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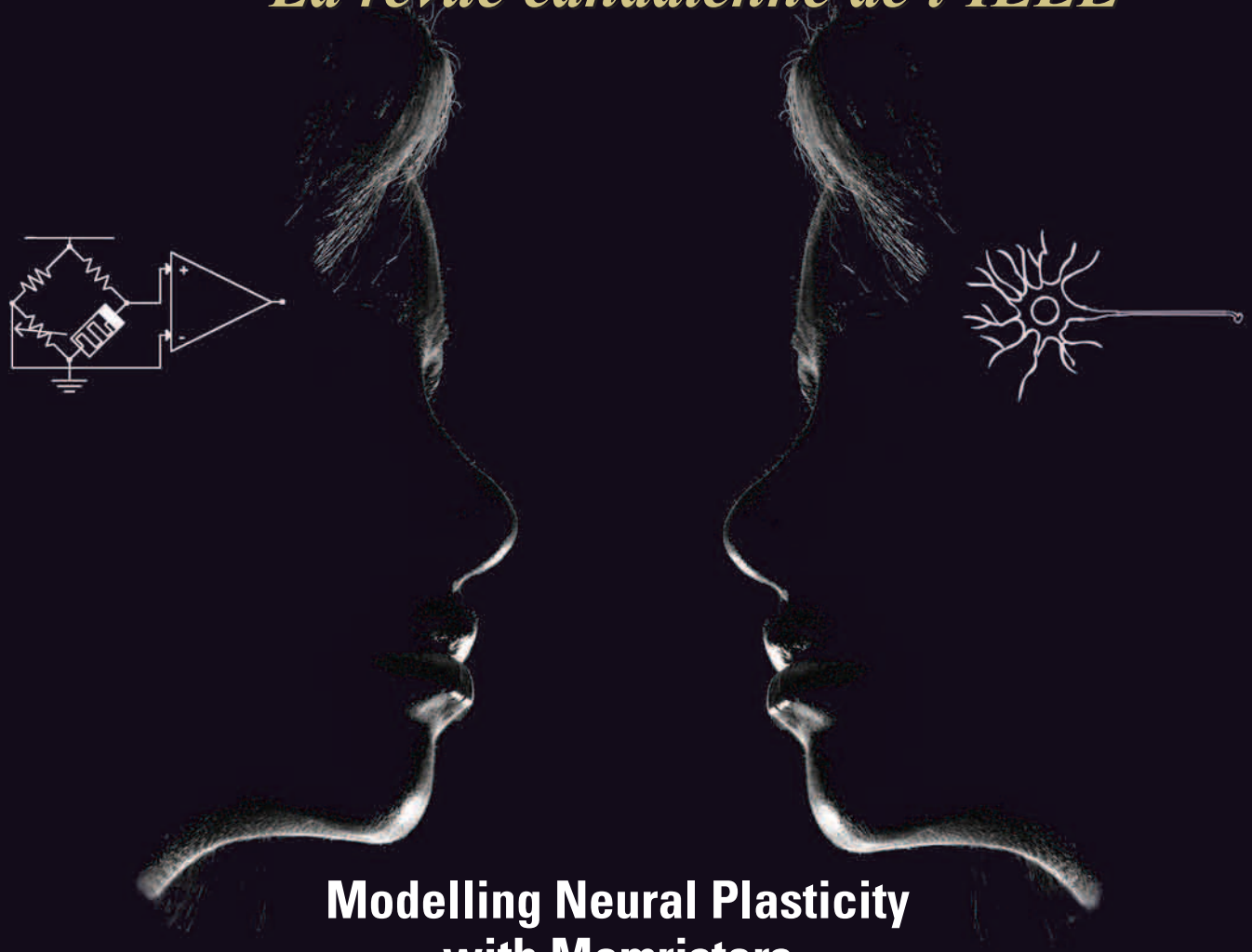

Modelling Neural Plasticity with Memristors

Limitations of Distance Protection Associated with the Integration of Renewable Sources

Japan's Recovery by Design

A Remembrance of Andy Sturton

Steve Jobs, IEEE and Canada

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The Institute of Electrical and Electronic Engineers Inc.

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IEEE Canadian Review
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The *IEEE Canadian Review* is published three times per year: mid March, end of June and mid October. Its principal objective is to project an image of the Canadian electrical, electronics, communications and computer engineering professions and their associated academic and business communities to:

(i) Canadian members of IEEE;

(ii) Canadian members of the profession and community who are non-members of IEEE;

(iii) The associated Canadian academic (i.e., universities, colleges, secondary schools), government and business communities.

To ensure that the *IEEE Canadian Review* has the desired breadth and depth, editors are responsible for screening articles submitted according to the following general themes:

1 - National Affairs
2 - International Affairs
3 - Industry
4 - Education
5 - Power
6 - Communications
7 - Computers
8 - Electronics

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Editorial / *Éditorial*

Amir Aghdam SMIEEE, Rédacteur en chef / Editor-in-Chief

Two years ago I wrote in my editorial that I took pride in providing my first column in an issue which had a special focus on humanitarian efforts initiative. Now I take pride in writing my last column as Editor-in-Chief, in an issue that suggests we can learn not just from the technological achievements of our fellow engineers, but in how they work with others.

In this issue we remember the highly accomplished Andy Sturton, recipient of the 2005 IEEE Canada McNaughton Award, whose success was certainly in part due to the "softer skills." A commentary about Steve Jobs connects the many facets of his achievements to a keen understanding of human nature, boundless imagination, and—perhaps not so often noted—a communications standards infrastructure established by IEEE enabling the signature interoperability of Apple devices. This issue's more technical offerings expand our knowledge of networks of other kinds. The first is concerned with how memristors can model the variable behavior of neural connections, the very basis for learning and memory. The second explores the challenges and potentially serious consequences of connecting renewable energy sources to the transmission grid unless a proper power protection scheme is adopted, offering some measures for protection engineers to consider. Adding international flavour, in a member field report, you will be surprised to learn how changes to infrastructure design following Japan's 1995 earthquake helped it recover more quickly from the March 2011 quake. The author offers his views on how Canada can be similarly proactive in anticipating and addressing future challenges.

I am also delighted to report that since the end of last fall Dr. Abdelwahab Hamou-Lhadj has been the Managing Editor of the magazine. Wahab has been providing quality service to the professional community in different capacities, the most recent (and relevant) one being his current position as Editor-in-Chief of IEEE Montreal Newsletter. Having known Wahab for more than five years now, I am confident that he will make a significant contribution in all aspects of the magazine. I would also like to welcome back Dr. Kexing Liu as the Advertising Manager, and thank Marcelo Mota for his strong efforts in that role over the past two years. I too will have new responsibilities—I have now assumed the position as IEEE Canada President-Elect, which is why I'm stepping down as Editor-in-Chief.

Being part of this magazine was an invaluable experience for me, and I owe this to the dedicated collaboration of several individuals who made this the most pleasant experience. I would like to thank the Executive Committee of IEEE Canada for their continuous support, our regular columnists, and the Advisory Committee for their wise words of advice throughout the past few issues. Peer Review team did a wonderful job in providing quick feedback and Translations Group amazed me with quick translation of the abstracts and editorials to French, sometimes in a matter of hours. My special

(continued on page 4)

Il y a deux ans j'écrivais dans mon éditorial que c'était avec fierté je produisais mes premières lignes d'éditorial dans un numéro qui se concentrait spécialement sur une initiative d'efforts humanitaires. Maintenant c'est aussi avec fierté que je rédige mon dernier éditorial en tant que rédacteur en chef, dans un numéro qui suggère que nous pouvons apprendre non simplement des accomplissements technologiques de nos confrères ingénieurs, mais aussi de la façon dont ils travaillent en interaction avec les autres.

Dans ce numéro nous nous rappelons de Andy Sturton, récipiendaire du Prix McNaughton de l'IEEE Canada en 2005, dont le succès était certainement dû en partie « à ces compétences moins techniques. » Un commentaire au sujet de Steve Jobs relie les nombreuses facettes de ses accomplissements à une compréhension de la nature humaine, une imagination illimitée, et—peut-être pas aussi souvent notée—une infrastructure de normes de communication établie par I'EEE permettant l'interopérabilité de signature des dispositifs d'Apple. Les articles plus techniques de ce numéro élargiront notre connaissance des réseaux de d'autres genres. Le premier concerne la façon dont les memristors peuvent modéliser le comportement variable des connexions neuronales, la base même de l'apprentissage et de la mémoire. Le deuxième explore les défis et conséquences potentiellement sérieuses de relier les sources d'énergie renouvelable à un réseau de transmission à moins qu'un schéma de protection approprié ne soit adopté. Il offrira aussi quelques mesures que les ingénieurs en charge de la protection devraient considérer. Afin d'ajouter une saveur internationale, vous serez étonnés d'apprendre comment les changements à la conception d'infrastructure suivant le tremblement de terre de 1995 au Japon ont aidé à récupérer plus rapidement suite au tremblement de terre de mars 2011. L'auteur partage ses vues sur la façon dont le Canada peut être proactif de la même façon en prévoyant et en relevant de futurs défis.

Je suis également enchanté de vous annoncer que depuis la fin de l'automne dernier, le Dr. Abdelwahab Hamou-Lhadj est le Rédacteur en chef de la revue. Wahab avait fourni un service de qualité à la communauté professionnelle en occupant différentes positions, les plus récentes (et pertinentes) étant sa position actuelle de Rédacteur en chef du bulletin de la Section de Montréal de l'IEEE. Connaissant Wahab depuis plus de cinq années maintenant, je suis confiant qu'il apportera une contribution significative au niveau de tous les aspects de la revue. Je voudrais également souhaiter la bienvenue au Dr. Kexing Liu qui est de retour en tant que chef en charge de la publicité, et je remercie Marcelo Mota pour ses énormes efforts fournis au niveau de ce rôle au cours des deux dernières années. J'aurai aussi de nouvelles responsabilités—en acceptant la position de Président élu de l'IEEE Canada, ce qui explique pourquoi je dois laisser ma place comme rédacteur en chef.

