, University of Saskatchewan

Highly Qualified Personnel:
Abayomi Oni (MASc)
Sahil Kapila (MASc)
Spandan Thaker (MASc)

Project 4.2 – Modelling Electricity Market Prices Considering Large-Scale ES Penetration

Project Description: This project aims to build techno-economic models for estimating the price impacts of the large-scale integration of ES in competitive electricity markets.

Progress: The project team has completed a literature review of batteries for grid-scale application and building of a database for the available real life market data from two electricity markets in Canada and one from a New York state market. Collaborations began with Hamid Zareipour, University of Calgary. Publications: 4 journal papers.

Project Leader:
Miguel Anjos, École Polytechnique de Montréal

Project Collaborators:
Hamid Zareipour, University of Calgary
Kankar Bhattacharya, University of Waterloo

Highly Qualified Personnel:
Juan Arteaga (PhD)
Payam Zamani (PhD)
Soroush Shafiee (PhD)
Adrien Barbry (MASc)

Project 4.3 – Provision of Ancillary Services by ES Systems

Project Description: This project will examine the role of ES solutions as ancillary service providers and their integration with the grid system. Research will be undertaken to determine cost structures and appropriate pricing mechanisms for these services.

Progress: Work is underway on several fronts: 1) development of a comprehensive energy management system (EMS) including pumped storage hydro to examine its participation in frequency regulation services; 2) development of a joint auction model for demand response (DR) for energy and spinning reserve provisions. Publications: 1 journal paper, 1 conference paper.

Project Leader:
Kankar Bhattacharya, University of Waterloo

Project Collaborators:
Steven Wong, CanmetENERGY
Miguel Anjos, École Polytechnique de Montréal
Hamid Zareipour, University of Calgary
Mark Winfield, York University

Highly Qualified Personnel:
Hisham Alharbi (PhD)
Nitin Padmanabhan (PhD)

Project 4.4 – Optimal Brokerage Models for the Grid Integration of ES

Project Description: The objective is to investigate different brokerage models for integrating ES into power systems, and to test the applicability and potential impact of such models using real-world data from Canadian settings.

Progress: So far, an exact method that addresses three challenges for integrating distributed ES – coordination, scalability and heterogeneity – has been designed. A study was carried out on how the presence of a storage operator in an energy market could stabilize the price of energy during peak demand periods and help avoid blackouts. Publications: 1 conference paper.

Project Leader:
Miguel Anjos, École Polytechnique de Montréal

Project Collaborators:
Gilles Savard, École Polytechnique de Montréal
Michel Gendreau, École Polytechnique de Montréal
Bala Venkatesh, Ryerson University

Highly Qualified Personnel:
Franklin Djeumou Fomeni (Postdoctoral fellow)
Mariana Rocha (PhD)
Mathieu Tanneau (PhD)

Theme 4:
Economics and Policy

Project 4.5 – Towards Federal and Provincial ES Policy Frameworks for Canada

Project Description: 1) Assess existing legislative and policy frameworks at the federal and provincial levels as they relate to the development and use of ES technologies, particularly in support of the large-scale integration of low impact but intermittent renewables, such as wind and solar energy. 2) Make policy framework recommendations at the federal and provincial levels to advance the further development and deployment of ES technologies in an environmentally and economically sustainable manner for the purpose of facilitating the large-scale integration of intermittent renewable energy technologies.

Progress: The project team completed development of a template for the comparative analysis of public policies related to ES in multiple jurisdictions. They organized and presented three panels (Community Energy Planning, the Future of Energy Systems, and Ontario's Long-Term Electricity Plan) focused on ES policy issues at the Ontario Climate Change Consortium Symposium May 12, 2017. A policy scan for Canada, U.S. and the EU was completed with 3 working papers published. Policy overview paper was submitted to Energy Policy. They created the NEST Section of the SEI website and are collaborating closely with project 4.6 and an SSHRC Funded Partnership Development Project on community energy planning. Publications: 3 working papers.

Project Leader:
Mark Winfield, York University

Project Collaborators:
Ian Rowlands, University of Waterloo
Amit Kumar, University of Alberta
Rajesh Karki, University of Saskatchewan

Highly Qualified Personnel:
Shahab Shokrzadeh (Postdoctoral fellow)
Adam Jones (MES)
Adlar Gross (MES)
Amanda Gelfant (MES)
Jenessa Doherty (MES)

Project 4.6 – Social Acceptance of ES Systems

Project Description: The main objective of this project is to explain why some ES technologies have been, and will continue to be, in turn, "supported," "accepted" or "rejected" by communities.