Mon implication au niveau de cette revue fut une expérience d'une valeur inestimable pour moi, et je dois ceci à la collaboration dévouée de plusieurs individus qui ont fait de ceci l'expérience la plus plaisante. Je voudrais remercier le comité de direction de l'IEEE Canada pour son soutien continu, nos chroniqueurs réguliers, et le Comité consultatif pour leurs sages conseils lors des derniers numéros. L'équipe de revue a réalisé un travail merveilleux en fournissant un feedback rapide, et aussi le groupe en charge de la traduction qui m'a stupéfié par son service de

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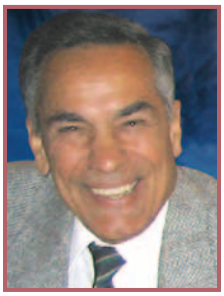
Dear Friends in IEEE Canada;



At the time of this writing I am already in the position of Past-President, IEEE-Canada, with Keith Brown having taken over as President, IEEE Canada, on January 1, 2012.

I attended the IEEE Board meetings in November 2011, my last official engagement as IEEE Canada President. IEEE MGA Board has taken on the task of pursuing the implementation of the top recommendations from the 2011 IEEE Sections Congress with the support of the IEEE Board. A major part of the business of the November meeting of the IEEE Board involves a number of routine functions, including 2012 appointments to a large number of Boards and Committees. One major item of interest that was discussed was the quality control and improvement of IEEE sponsored conferences. There has been a feeling that the quality of some of the conferences, in particular of those technically co-sponsored by the IEEE, has been dropping. So steps are being taken to ensure that the technical standard of these conferences remains at a high level. Another item of interest was that the IEEE Board approved the creation of an open-access online publication. IEEE Publication Services and Products Board has been asked to develop such an IEEE e-journal.

I would like to take this opportunity to thank everybody for the help and support that I received during my term as President, IEEE Canada. It is now time to bid a fond farewell and welcome Keith. I wish him all the success during 2012-13. I am sure that he will enjoy as much support during his term as I did.

Thanks again and adieu.

Chers amis de l'IEEE Canada;

Au moment où je rédige ceci, je ne suis plus Président de l'IEEE-Canada, et c'est maintenant Keith Brown qui me succède comme Président, IEEE Canada, depuis le 1er janvier 2012.

J'ai assisté aux réunions du conseil d'administration de l'IEEE en novembre 2011, mon dernier engagement officiel comme Président de l'IEEE Canada. Le conseil MGA de l'IEEE a pris pour tâche de poursuivre la réalisation des principales recommandations du congrès des sections de l'IEEE 2011 avec l'appui du conseil de l'IEEE. Une majeure partie des affaires découlant de la réunion de novembre du conseil de l'IEEE implique un certain nombre de fonctions de routine, y compris des nominations à un grand nombre de conseils et de comités en 2012. Un item d'intérêt majeur qui fut discuté était le contrôle de la qualité et l'amélioration des conférences commanditées par l'IEEE. On a l'impression que la qualité de certaines des conférences, en particulier de ceux techniquement coparrainées par l'IEEE, s'était dégradée. Ainsi des mesures ont été prises afin de s'assurer que le niveau technique de ces conférences demeure élevé. Un autre item d'intérêt fut que le conseil de l'IEEE a approuvé la création d'une publication en ligne à libre accès. Le conseil des services et produits de publication de l'IEEE a été invité à développer un tel journal électronique de l'IEEE.

Je voudrais saisir cette occasion pour vous remercier tous pour l'aide et le support que j'ai reçu pendant mon mandat de Président de l'IEEE Canada. Il est maintenant temps de vous offrir mes adieux sincères et de souhaiter la bienvenue à Keith. Je lui souhaite le meilleur succès pendant son mandat 2012-13. Je suis sûr qu'il appréciera autant que moi le support qui lui sera offert pendant son mandat comme ce fut le cas pour moi.

Merci encore et adieu.

Dr. Om Malik, P.Eng., LFIEEE, FCAE, CEIC, FEIT, FEIC
2010-2011 IEEE Canada President and Region 7 Director

Editorial (cont'd from p. 3)

thanks to the Art & Production Manager who played an important role in maintaining the high standards of the magazine. The Faculty of Engineering and Computer Science of Concordia University has always been very supportive and has provided me with generous resources in the past few years, which is very much appreciated. Last but not least, thanks to the readers. Your feedback (which most of the time was very encouraging) gave me the energy I needed to serve for this magazine. Merci beaucoup.

Éditorial (Suite de p.3)

traduction rapide des résumés et des éditoriaux en français, parfois même à quelques heures d'avis. Mes remerciements spéciaux vont au Directeur de la production artistique qui a joué un rôle important en maintenant les standards élevés de la revue. La faculté de génie et de Science informatique de l'université Concordia a toujours été d'un très grand support et m'a fournie des ressources généreuses lors de ces dernières années, ce qui fut très apprécié. Les derniers mais non les moindres que j'aimerais remercier sont les lecteurs. Votre feedback (qui était la plupart du temps très encourageant) m'a donné l'énergie requise pour vous servir au niveau de cette revue. Merci beaucoup.

Dr. Amir Aghdam, SMIEEE
Editor-in-Chief 2011-2012; Managing Editor 2009-2011

GOLDen Opportunity for Wordsmiths

Three Associate Editor positions are available for *Aurum*, a quarterly newsletter published for the Canadian audience of IEEE GOLD. If you are an energetic IEEE member with good writing skills and looking for a volunteering opportunity, please contact the IEEE Canada GOLD Coordinator, Dan Hosseinzadeh (dan.zadeh@ieee.org). Each Associate Editor will focus on a geographical area in Canada (east, central or west), assisting the *Aurum* Editor, Eugene Wong.

IEEE Graduates Of The Last Decade (GOLD) group is a dynamic subset of IEEE members who are young professionals and recent engineering graduates. *Aurum* highlights GOLD activities throughout Canada and provides a national forum for GOLD members to express their opinions. *Aurum* is published in French and English.

Ottawa Section Member Wins MGA Award

Raed Abdullah, Ottawa Section Past Chair and current IEEE Canada Secretary, is the recipient of a 2011 IEEE MGA Achievement Award. The Member and Geographic Activities (MGA) Board seeks to serve member needs in IEEE's Geographic Units (Regions, Geographic Councils, Areas, Sections, Chapters, Student Branches and Student Branch Chapters). Its awards and recognition program is designed to promote and reward excellence in MGA operations and in the activities of Geographic Units.

Abdullah is currently serving in his second year as one of four Regional representatives on the MGA Individual Benefits and Services Committee. The citation for his Award reads "For his drive and dedication to lead by example and promote MGA Goals, while encouraging members to remain engaged at all levels of IEEE."

Has it been two years already? It seems like only yesterday that I assumed the role of your Vice President for 2010-2011. We are now five months into 2012 and it is with great honour I assume the role of your Region 7 Director and President of IEEE Canada for 2012-2013. First, I want to express my sincere thanks to Ferial El-Hawary who has completed her six years of service to the board, and to Om Malik who has completed his term as President and is now in the role of Past President. I would also like to welcome Amir Aghdam as your new Vice President and Ashfaq (Kash) Husain as your new treasurer. Kash is stepping into this role following Gerard Dunphy's two years as treasurer — thank you Gerard.

During the spring board meeting in April I presented my national strategic plan for 2012 and beyond, previously presented in draft form at the fall board meeting in October. This plan is focussed on three key principles: *Visibility*, *Impact* and *Growth*. In terms of visibility, I encourage volunteers and members to look for ways to promote the IEEE, here at home and abroad, as they carry out their various activities. Do your colleagues know you are a member of the IEEE? Do they know you are a volunteer with significant leadership responsibilities? Share your story and help fulfill my vision of improved visibility. As for impact, each of us has a finite amount of time and energy in our daily lives in which to focus on things that are meaningful and rewarding. In order to best use the time donated by our volunteers, an ad-hoc committee is presently reassessing the structure and activities of the IEEE Canada Board. This review is conducted every three years as per our operations manual, to ensure our volunteers' time and efforts effectively support IEEE's mission and core purpose: to foster technological innovation and excellence for the benefit of humanity. As a Canadian who has served in our Armed Forces, I recognize the deep significance of these core values. I believe that by improving the visibility of the IEEE and by generating a positive impact: membership will go up, volunteerism will increase, and member retention rates will improve. In other words, we will experience growth. Over the next few months, with the assistance of our senior volunteers, together we will begin to refine the details of how we implement this plan. Stay tuned.

On the global front, IEEE reached two significant milestones at the end of 2011. In December, the total number of members worldwide exceeded 400,000 (415,989 was the official tally). Also for the first time in its 128-year history, the IEEE has slightly more than half of its members residing outside of the United States (50.2%). This latter marker is no surprise, as the trend towards internationalization of our membership has been observed for a number of years. In preparation, the IEEE has become globally strategically focused. Satellite offices in Tokyo, Singapore, Beijing, and Bangalore now complement those in New York, New Jersey, Washington DC and California. Most recently, IEEE and UNESCO (United Nations Educational, Scientific and Cultural Organization) signed an agreement that is the first step in a strategic partnership to implement projects that will help produce a thriving and sustainable engineering community in Africa.

Back in Canada, we recently celebrated the Silver Anniversary (25 years) of the Canadian Conference on Electrical and Computer Engineering on April 29 - May 2 in Montreal. As per tradition, the 2012 IEEE Canada awards ceremony was also held in conjunction with this conference. These annual awards provide us the opportunity to publicly recognize those members who have distinguished themselves either in their profession or as volunteers. Nominations are always welcome and more information is available at http://www.ieee.ca/awards/nominate.htm.

I also recommend each of us investigate the abundant and varied member benefits that IEEE offers (www.ieee.org/benefits). The site has a very useful app that displays a relevant list based on the user's drop-down selections of career phase and country.

In closing, 2012 is off to a fast start and I look forward to working with you over the next two years and am always open to your comments or suggestions. Please send them to kbbrown@ieee.org.

Deux années sont-elles déjà écoulées ? Il semble que c'était seulement hier lorsque j'ai assumé le rôle de votre vice-président pour 2010-2011. Il y a maintenant cinq mois écoulés en 2012 et c'est avec un grand honneur que j'assume le rôle de votre Directeur de la région 7 et Président de l'IEEE Canada pour 2012-2013. D'abord, je veux exprimer mes sincères remerciements à Ferial EL-Hawary qui a complété six années de service au conseil, et à OM Malik qui a complété son mandat comme Président et qui est maintenant Président sortant. Je voudrais également accueillir Amir Aghdam en tant que votre nouveau Vice-président et Ashfaq (Kash) Husain en tant que votre nouveau trésorier. Kash occupera ce rôle suite au mandat de deux ans de Gerard Dunphy comme trésorier — merci Gerard.

Lors de la réunion du conseil d'administration du printemps en avril, j'ai présenté mon plan stratégique national pour 2012 et au-delà, qui avait déjà été présenté de façon préliminaire à la réunion du conseil d'administration de l'automne en octobre. Ce plan se concentrait sur trois principes principaux : *Visibilité*, *impact* et *croissance*. En termes de visibilité, j'encourage les bénévoles et membres à rechercher des façons de faire la promotion de l'IEEE, ici et ailleurs, lorsqu'ils accomplissent leurs activités diverses. Vos collègues savent-ils que vous êtes membre de l'IEEE ? Sont-ils au courant que vous êtes un bénévole possédant des responsabilités de leadership significatives ? Partagez votre histoire et aidez à accomplir ma vision de visibilité améliorée. Quant à l'impact, chacun de nous possède un nombre de heures et une énergie finis faisant partie nos vies quotidiennes pour se concentrer sur des choses qui sont significatives et enrichissantes. Dans le but de mieux utiliser le temps offert par nos bénévoles, un comité ad hoc réévalue actuellement la structure et les activités du conseil de l'IEEE Canada. Cette revue est conduite à tous les trois ans selon notre manuel d'opération, pour s'assurer que le temps et les efforts de nos bénévoles soutiennent effectivement la mission de l'IEEE : de stimuler l'innovation technologique et l'excellence au profit de l'humanité. En tant que Canadien qui a servi au sein de nos forces armées, je reconnais la signification profonde de ces valeurs. Je crois qu'en améliorant la visibilité de l'IEEE et en produisant un impact positif : l'adhésion sera en croissance, le bénévolat augmentera, et le taux de rétention des membres s'améliorera. En d'autres termes, nous connaîtrons la croissance. Au cours des prochains mois, avec l'aide de nos bénévoles seniors, ensemble nous commencerons à raffiner les détails de la façon dont nous mettrons en application ce plan. Demeurez à l'écoute.

De façon globale, l'IEEE a atteint deux étapes importantes significatives à la fin de 2011. En décembre, le nombre total de membres dans le monde entier a dépassé le cap des 400,000 (415,989 selon le chiffre officiel). En outre pour la première fois en 128 ans d'histoire, l'IEEE a légèrement plus de la moitié de ses membres résidant en dehors de des États-Unis (50.2%). Ce dernier fait ne constitue pas une surprise, car on a observé une tendance vers l'internationalisation de notre adhésion pendant un certain nombre d'années. En préparation, l'IEEE est devenu globalement et stratégiquement focalisé. Les bureaux satellites à Tokyo, à Singapour, Pékin, et à Bangalore complètent maintenant ceux à New York, New Jersey, Washington DC et en Californie. Récemment, l'IEEE et l'UNESCO (Organisation des Nations Unies pour l'éducation, la science et la culture) ont signé un accord qui constitue la première étape vers une association stratégique pour mettre en application des projets qui aideront à produire une communauté d'ingénieurs prospère et soutenable en Afrique.

De retour au Canada, nous avons célébré récemment l'anniversaire d'argent (25 ans) de la conférence canadienne sur le génie électrique et informatique du 29 avril au 2 mai à Montréal. Comme le voulait la tradition, la cérémonie de remise des prix de l'IEEE Canada 2012 s'est tenue en même temps que cette conférence. Ces prix annuels nous fournissent l'occasion de reconnaître publiquement ces membres qui se sont distingués soit dans leur profession ou soit en tant que bénévoles. Les nominations sont toujours bienvenues et on retrouve plus d'information à http://www.ieee.ca/prix/icanprix.htm.

Je recommande également à chacun de nous d'étudier les avantages abondants et divers que l'IEEE offre aux membres (www.ieee.org/benefits). Le site très utile montre une liste basée sur les choix d'un menu déroulant d'utilisateur concernant la carrière et le pays.

En conclusion, 2012 débute rapidement et je compte avec intérêt travailler avec vous au cours des deux années à venir et je suis toujours ouvert à vos commentaires ou suggestions.Veuillez les envoyer à kbbrown@ieee.org.

Dr. Keith B. Brown, Ph.D., P.Eng., SMIEEE
2012-2013 IEEE Canada President and Region 7 Director

Newslog Editor
Rédacteur des Coupures de presse

Alexandre Abecassis is a patent agent and Partner at Fasken Martineau DuMoulin LLP, Lawyers and Patent and Trade-mark Agents.

Alexandre Abecassis est agent de brevets associé chez Fasken Martineau DuMoulin S.E.N.C.R.L., s.r.l., Avocats et agent de brevets et de marques de commerce.

Send any news clippings you would like to contribute via e-mail to alexandre.abecassis@ieee.org

Veuillez faire parvenir les coupures de presse proposées par e-mail à alexandre.abecassis@ieee.org

MONT-ST-HILAIRE, QC. 15 mar. 2012. MediaMed Technologies annonce qu'elle est finaliste du concours d'affaires Les Mercuriades dans la catégorie Innovation investissement Québec. Ce concours est organisé par la Fédération des chambres de commerce du Québec. MediaMed offre notamment une solution informatisée destinée à la gestion de la performance des soins. Cette solution informatisée utilise les approches Lean et Six Sigma.

BURNABY, BC. Mar. 8, 2012. More than $200,000 in technology grants has been awarded by BC-based Best Buy Canada to 12 elementary schools across Canada. The purpose of the grants is to fund new programs to enhance learning and incorporate new technologies. Nearly 1M$ have been donated for this initiative by Best Buy Canada since 2008.

MONTRÉAL, QC. 6 mar. 2012. Montréal va accueillir le Congrès mondial des technologies de l'information du 22 au 24 octobre 2012. Cet évènement est organisé tous les deux ans. Il s'agit du plus grand rassemblement mondial dans le secteur des technologies de l'information. Il rassemble plus de 3000 chefs de file mondiaux issus des secteurs des affaires.

QUÉBEC, QC. 29 fév. 2012. Des formateurs et des techniciens en informatique de la compagnie EBR sont allés former des enseignants de la commission scolaire de Kativik (Nuvavik) à l'utilisation de tableaux blanc intéractifs. Cette commission scolaire, située au dessus du 55ième parallèle, est la plus isolée du Québec et elle comprend 14 villages.

WINDSOR, ON. Jan. 31, 2012. A new cloud-based environmental monitoring service has been launched by Enviromon.net. This new service will enable consumers to monitor environmental data from anywhere via a secured web browser. Temperature/humidity, airflow, water leakage sensors may be used. This solution may be used to monitor various types of locations such as restaurants, labs, server rooms, etc. In case of a change of a condition a text message or an email may be sent to alert an operator.

BURLINGTON, ON. Jan. 30, 2012. Siemens has announced that it has acquired the company RuggedCom. RuggedCom is a leading provider of robust, industrial-quality Ethernet communication products and network solutions.

MONTRÉAL, QC. 26 janv. 2012. 72 commissions scolaires du Québec vont pouvoir avoir accès à la technologie de Luidia Inc. Ainsi, 43000 classes vont pouvoir bénéficier d'une partie du budget de 160 millions de $ qui est étalé sur 5 ans et qui a été annoncé par le premier ministre M. Jean Charest pour équiper notamment les classes de la maternelle à la 5ieme année du secondaire avec des tableaux électroniques.

VANCOUVER, BC. Jan. 9, 2012. Absolute Software Corporation, a provider of firmware-embedded endpoint security and management solutions has announced that it has expanded the platform coverage of its industry leading service to Android tablets. This solution can survive operating system re-installation as well as hard-drive reformats, replacements, etc. It is possible using the solution to also remotely delete data on a stolen or lost article.

RICHMOND, BC. Jan. 5, 2012. MacDonald, Dettwiler and Associates Ltd has announced that it has signed an agreement for the provision of Radarsat distribution rights for three years in China. The data will be used for, inter alia, environment monitoring, subsidence monitoring and disaster response.

TORONTO, ON. Jan. 4, 2012. Communique Laboratory and WiLAN have announced that they have commenced litigation against Bomgar in the United States. According to the plaintiffs, US Patent 6,928,479 is infringed by the defendant.

MONTRÉAL, QC. 5 déc. 2011. Le Centre de recherche informatique de Montréal (CRIM) et Irosoft ont annoncé la signature d'une entente de collaboration à long terme pour unir leurs expertises respectives en analyse textuelle et vocale, web sémantique et en infonuagique.

MONTRÉAL, QC. 10 janv. 2012. Ultra Electronics SCT a annoncé avoir obtenu des commandes pour un montant de 23 millions de $ en équipement de communication tactique. Ces équipements seront fournis à l'armée américaine.

Community News / *Nouvelles de la communauté*

IEEE-Eta Kappa Nu comes to Region 7

HALIFAX, NS. Mar. 5, 2012. IEEE-Eta Kappa Nu (IEEE-HKN) has installed its first chapter in Canada at Dalhousie University. IEEE-HKN is an honour society recognizing academic excellence, leadership, outstanding character and service, formed when IEEE and U.S.-based Eta Kappa Nu Association merged in September 2010. Dalhousie's chapter, named Lambda Theta, is only the third to be installed outside the U.S.

Students selected to become members receive leadership training from working professionals in the Chapter. But there is also an expectation they will help others over the course of their career and stay involved once they graduate, says faculty advisor Mo El-Hawary. "Student members mentor their classmates, and extend this intellectual philanthropy down to classes following them, even to the high school level."

Membership at Dalhousie's student branch overlaps with the newly formed IEEE-HKN chapter, says El-Hawary, who is also faculty advisor to the Branch. The Branch chair is also a member of the executive of the IEEE-HKN chapter, with other students belonging to both, he says.

IEEE-HKN may be of most benefit to larger universities and colleges, suggests IEEE Canada President Keith Brown, noting in these instances potential members and resources for both IEEE-HKN and Branch activities are greater. But he's quick to give an A+ to El-Hawary for his initiative. "Congratulations to Mo, and my appreciation to all our student activities Section volunteers, who make the first connection with one of our most important sources of new members, and the future of our profession." For more information about IEEE-HKN, please visit www.hkn.org.