Progress: A review on the state of relevant literature was completed and a paper was submitted to an international journal. The project team completed primary research (29 interviews) on the socio-political acceptance of ES in the province of Ontario. They completed a review of public engagement methods with respect to energy infrastructure projects, and also exploratory research on public perceptions of ES – both "generally" and with respect to specific projects – as well as a project web page online.

Project Leader:
Ian Rowlands, University of Waterloo

Project Collaborators:
Mark Winfield, York University
Bala Venkatesh, Ryerson University
Miguel Anjos, École Polytechnique de Montréal

Highly Qualified Personnel:
James Gaede (Postdoctoral fellow)
Dane Labonte (PhD)
Danielle Lavergne-Giroux (MES)
Holly Smale (Undergraduate)
Ian Search (Undergraduate)
Sara Ganowski (Undergraduate)

5.0

EVENTS


Sears
ATRIUM
Sears
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Welcome to
Leading
the Charge
Conference
Welcome to
Leading
the Charge
Conference

5.1 WINTER SCHOOL

By Jonathan Nikodem

Earlier this year we held our first round of NESTNet theme-based Winter Schools. Between January 20th and February 27th the network came together to share the progresses made since last year.

The Theme 1 (Energy Storage Technologies) Winter School, led by Dr. F. Handan Tezel, took place February 24th at the University of Ottawa. In addition to progress updates of each of the six projects, the postdoctoral fellows and students of this theme were invited to give brief presentations to industrial organizations. In attendance were Reda Djebbar of Natural Resources Canada, Bill Wong of Leidos, Robert Triebe and Feikai Chu of Thermal Energy International, and Christina Bock of NRC who also took the opportunity to give presentations of their own.

Theme 1 Winter School at the University of Ottawa, February 24, 2017.

The University of Toronto was host to the Theme 2 (Power Electronics Converters) Winter School, led by Dr. Liuchen Chang. This was held January 20th. Project updates were followed by discussions about technology developments and potential research directions for power electronics in ES systems. This was followed by a tour of the research facilities at the University of Toronto. Imran Khan of NRC joined for this day of Winter School.

Theme 2 Winter School at the University of Toronto, January 20, 2017.

On February 14th, Theme 3 (Power Systems Integration) gathered at the University of Waterloo. Led by Dr. Claudio Cañizares, project presentations were supplemented by presentations from industrial partners to share their perspectives, concerns and ambitions. Edward Arlitt of the Independent Electricity System Operator, Yuri Grinberg of NRC, Steven Wong of Natural Resources Canada, Shivani Chotalia of NRStor and Ehsan Nasr of Canadian Solar provided thoughtful presentations, which rounded off the Theme 3 Winter School.

Theme 3 Winter School at the University of Waterloo, February 14, 2017.

The Theme 4 (Economics and Policy) Winter School took place on February 27th, again at the University of Waterloo. Dr. Miguel Anjos, theme leader, opened the day and was followed by Jatin Nathwani, of the University of Waterloo, who gave an engaging presentation, “Is storage the critical link to affordable energy for humanity?” Project updates were then followed by Maurice Dusseault, of the University of Waterloo, providing a presentation, “Storage of renewable energy in deep geological media.” The day concluded with visits to the High Voltage Engineering Laboratory and the Centre for Advanced Photovoltaic Devices and Systems.

Theme 4 Winter School at the University of Waterloo, February 27, 2017.

In total, there were 60 participants in Winter School despite some travel constraints due to winter weather conditions. Next year’s plan is to hold the Winter School in different locations to allow students to view some other ongoing research activities.

5.2 SUMMER SCHOOL

By Kiki Cekota

This year's NESTNet week-long conference, hosted by the Centre for Urban Energy (CUE), explored the future of ES and solutions to the ever-increasing demand for clean energy. The week ran from June 19 to 23 in various locations on Ryerson's campus and was comprised of three main parts: a Summer School for students of the network, a two-day technical conference for all network researchers and partners across Canada, and Friday's Leading the Charge conference, which was open to members of the public. The week's events had over 100 attendees in total, with participants representing both Canadian and international universities, and industrial and governmental organizations.

Twenty-seven postdoctoral fellows and students from across Canada and 11 from the U.K. attended our Summer School, which ran for the first two days of NESTNet Week. It featured several guest speakers and tours of the Toronto Hydro and Independent Electricity System Operator (IESO) control rooms.

Day one opened with remarks by Dr. Bala Venkatesh, academic director of the CUE, welcoming the attendees. This was followed by a presentation from Bob Singh, an IESO distinguished research fellow of the CUE, who touched on energy planning in transition. Singh compared energy planning in the past to the present to what it could be like in the future, the benefits of smart technologies for consumers and utilities and new technology "game changers," like microgrids and DC transmission and distribution. He also discussed what is needed to better plan and operate energy distribution. Aaron Lampe, principal at Southcott Ventures, then continued sharing his experience about flywheels and getting ES on the grid.