Back (L to R): *Dr. Josh Leon (Dean of Engineering at Dalhousie), Dr. Zhizhang (David) Chen (Head of Elect. and Comp. Eng. Dept.), Dr. Ferial El-Hawary (past IEEE Canada Pres.), Dr. Mo El-Hawary (Faculty Advisor, past IEEE Canada Pres.), Dr. Stephen Goodnick (IEEE-HKN President), Lauren Haley, Ernest Paul Dickson, Gillian Fung, Moteb Ateeq Alsumiry, Katherine Latham, Andrew Hebb, Kyle Park, Paul Skene, Scott Melvin, Hossam El Derbi*

Seated (L to R): *Kathleen Svendsen, Selina Cajolais (Faculty Administrative Secretary), Lei Huang, Ahmed Youssef*

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A View from the West

By Terrance Malkinson

British Columbia

British Columbia is one of seven provincial education ministries that accredits offshore schools, offering them for a fee the rights to a Canadian curricula education and awarding Canadian diplomas. David Godsall describes the concept in the August 2011 issue of *BC Business* "Selling Canadian Teaching in China" [www.bcbusinessonline.ca]. British Columbia is the only province that lets school districts operate as profit-making intermediaries, with six school districts having started companies offering a range of educational services. Abbotsford's School District No. 34 Business Co. for example made $3.7 million in offshore tuition fees in 2010.

Emmanuel Samoglou describes in "Staking Out New Ground" [*Canadian Business* October 24, 2011. pp. 80-82. www.canadianbusiness.com] how a relatively unknown Company called Weatherhaven [www.weatherhaven.com] headquartered in Burnaby BC outfits militaries, relief organizations, exploration companies, and others with portable and reusable shelters for hostile environments such as the Antarctic, jungle or desert. Established in 1981 the company now has a global presence on all seven continents and deploying to more than 50 countries. The structures have an estimated lifespan of 20 years.

As described by Tony Wanless in the September 2011 issue of *BCBusiness* [B.C.'s Geothermal Power Pipe Dream], a team of 12 scientists led by the Geological Survey of Canada has discovered that there is a massive store of geothermal energy in the ground throughout Canada that could potentially replace all our current energy supply. Because BC is part of the Pacific Ring of Fire, it has many of these closer-to-the-surface fissures and tapping these could produce as much energy as a large hydroelectric dam. Geothermal energy is used by many other countries [www.geothermal-energy.org]. The article discusses the opportunities and technology/regulatory/environmental challenges.

Alberta

Two Canadian teams have been selected as participants in the 2013 U.S. Department of Energy Solar Decathlon [www.solardecathlon.gov/] in Irvine, CA. A student-led team from the University of Calgary and another from Queen's University/Carleton University/Algonquin College were selected as two of only 20 collegiate teams selected to take partk, and two of only four international participants. In this biannual competition to design, build and operate a highly efficient and sustainable house, teams are required to compete in ten different categories. Historically, Canadian teams have ranked very high in the competition.

With two accredited post-secondary institutions and lifestyle advantages common to a smaller city, Lethbridge, as described by Max Fawcett in the October 2011 issue of *Alberta Venture* [Lethbridge 2.0". www.albertaventure.com], is in the process of creating a high-tech sector. InfoChip, a company that deals in radio frequency identification safety solutions, set up shop in November 2010. A brand new high-tech incubator, Tecconnect, located on the northeast side of the city has a direct link to a tier-three data center. Lunctus Geomatics, a Lethbridge-based firm provided $1M of its own money to see Tecconnect built. BlackBridge Technology Infrastructure recently finished building the data center.

WestJet's goal is to be one of the top five international carriers by 2016. The company has now consolidated its five Calgary offices into one central head office location near the city's international airport [WestJet Invests in Human Capital with New Calgary Headquarters,"Max Fawcett. *Alberta Venture*. January 2012]. The multibillion-dollar company, with annual revenues in excess of $2 billion, has posted 26 consecutive profitable quarters. The building itself, which was certified LEED Gold this past October, is a reflection of a longstanding commitment to putting people first, the company says.

Dr. Garnette Sutherland a University of Calgary Neurosurgeon has been named as a member of the Order of Canada for leading the team that developed the neuroARM—the world's first MRI-compatible surgical robot capable of both microsurgery and image guided biopsy [www.neuroarm.org]. Receiving international acclaim, the Robotic surgical system is controlled by a surgeon from a computer workstation in conjunction with intraoperative magnetic resonance imaging. The MRI machine was developed with the National Research Council and Winnipeg-based IMRIS Inc.

Saskatchewan

Saskatchewan led the nation in growth in wholesale trade, retail sales and non-residential construction. ["Saskatchewan Economy Off To A Strong Start In 2012: Leading The Nation In Several Categories." Deb Young. January 30, 2012. www.gov.sk.ca/news]. Positive economic news include job numbers and wholesale trade setting monthly records. Weekly earnings increased with competitive wages and low unemployment — Saskatchewan has the second lowest per capita receipt of EI benefits in Canada at 1.2 percent. A report from Statistics Canada [January 26] reveals average weekly earnings of $904.42, the second highest in Canada. All of the major economic forecasters are projecting that Saskatchewan will be either first or second in economic growth in Canada this year.

Other articles of interest

Canadian-born Ralph Steinman shared the 2011 Nobel Prize in Medicine with American Bruce Beutler and French scientist Jules Hoffmann. [www.nobelprize.org/nobel_prizes/medicine/shortfacts.html]. Steinman's discovery dates back to 1973, when he discovered the dendritic cell, which has a unique capacity to activate T-cells. Hoffmann's discovery came in 1996 during research on how fruit flies fight infections. Two years later, Beutler's research on mice showed that fruit flies and mammals activate innate immunity in similar ways when attacked by germs. Regrettably, Steinman died shortly before the award was announced, unaware his life's work had been thus recognized. The Nobel Prize committee made an exception to the normal rule that only the work of the living can be recognized, on the grounds the Prize was awarded in good faith that Steinman was alive. The 68-year-old physician died after a four-year battle with pancreatic cancer. He had prolonged his life with a new therapy based on his research into the body's immune system.

In "The Golden Age of Natural Gas" [*Canadian Business.* October 10, 2011. 46-50] Michael McCullough discusses a vision of the future where natural gas might replace oil as the energy source of choice. The employment of horizontal fracking techniques ["The Quiet Energy Revolution" *The American.* Max Schulz February 2010. www.american.com/archive/2010/february/the-quiet-energy-revolution] is increasing supply of recoverable gas by an estimated six times to the point where it could satisfy current demand for 250 years not just in Canada but also globally. Issues associated with the adoption of this source of energy are discussed.

About the Author

Terrance Malkinson is a communications specialist, business analyst and futurist. His career path includes technical supervisor and medical researcher at the University of Calgary, business proposal manager for the General Electric Company, and research administrator with the School of Health and Public Safety at SAIT Polytechnic in Calgary. He is currently an international correspondent for IEEE-USA Today's Engineer, associate editor for IEEE Canadian Review, and a member of the editorial advisory board of IEEE The Institute. He was Vice-Chair of the IEEE-USA Communications Committee (2004-2010), and editor-in-chief of IEEE-USA Today's Engineer Digest (2004-2008). An author of more than 420 publications, he is an accomplished triathlete.
malkinst@telus.net

Steve Jobs, IEEE and Canada

By Jon Rokne, University of Calgary

Steve Jobs passed away on October 5, 2011 due to complications related to pancreatic cancer. His passing was noted in all of the major media of the world. He was remembered as a guru of technology. His innovative ideas propelled Apple to become the world's most valuable company by market capitalization.

Steve Jobs left a profound legacy in the realm of technology, providing us with innovative ideas and designs for equipment and processes. Much of what he gave us was not necessarily new, but he saw how to combine technology, form and function, in a unique manner aiming for solutions that would be usable, aesthetic, functional and "insanely great." His quest required him to resist influences and pressures within his companies that focused on single aspects of product design, development and marketing.

Apple CEO Tim Cook speaks to employees at a celebration of Steve Jobs' life, October 19, 2011, Cupertino, California. Photo courtesy of Apple Inc.

For Jobs no detail was too small to be ignored. A key insight of his was understanding that a person's complete experience as they interacted with an Apple product was more important than the brilliance of an individual technical feature. This meant that every detail right down to the packaging of a product needed to be exceptional. A curious byproduct of Jobs' search for perfection led him to insist that the systems he designed would be proprietary so that they could not be changed in ways he did not approve. This closed system concept was counter to the philosophy of the open licensing concept advocated by Microsoft.

In his quest for the perfect product solution Jobs had to be the artful one, the technologically savvy one, the pushy one, the aesthetic one and the judging one. We all know individuals with one or more of these traits. Steve Jobs combined them all.

According to his biographer, Jobs could look at an array of products for a specific function, say cell-phones, and declare that they were "all crap." He would declare them to be too clunky, too ugly, too difficult to use and thus he developed a new smartphone, the iPhone, that would appeal to the aesthetics of the users, be technologically sound and at the same time be easy to use.

During the development process for a new piece of equipment Jobs would make design decisions that optimized the user experience while not necessarily be the best solution from a singular viewpoint. For example, marketing may decide that a product such as the iPhone was too expensive. But the new design and features appealed to people and they lined up to buy it in spite of the high cost. Marketing was wrong. The simplicity, usability and the aesthetic design of the iPhone made it a must-have object for which the users were willing to pay a premium price.

Steve Jobs did not feel constrained by the standard rules of product development and fabrication. When told that a product development would require 6 months he would allow 3 months. He hectored his people to put forth herculean efforts. If he needed an item that was not available he would either buy a factory to produce it or badger an existing producer to develop it. An example was the gorilla glass that Corning developed specifically for the iPhone because available glasses were not strong enough at the thickness required and Jobs had wanted his phone to have a glass front. Sometimes his aesthetical requirements trumped the underlying physical reality. In this event the beautifully designed original iPhone4 had a fine metal case that occasionally caused phone calls to be dropped due to an inadequate antenna.

A man of Jobs drive and exacting nature must surely bump against the edges of courtesy and sometimes even logic. So it was for Jobs. The original Mac borrowed heavily from the ideas developed at the Xerox Park laboratory. When Microsoft then developed an interface that borrowed from the Mac he was furious. Yet in the face of his achievements and generosity he might be forgiven if not understood.

Steve Jobs and Apple owe a great deal to IEEE and IEEE Standards. IEEE members developed the tools and techniques that enabled computing devices to be built. To connect these devices the IEEE standards enables the computer industry, and in particular Apple, to prosper due to the interoperability of devices. The IEEE 802 standards is the main standard for mobile communication today and it is foundational for mobile devices such as the iPhone, iPad and their clones.

Jobs borrowed the idea of smart phones from the Blackberry series of mobile phones. Again Jobs' genius was that he took current development further, simplified the phone interface and made it an object of desire. When shown the original iPhone, the management of RIM ridiculed it, declaring it would never displace Blackberries. We now know the outcome was quite different. The iPhone became a sought after object. With the next device, the iPad, the market share of intelligent mobile devices made by Apple has increased beyond the wildest expectations.

In marketing, Jobs developed a style that made him the master of product release. He worked on a new product release demonstrations, insisting on being personally involved in the set up and presentations, even including such issues as the placements of the lights. He loved to use the phrase "One more thing" at the end of the presentation, always with great effect. This was Steve the showman. When he appeared on the stage he was greeted and feted like a movie star. When he Steve Jobs passed away the headline from the Guardian on October 21 was "The deification of Steve Jobs is Apple's greatest marketing triumph to date."

With the passing of a great man we are left to consider his legacy. Due to Steve Jobs unique gifts and exceptional drive, common folk — not just the computer savvy or social elite — now have flexible access to advanced technology. Steve Jobs' passing saddened the world. He was a great and generous man. He leaves us to wonder what might have been achieved had he lived longer.

Perhaps greater than any or even the sum of all the products he spearheaded is the resulting democratization of access to complex computer technology that Steve Jobs initiated with his user friendly devices. Because of this the ordinary person now has the extended reach into the greater world that such technology enables. Steve Jobs set in motion a new kind of revolution.

About the Author

Jon Rokne is a Professor in the Department of Computer Science at the University of Calgary, having been Chair from 1989 to 1996. His research interests include interval analysis, global optimization, computer graphics and social networks. Dr. Rokne organized the installation of the first university FDDI network in Canada at the University of Calgary, and actively worked towards connecting the University to the world wide web (WWW). He spearheaded the acquisition and installation of a top 500 supercomputing facility shared with the Department of Chemistry. An IEEE member since 1970, Dr. Rokne has volunteered in a number of capacities. In the Computer Society, he has completed two terms as Vice-President, Publications and three terms on the Board of Governors. Dr. Rokne is an Associate Editor of the *IEEE Canadian Review*.

Modelling Neural Plasticity with Memristors

By Michael Crupi, Laxman Pradhan and Stuart Tozer
Carleton University

Abstract

The goal of this project was to explore the use of memristors for modelling the behaviour of neurons. This paper outlines the approaches used to build a neuromorphic circuit using only passive electronic components, including memristive devices fabricated at Carleton University. Specifically, a model of real-time pattern recognition in the human visual system was used to demonstrate how memristors could be used to simulate memory storage in the brain.

Sommaire

Le but de ce projet était d'explorer l'utilisation des memristors afin de modéliser le comportement des neurones. Ce document décrit les approches employées afin d'établir un circuit neuromorphique utilisant seulement des composants électroniques passifs, comprenant les dispositifs memristive fabriqués à l'université Carleton. Spécifiquement, un modèle de reconnaissance des structures en temps réel dans le système visuel humain a été employé pour démontrer comment des memristors pourraient être employés pour simuler le stockage de la mémoire dans le cerveau.

1.0 Introduction

The human brain is made up of over one hundred billion neurons, connected and organized into highly-specialized regions with specific functions such as processing sensory inputs, storing information and executing motor responses [1]. These regions have well-defined relationships that allow them to work together.

From an electrophysiological perspective, the brain is not well understood. Functional magnetic resonance imaging (fMRI) techniques allows neural activity to be inferred between multiple areas of the brain; however, it is not fully understood how individual neurons work together in this process [1]. Using the computer as an analogy, the individual transistors in a digital logic circuit can be compared to neurons within a brain region. It is understood how individual transistors work, but not how they are arranged into logic gates to perform operations. Modelling the connection between neurons using only simple electronic components would allow complex neural circuits to be analyzed and better understood. The difficulty with modelling neural behaviour is due to the fact that neurons exhibit memory. Modelling memory with passive electronic components only became feasible with the recent invention of the memristor.

2.0 Motivation

The original concept for this project arose from a basic understanding of memristors and how their plastic properties are similar to the behaviour of neurons and neural synaptic connections. Current research into neurophysiological mechanisms indicates that the connection between neurons is strengthened through repeated stimuli [1]. This strengthening is a graded response that represents the memory of a single neuron. An individual neuron will remember this strengthening for either a few hours (short term memory) or for years (long term memory). Memristors show analogous properties with their ability to change their resistance according to an applied current, and then remember the last resistance state after the current source has been removed [2].

Circuits that display behaviour similar to neurobiological systems are said to be neuromorphic and they are well-suited for applications that require many simultaneous processes. This parallel processing is the reason why the brain is able to manage incoming stimuli from numerous sensory systems in real-time. The visual system is a wonderful example of parallel processing because it simultaneously demonstrates an analysis of shape, motion, colour and brightness [1].

The current method for modelling neural systems involves the use of software to simulate the communication between neurons [3]. Since the act of transferring information also modifies the behaviour of each neuron, the simulating software must re-calculate the state of every neuron involved in processing a single message. The alternative solution for modelling neural behaviour could be inexpensive analog electronics that exhibit neural behaviour naturally as a result of physical properties. While modern computers operate on digital logic using only "on" and "off" states, a neuromorphic circuit would allow for graded responses that are able to store more information. Furthermore, the act of transferring information in a neuromorphic component also changes its memory, similar to the behaviour of a neuron. Fabricating these components into an integrated circuit (IC) using current CMOS technology would make it possible to build entire neural networks on a small scale and at minimal cost [4]. The primary objective of this project was to demonstrate that memristors have basic analogous properties to neurons and can therefore be used to model a neural system. The visual system provided a simple demonstration of memory storage for pattern recognition.

3.0 Background

3.1 Neuronal Signals

Communication within the human body is carried out through a complex network of nerves connecting tissues, organs and muscles to the brain. Nerves are made up of bundles of axons forming a chain for conducting a signal called an action potential [1]. These signals are said to be all-or-nothing responses because they would appear as voltage spikes with consistent amplitude if measured by an oscilloscope. The shape of each pulse is identical, regardless of the intensity of the stimulus used to trigger the signal. Instead, the strength of a signal is represented by the frequency of these spikes [1].

Without any stimulus applied, neurons fire action potentials at a predictable average rate known as the baseline response, as shown at the top of Figure 1. Strong signals, or excitation, are represented as an increased frequency in the spikes. Conversely, weak signals, or an inhibitory response, will fire action potentials at a reduced rate.

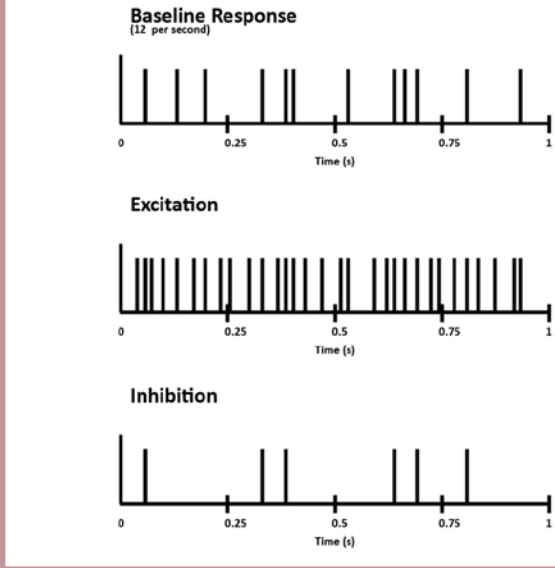

Figure 1: Frequency of action potentials for baseline, excitatory and inhibitory neuron responses. Image adapted from [1].

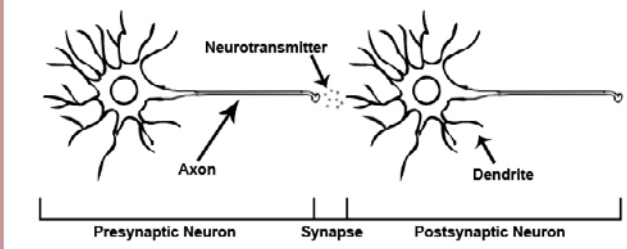

Figure 2: Dendrites receive either excitatory or inhibitory neurotransmitters from thousands of presynaptic axons. Image adapted from [1].

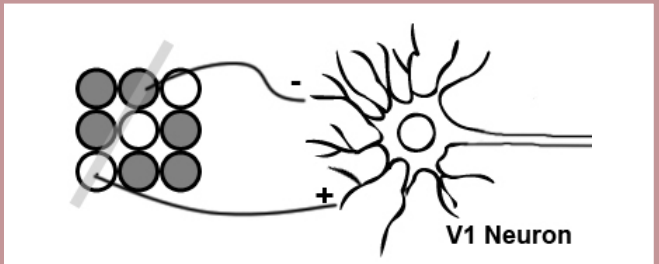

Figure 4: Inhibitory response of the V1 neuron. Image adapted from [1].

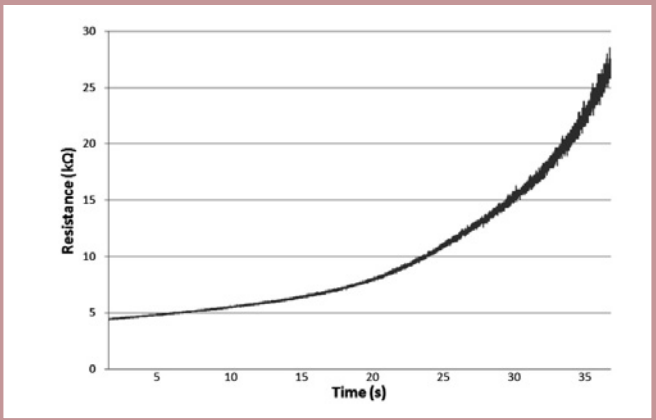

Figure 6: Plot of the measured resistance of a memristor with a constant 2.5V applied over 35 seconds.