The tour of Toronto Hydro Monday afternoon was led by the control centre supervisor, Sammy Elias. He discussed what Toronto Hydro does, the regions of Toronto served and the layout of the control room.

"It was really interesting to see the Canadian aspect of ES and how the electricity network operators actually work here in comparison to the U.K.," said Andreas Georgakarakos, a postgraduate research student at the University of Sheffield.

Day two started with a presentation by Tom Chapman, the senior manager of market development at IESO, who explained how "solving ES is like solving a Rubik's cube" – both are complex but the more we learn about them the easier they get to solve. Chapman looked at six different ES challenges, as well as how ES is integrated into markets and what the future of ES technologies looks like.

Omid Alizadeh, a CUE research fellow, continued with a presentation about the application of battery storage systems in improving power quality. Alizadeh also spoke about voltage sag and power interruption, two of the most common power quality events. The day concluded with a tour of the IESO control room.

Mohammed Yasin Ali, a master's student at UOIT, said this year's Summer School helped him to understand how things in the energy sector operate in a more practical way as opposed to learning about it in theory at university.

"It's given me good exposure to life outside studying, and to the industry," said Ali. "How everything that we're learning and researching about is being applied in the real world."

Tour of Toronto Hydro, June 19, 2017.

5.3 ANNUAL TECHNICAL CONFERENCE

Prof. Christopher Jones delivers a keynote address.

The two-day technical conference on Wednesday and Thursday included updates from project leaders on progress that's been made in the second year of their research projects. NESTNet is made up of four different research themes: energy storage technologies, power electronic converters, power systems integration and economics and policy. The theme leaders are Handan Tezel of the University of Ottawa, Liuchen Chang of the University of New Brunswick, Claudio Cañizares of the University of Waterloo, and Miguel Anjos of École Polytechnique de Montréal, respectively.

The first three themes were presented on day one of the technical conference. The second day of the technical conference focused on the fourth and final theme: economics and policy. This was followed by meetings of the Research Steering Committee and Board of Directors.

There was significant progress made on several of the projects throughout the year, such as project 1.2, led by Marc Secanell and focused on the fabrication, mathematical modelling, design and testing of flywheels. The participants have now completed construction of an enclosure for flywheel testing.

Project 1.6, which designed a pole-top energy system and was led by the CUE's own Bala Venkatesh, and funded in part by Ontario's Smart Grid Fund, has been completed. The unit was installed in August 2016 and successfully field tested until February 2017.

Another major development was seen by project 2.5, led by Lukas Swan, which is examining control systems for second-life batteries for grid-scale energy systems. The team has acquired training and batteries for testing and completed a battery array concept.

Project 3.2 was also led by Venkatesh and has now been completed. It looked at optimal planning of ES in distribution systems considering feeder investment model, and all parts of it have been finished.

A keynote was given on the second day by Christopher Jones, lecturer at the University of Sheffield and acting director of its ES postdoctoral program. He described the energy research being done at the university, with topics varying from batteries to cryogenics to ES for transportation.

"NESTNet and our Centre for Doctoral Training in ES and its Applications share a number of common objectives. While the U.K. and Canada present different contexts for advancing the research, development and deployment of ES technologies, there is much that we can learn from one another," said Jones.

The Centre for Doctoral Training is 1) funded by the Engineering and Physical Sciences Research Council (EPSRC) and 2) is a joint initiative with the University of Southampton. For more information, please visit www.energystorage-cdt.ac.uk.

This year's technical conference saw much more networking and many partnerships being fostered, university to university and university to NEST partner, as described by Jones: "We view this initial visit to the Centre for Urban Energy to be a first step along a long and productive road of future collaboration."

5.4 LEADING THE CHARGE CONFERENCE

Leading the Charge Conference at Ryerson University's Sears Atrium, June 23, 2017. Hon. Glen Murray, Ontario Minister of the Environment and Climate Change, gave the opening keynote address.

The final event of the summer, Friday's Leading the Charge, boasted three notable keynote speakers: Ontario Minister of the Environment and Climate Change Glen Murray, MPP Bob Delaney and Mark Henderson, senior vice-president of energy solutions and services for Alectra. There were also three panel discussions throughout the day about innovation in the energy sector, challenges and opportunities in ES and use of new language in the innovation agenda.