Signals propagate from one neuron to the next through a small gap called the synapse via chemical messengers called neurotransmitters, as shown in Figure 2 [1]. The response of the post-synaptic neuron (i.e., excitation or inhibition), is determined by a summation of the incoming signals. If the resulting potential is greater than a certain threshold, the neuron will itself fire an action potential [1]. The synapse determines the strength of the communication between neurons, and therefore is the probable site of all memory storage in the brain.

In the visual system, photoreceptors convert light entering the retina of the eye into action potentials. The signal is then passed on through retinal ganglion cells to the primary visual cortex (V1) of the brain in order to interpret the image. As shown in Figures 3 and 4, retinal ganglion cells perform a certain level of pre-processing on the light that strikes their receptive fields. These receptive fields, made up of thousands of photoreceptors, are programmed to recognize a specific pattern of light, in this case, a diagonal line. When this pattern is viewed, the positive responses are summated at the V1 neuron, generating a strong response (Figure 3). When the pattern is not exact, a weaker response is exhibited by the V1 neuron (Figure 4). This is the basis of shape recognition in the visual system [1].

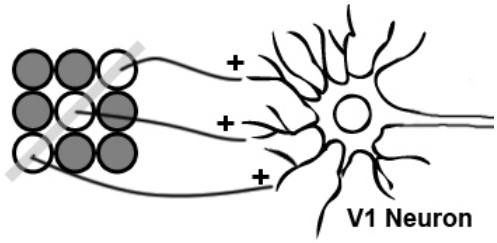

Figure 3: Excitatory response of the V1 neuron. Image adapted from [1].

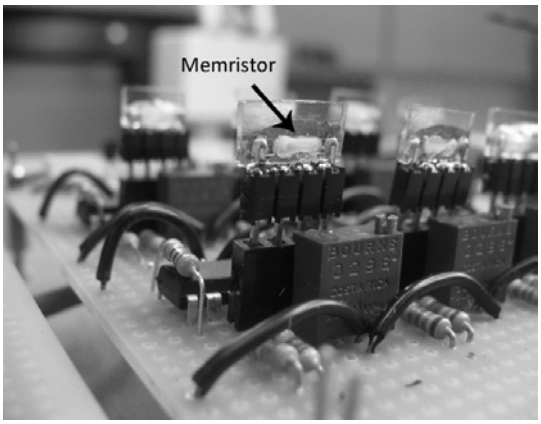

Figure 5: Circuit board containing nine memristor devices, one for each of the nine synapse circuits. Each memristor is a two terminal device printed onto a glass plate and covered by epoxy, a process developed at Carleton University.

3.2 Memristive Devices

The concept of a missing fundamental element in electronic circuit theory was first described by Leon Chua in 1971. Dr. Chua theorized that there must be a passive two-terminal circuit element that relates the time integral of voltage (flux) to the time integral of current (charge). The element was named a "memristor" because it possesses a resistance value that is a function of current flow and this resistance value is retained when the memristor is disconnected and therefore has memory [2].

The memristive devices that were used for this project were fabricated in the Organic Device Fabrication Lab at Carleton University by Professor Steven McGarry. The memristors, shown in Figure 5, have a resistance that changes based on the direction of current flowing through the device.

In one direction, current will cause the resistance in the memristor to increase, as shown in Figure 6. Current in the opposite direction will decrease the resistance.

These particular memristors work by intercalating ions from a storage region of the device into the active region. When a voltage is applied to the device, the electric field causes the ions to drift towards either the anode or cathode depending on the charge of the ions being used. When the concentration of ions within the active region of the device is changed, the resistance is changed as well. When no voltage is applied, the concentration gradient of the ions forces them back into their initial state, and therefore initial resistance [5]. As a result, when no voltage is applied, the resistance of the device slowly reverts to its default value. This is analogous to the short term memory of a neuron where the connection strength decreases over time if the neuron is not used.

Using various geometries, substrate materials and ions, the rate at which the ions intercalate into the active region and then diffuse back to their original state can be adjusted. Therefore, memristors with various time constants can be created to simulate short and long term memory [5].

4.0 Synapse Circuit

A modified Wheatstone bridge circuit was used as the basis for modelling the behaviour of a neural synapse. Similar Wheatstone bridge circuits are commonly used in sensors to compare the value of a condition-

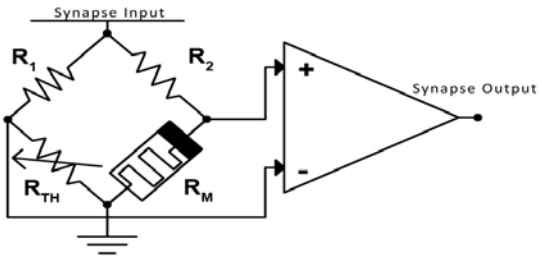

Figure 7: Implementation of a memristor in a Wheatstone bridge circuit to represent a neural synapse.

varying resistance to a fixed reference. In this case, the circuit was used to compare the resistance of the memristor (R_M) against that of a threshold potentiometer (R_{TH}), as shown in Figure 7. The potentiometer is used to account for slight variations in device properties and ensure that the memory time of each synapse circuit is identical. In Figure 7, R_1 and R_2 are matched resistors to ensure the memristor can be accurately compared to the threshold resistor. The memristor represents the strength of the synapse connecting two neurons while the threshold resistor is used to set the time required for the synapse to learn. Initially, each stimulated neuron produces an inhibitory output until it has been trained, at which point it produces an excitatory output. Similarly, the resistance of the memristor is initially less than that of the threshold resistor and the circuit will output a negative voltage. When the resistance of the memristor is increased to above that of the threshold resistor, the circuit will output a positive voltage. Therefore, the memristor is used to remember the strength of the synapse while the Wheatstone bridge is used to model the inhibitory and excitatory behaviour of the neuron.

During implementation, the circuit would initially receive a large input voltage so that the memristor could be trained (increase its resistance). Later, the memristor would be tested at a lower voltage in order to test the resistance without changing its value. When tested, if the resistance of the memristor was above that of the threshold resistor, the amplifier would output a positive voltage. Given no input, the memristor's resistance would gradually decrease over time and fall below that of the threshold resistor's resistance. When this occurred, the amplifier output would become negative when tested. Table 1, below, is the state table of this circuit.

Case #	Trained?	Stimulus	Output (V)
1	Yes	Yes	+5
2		No	0
3	No	Yes	-5
4		No	0

Table 1: Synapse circuit state table

As shown in the state table, if there are no inputs to the circuit, the output is 0V regardless of the training state of the memristor. This behaviour is representative of the baseline response of a neuron that is not being stimulated. When the circuit receives an input from the phototransistors, the output will depend on the state of the memristor. If the memristor has been trained, its resistance will be high and the output will be +5V. If the memristor has not been trained, its resistance will be low and the output will be -5V. In all other cases, the output will be the baseline response (0V). Therefore, a very simple circuit utilizing a memristor can be used to model the behaviour of a synapse.

5.0 Neuromorphic Circuit Design

The visual system contains many overlapping arrays of photoreceptors and associated neurons, programmed to identify specific patterns. To model this, a 3x3 grid of nine synapse circuits was built, as shown in Figure 8.

Each synapse circuit was designed to take an input from a phototransistor, and each phototransistor was matched with an LED, as shown in Figure 9. The output of the phototransistor was then used as an input to the synapse circuit.

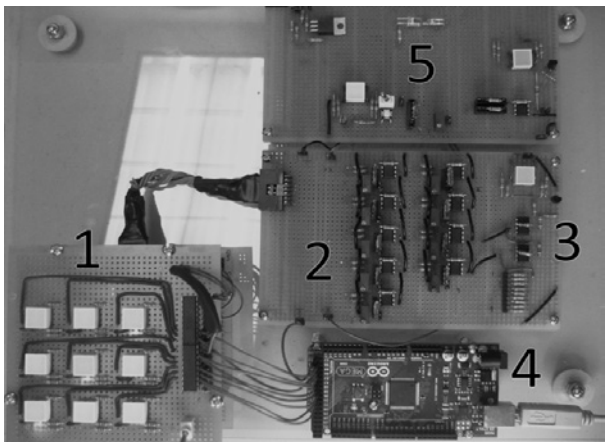

Figure 8.: The completed neuromorphic circuit
(1) LED and phototransistor grids
(2) Memristor array circuit
(3) Summation circuit
(4) Microcontroller for LED control
(5) Single-synapse proof of concept circuit

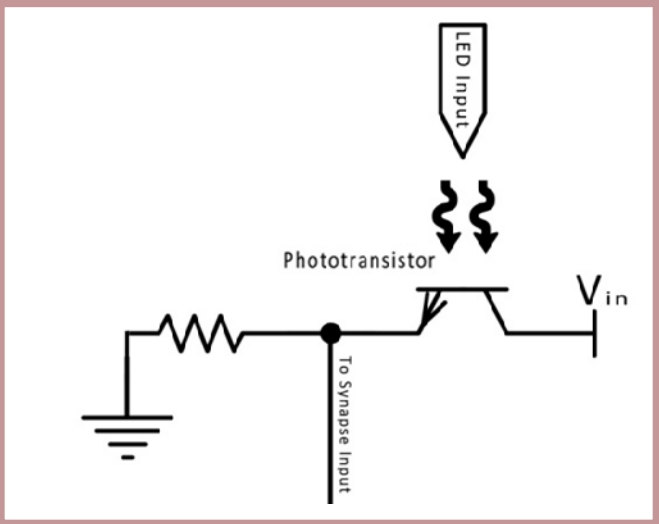

Figure 9: Implementation of a phototransistor for receiving light as an input to the synapse circuit.

When an LED was turned on, a voltage was generated at the corresponding phototransistor. Since the LEDs were individually triggered by a microcontroller, various patterns of stimuli could be generated for the grid. For example, if only the middle row of three LEDs was turned on, only the three corresponding memristors would increase their resistance value. After they had been trained, a test pattern could be shown to the grid. If the test pattern was identical, the three trained synapse circuits would output positive voltages while the remaining six synapse circuits would output the baseline response (0V). If the pattern was incorrect, untrained synapse circuits would be receiving inputs which would produce a negative voltage. Each of these output voltages was then processed at the summation circuit. The complete input stage is shown in Figure 10.

6.0 Summation Circuit

In order to process the output from the nine synapse circuits, an op-amp based summation circuit was built, as shown in Figure 11. The summation circuit was setup with a particular threshold such that if the sum of all the voltages was above that threshold, there would be a positive output signal. In all other cases there would be a baseline response (0V). This is similar to the way neurons work where all the inputs are summed at the cell membrane and if the result is above a certain threshold, the neuron will produce an action potential.

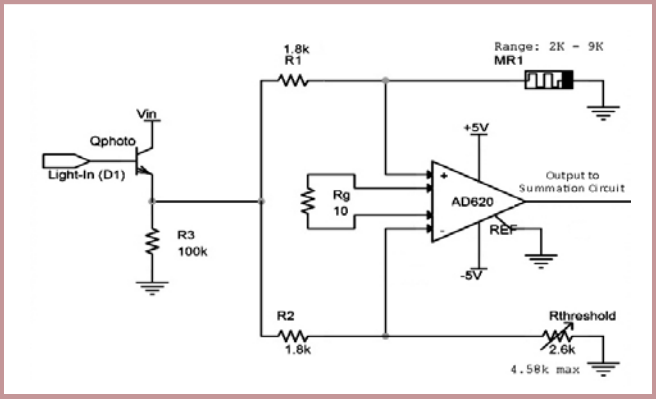

Figure 10: The single-synapse circuit with a phototransistor input and an output to the summation circuit.

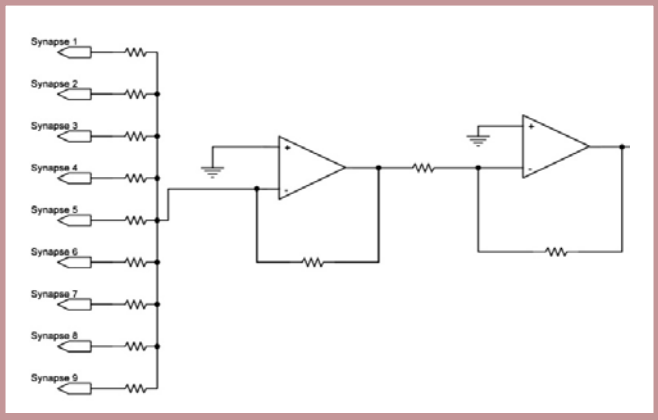

Figure 11: The Summation Circuit

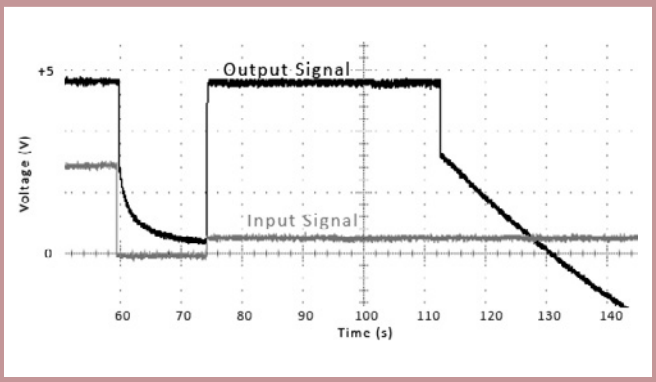

Figure 12: Excitatory memristor response, represented as +5V for a small 0.5V input.

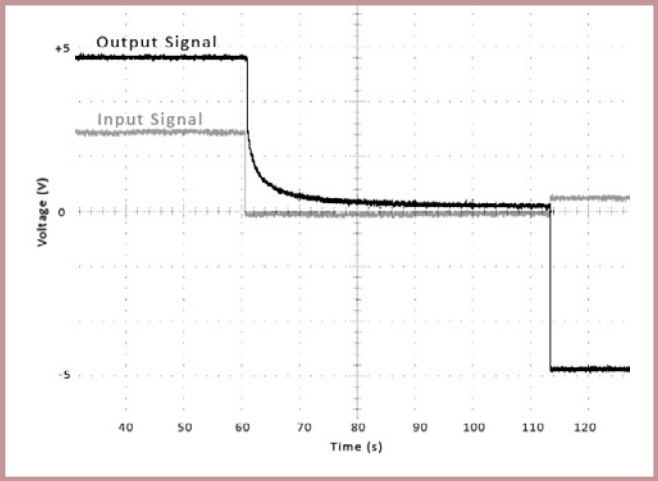

Figure 13: Inhibitory memristor response, represented as –5V for a small 0.5V input.

7.0 Results

7.1 Single Synapse Circuit Testing

The single synapse circuit was a proof of concept demonstration of the implementation of a Wheatstone bridge with a memristor. As seen in Figure 12, the memristor was trained for 60s with a 2.5V input signal. The input signal was then removed for 14s, lowered to 0.5V, and re-applied, generating a high (+5V) output. The figure shows recognition of training for approximately 40 seconds after the input signal voltage was lowered from the training voltage to the testing voltage. At this point (seen at the 112s mark in the graph), the output signal begins to fall off, with the effect of training completely disappearing in approximately another 50s (beyond the cut-off point of the graph).

At the molecular level, the memristor begins to "forget" that it was trained as soon as the training voltage ends at 60s; its resistance starts to decrease as ions previously accumulated drift apart. The input voltage of 0.5V applied at 74s to detect how long the training effect lasts is low enough that it does not interfere with this decay process.

In Figure 13, a synapse circuit was trained for approximately 60s and then had no input for 54s. During this time the ions of the memristor drifted back to their original state. When the input stimulus was reapplied, the result was a negative voltage, indicating that the memristor was no longer trained and the memory time had expired. These devices were designed to be trained in approximately 60s (+/- 10s) and then retain that memory for another 60s (+/- 10s).

The results from the single synapse circuit allowed the memory time of a single memristive device to be characterized. This was useful for the eventual implementation of nine memristors in a grid array for the next stage of the project.

7.2 Testing Methodology for Pattern Recognition in Grid

Each LED in the grid was individually controlled by a microcontroller which allowed various patterns of inputs to be used on the synapse circuits in a repeatable and predictable manner. Initially, a training pattern would be shown for 60s to allow the resistance of the corresponding memristors to increase, thereby learning that pattern. Once the pattern was learnt, different test patterns were shown to the circuit. If the test pattern was the same, the summation circuit would output +5V. In all other cases it would output less than +5V. Therefore the final threshold indicating a correct memory was the +5V output from the summation circuit. The summation circuit was connected to an LED for demonstration purposes so that the LED would turn on if the pattern being shown was the same one that was learnt. This provided a quick visual verification for each test. Various patterns of three LEDs were taught to the circuit. For each pattern, a set of ten test patterns were shown to see if the correct pattern would be recognized and if the incorrect patterns would be rejected. Some of these results are shown in Table 2 on page 14.

7.3 Pattern Recognition

Using the complete memristor array circuit, a series of pattern inputs from the LED stimulus grid were tested. The training patterns shown below were compared with very similar patterns (only one displaced node) as well as very different patterns (all three test nodes are different). The resultant voltage was not identical in every test case, so the summation results are an average over multiple test trials and summarized in Table 2.

The summation circuit was designed such that only a +5V output would turn on the final LED to indicate a correct pattern match. This additional level of thresholding was useful for obtaining a high sensitivity, because the circuit was able to successfully identify all the correct patterns that it was shown, as long as the memristors were still in their memory state (high-resistance). The results in Table 2 also show that incorrect patterns, even ones which were very similar to the original, did not yield a +5V output. Due to the same thresholding factor, the circuit was also able to successfully reject all incorrect patterns that were tested during the memristor memory stage, indicating a high specificity.

Training pattern	Testing pattern	Summation output voltage	Final LED (ON/OFF)
1, 7, 9	2, 6, 8	-5.0 V	OFF
	3, 7, 9	+1.7 V	OFF
	1, 7, 9	+5.0 V	ON
2, 4, 8	3, 7, 9	-5.0 V	OFF
	2, 6, 8	+1.7 V	OFF
	2, 4, 8	+5.0 V	ON
1, 5, 9	3, 5, 7	-1.7 V	OFF
	2, 4, 5	+1.7 V	OFF
	1, 5, 9	+5.0 V	ON
5, 6, 9	4 , 5, 7	-1.7 V	OFF
	2, 5, 6	+1.7 V	OFF
	5, 6, 9	+5.0 V	ON

Table 2: Results for the comparison tests for sensitivity and specificity of the circuit

7.4 Future Developments

The synapse circuit was designed to work with binary excitatory or inhibitory inputs. The next stage of this project would take advantage of the graded response behaviour of memristors in order to create a more accurate model of the neuron. In terms of image recognition, this would mean identifying similar patterns and distinguishing them from patterns that were completely incorrect or only partially incorrect.

Future work would also involve multiple synapse grids, each trained to recognize a particular pattern. Light from an image would be shown on each grid simultaneously such that complex images could be deconstructed into basic patterns such as horizontal and vertical lines. The output of each grid would allow the image to be quickly deconstructed into its various elements. This is how the human visual system is able to quickly recognize complicated objects. Simulating neurons in software on a human scale is not feasible because every time a neuron is used, its synapse strength would have to be recalculated. Computing millions of calculations for every single action potential is not feasible with current technology. However, using existing CMOS technology, millions of memristors can be fabricated cheaply. By virtue of the memristor's electrical properties, the synapse strength is automatically changed in response to the input. This allows millions of neurons to be simulated efficiently.

8.0 Conclusion

The analogous properties of memristors and neurons are emerging as an intriguing and innovative area of research in recent years. The successful demonstration of pattern recognition with the memristor grid circuit is an important step towards furthering this research as well as emphasizing the potential application of memristors in neuromorphic circuits. In particular, pattern recognition with LEDs, phototransistors, and memristors can be directly compared to the biological processes with neurons in the visual system. This model demonstrates how memristors could be used to passively store memory states, and then recall this information in future processes.