Moderators:

- Patricia Phillips, executive director, Energy Storage Canada
- Neetika Sathe, vice president, advanced planning, Alectra
- Bob Singh, IESO distinguished research fellow, CUE, Ryerson University

Panelists:

- Scott Dodd, director, business development, Enbridge
- Jayesh Shah, interim vice-president, engineering and operations, Oshawa Power and Utilities Corporation
- Vinay Sharma, chief executive officer, London Hydro and chair, Electricity Distributors Association
- Sunita Chander, director, distribution and agency policy, Ontario Ministry of Energy
- Michel Losier, executive director, energy efficiency, New Brunswick Power
- Robert Wilhite, managing director, Navigant, Charlotte, N.C.
- Tim Curtis, president, Niagara-on-the-Lake Hydro
- Michael Melisek, general manager, Toronto Hydro
- Cole Tavener, director of engineering, London Hydro

The day began with introductions from Bala Venkatesh and Steven Liss, Ryerson's vice-president, research and innovation.

"From energy storage to sustainable homes to electric vehicles, the Centre for Urban Energy is developing real solutions for issues with sustainable green energy in cities," said Liss.

Murray (pictured left) stressed the need for immediate action on climate change in his address.

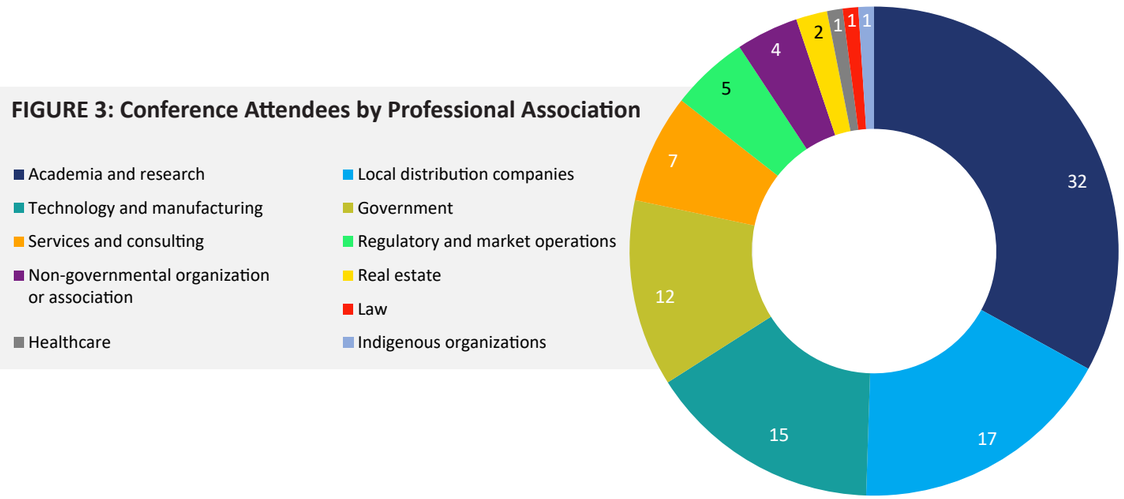
"We are probably living in the most difficult time in human history. Climate change is changing our culture, the way we live and think about ourselves. It is hard for us to talk to each other about managing the change," said Murray. "We have to decarbonize our electricity system, retrofit our buildings and our homes – we can do that."

Carmen Suchorab, director of facilities management at Canada Post and a first-time Leading the Charge attendee, said she enjoyed the event.

"It was really interesting to hear different perspectives and considerations that need to be made in order to properly implement energy storage solutions," she said. "I also loved Minister Murray's speech – he's a very passionate speaker."

Overall, the 2017 NESTNet Week was interesting and informative, and provided valuable networking opportunities for the attendees. We look forward to next year's conference which will take place June 18 to 21, 2018, following another 365 days of progress from our researchers.

FIGURE 3: Conference Attendees by Professional Association



6.1 A NOTE FROM THE NETWORK MANAGER

For year two's NESTNet Week, our expectations were set high. We aimed for greater engagement from the NESTNet researchers, committee members and partners. We hoped for more visibility, both nationally and internationally. And we intended to build on discussions from last year's Leading the Charge. Thanks to the support and engagement of our NESTNet members, our expectations were impressively surpassed.

Planning and execution of NESTNet Week would not have been a success without the help of my colleagues, especially Matthew Kerry, marketing and communications manager, and the NESTNet team. It was quite the task to accomplish and I'm very thankful for the team's enthusiasm and commitment.

Work on year three's events are already underway. Please block these dates: June 18 to 21, 2018 and check the NESTNet website for travel details.

Karen Ho-Cespedes

Year Three: Key Dates

Monday, June 18, 2018
Summer school for students of the network (with one student from each project attending, rotating annually).

Tuesday, June 19 - Wednesday, June 20, 2018
Annual technical conference for all researchers (project leaders, collaborators, and students), committee members and partners (industry/government).

Wednesday, June 20, 2018
Annual General Meeting for the Board of Directors and Research Steering Committee members.

Thursday, June 21, 2018
Industry conference for all project leaders and committee members of the network. This is a paid event with a discounted rate for members.

Visit us

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