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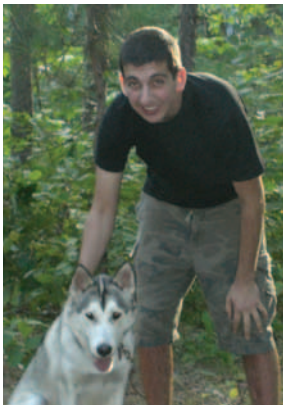
About the Authors

Laxman Pradhan received his Bachelor of Biomedical and Electrical Engineering degree from Carleton University in 2011. A member of IEEE for five years, he was also Chair of Carleton's IEEE Student Branch and President of the Biomedical Engineering Society. Currently enrolled in St. George's Medical School, he looks forward to working in the field of biomedical engineering and applying that research knowledge in a clinical setting with patients. Outside of work, Laxman enjoys traveling around the world looking at different types of architecture and tasting the local whiskey, especially from Europe and Japan.

Stuart Tozer received his Bachelor of Biomedical and Electrical Engineering degree from Carleton University in 2011. Stuart is currently working towards a Master of Science degree in Aerospace Engineering Sciences, focusing on Bioastronautics, at the University of Colorado Boulder. His ongoing project work includes a conceptual design for a sustainable lunar base and the development of a hybrid sounding rocket. Stuart has been a member of IEEE for five years and he is a member of Students for the Exploration and Development of Space (SEDS). In his leisure time, Stuart enjoys hiking Colorado's many "fourteeners" (14,000 ft peaks), snowboarding, and playing hockey.



Michael Crupi received his Bachelor of Biomedical and Electrical. Engineering from Carleton University in 2011. He is currently a Master's of Health Science in Clinical Engineering candidate at the University of Toronto, where his thesis work investigates improving patient safety during radiation therapy. His hobbies and personal interests include team sports such as hockey, ball hockey and flag football as well as outdoor activities such as golfing, fishing and hiking. (This photo shows Mike and his dog Meeko enjoying the great weather while camping in Bancroft, ON).

N. Ed.

The authors' article was originally submitted to the 2011 IEEE Canada Student Paper Competition, and selected as the best paper from amongst Eastern Canada entrants. Two prizes of $500 are funded annually by Life Members, awarded to the top papers from Western and Eastern Canada.

The winning paper from the West was authored by Kane Anderson, Tahir Diop and Yin Fei Meng, and was entitled "Variable Lift Controls in Weather Balloons for Near Space Applications." The authors are all from the University of Manitoba.

A third paper is selected as Runner up, receiving the Hackbusch Award of $250. The 2011 recipient was Emily Landry from the University of British Columbia's Okanagan Campus for her paper, "Modeling of Water Droplet Contact Angle Manipulation Using a Pulsed Wave Beam."

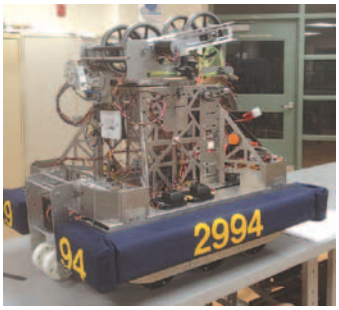
IEEE Canadian Foundation Special Grants

Benefitting humanity is no small goal—whether through "fostering technological innovation and excellence" or otherwise. So when the IEEE Canadian Foundation (ICF) chose a name for its grants to students that advance IEEE's core purpose, "Special Grants" seemed quite apropos. Following are reports on three of them.

The University of Manitoba Student Branch received a grant for its T-Sat project. The project is a continuation of the Canadian Satellite Design Challenge that is repeated every two years to encourage universities to build on their previous experiences. The competition involves the implementation and testing of an operational triple pico-satellite; the University of Manitoba team is designing the COM system. The winning design will be launched into a low-earth orbit, and the students who designed it will follow the telemetry, and payload data for the life of the satellite.

The University of Waterloo Nano-Robotics Group is building a micro-scale robot to manipulate micro-scale objects with micrometer precision. This is a polymer assembly with a micro-compressor incorporated to provide the motive power. The compressor is thermally activated by a high powered laser shining on the compressor's membrane. Funding from the ICF was towards participation in the 2012 IEEE ICRA Microassembly Challenge in Minnesota. In addition to ongoing competitions, the group members participate in community outreach programs to encourage continued participation at the high school level in robotics competitions.

The All Saints High School Robotics Team (Kanata, Ontario) has had a busy spring. With support from the ICF, the team competed in the FIRST Robotics Competition in Oshawa, Ontario, March 8-10, 2012, then at the Ontario Skills Competition, held April 30 - May 2, 2012 in Waterloo, Ontario. Dubbed the ASTECHZ, it was founded in 2006, says Team Mentor Paul McDonough. "Team members gain experience in various technologies and disciplines such as engineering, programming, design and project management, as well as team building and gracious professionalism," McDonough says.



The Team's entry for the 2012 FIRST Robotics competition. The device was designed to score baskets in the Rebound Rumble, this year's challenge. Higher baskets yielded more points.

For these and all Special Grant recipients, a portion of the funding is expected to be raised through additional donations. Upon completion of the project, recipients submit a full report.

Many thanks to ICF Development Committee member John Mowbray for contributing this report.

2011 IEEE Canada WIE Prize Presented

Susan Ryan had a few reasons to smile at the Newfoundland and Labrador Section Annual General Meeting last December. As head of membership development, seeing the strong turn-out was certainly one.

But being presented with IEEE Canada's 2011 Women in Engineering Prize was definitely a proud moment too. The annual prize of $1,000 is funded by donations to the IEEE Canadian Foundation.

Graduating in 2010 from Memorial University of Newfoundland in electrical engineering, Ms. Ryan was selected from a field of five nominees. She was a Junior Representative for her student branch for two years and then became Chair for the last two years of her undergraduate degree studies. While serving in these roles, she attended the Annual IEEE Student Congress, volunteered with the NL Electrical and Computer Engineering Conference, volunteered at the Annual Term 8 IEEE Night, attended the IEEE Student Meeting in Singapore, and attended the Region 10 Student Congress there, as well. While a student member, she was awarded the Term 6 IEEE NL Section Award. Ryan has been involved with both IEEE GOLD and WIE since fall 2011.

Susan Ryan (left) is presented with the 2011 WIE Prize by outgoing NL Section Chair Lori Hogan at the Section's AGM, December 5, 2011.

Among her non-IEEE extracurricular activities, Ryan raised money annually for the Crohn's and Colitis Foundation. She was also the Engineering Representative for the Women in Science and Engineering Student Branch. Ryan has also volunteered with the Girl Guides. She enjoys hiking and reading in her spare time.

Not that many hours in Ryan's day are unspoken for, though. Dr. Octavia Dobre, head of Section WIE activities and Ryan's nominator, is planning outreach events targeting high school female students involving her. No resting on laurels here!

Can. Atlantic Section Boosts IEEE Visibility with Engineering Month, Unmanned Systems Conf.

For most members, the idiom "hitch your wagon to ... " conjures up imagery belonging to the distant past. But for Mae Seto and Dirk Werle of Canadian Atlantic Section, joining in on local events already planned is a visibility strategy surely as effective as IEEE spells 21st century.

"Engineering Month is a pretty big train," observes Werle, TISP Champion for the Section and recently appointed editor-in-chief of the *TISP Canada Courier*. "Engineers Nova Scotia was the engine we hitched up with, giving us far more traction than what we could achieve alone."

The main stop on the line in Nova Scotia was at Halifax's Mic Mac Mall on March 24th. Several events were jointly organized by Engineers Nova Scotia, Dalhousie University's SuperNova Science Program and IEEE Canadian Atlantic Section. The latter's TISP Committee and joint Robotics and Automation Society/IMS Chapter hosted a senior high school level robotic arm building competition. "Lower micro-processor and sensor costs have made robotics extremely popular with the public and especially students," notes Dr. Seto, RAS/IMS Chapter Chair. "The RAS is increasingly seeking to help IEEE engage the public and government to build on this interest."

Photo Credit: Dirk Werle

Mae Seto of Canadian Atlantic Section judges at the robotic arm building competion as part of 2012 Engineering Month activities the Section organized.

An Adjunct Professor at Dalhousie University's Department of Mechanical Engineering, Seto helped colleagues from the Civil Engineering Dept. in organizing the 6th Annual Provincial Junior High Popsicle Bridge Challenge. The crowd-pleasing finale being the inevitable crunch as each entry was subjected to destructive load testing.

Back in October, Seto's gaze down another set of tracks positioned the RAS/IMS Chapter right at the front of a different train. The Unmanned Systems Conference is an annual event organized by Unmanned Systems Canada, a Canadian-registered not-for-profit industry association. The 2011 Conference was to take place in Halifax, November 7-10. Seto, also a Defence Scientist with Defence R&D Canada (DRDC) with expertise in unmanned marine robots, had already been tasked with organizing a demonstration at the Conference. Land, sea and air capability was to be showcased in Halifax by DRDC's five labs across the country.

Negotiating a booth for the Section's RAS/IMS Chapter, Seto arranged for Dalhousie graduate students to staff it, and also participate in the DRDC demonstration. As a Faculty Advisor for the Dalhousie ROV team, Seto brought its 15 students in to display their project, with the "tremendous" support of Conference Coordinator Leah McGroggan. Seto also arranged for students from the Robotics Club of Halifax's Sacred Heart High School to showcase their club's robot, meet exhibitors and view the DRDC demonstration.

Photo Credit: Leah McGroggan Unmanned Systems Canada

Clarissa Brisseau (left) and Rebecca Ford (right) from Sacred Heart High School in Halifx chat with the Honourable Percy Paris, Nova Scotia Minister of Economic and Rural Development and Tourism at the 2011 Unmanned Systems Conference last November.

Japan's Reco

by Keith Hipel,

There is no denying the grim statistics of the biggest earthquake ever to wreak havoc on Japan. The Great East Japan Earthquake struck Friday March 11, 2011, at 2:46 pm in the afternoon 70 km east of the Oshika Peninsula along the Pacific coast of northern Honshu in a region called Tohoku.

At magnitude 9.0, it triggered tsunami waves that reached unimaginable heights of 40.5 meters, travelling 10 km inland near the city of Sendai, actually moving the main island of Honshu 2.4 meters eastwards. Such a massive tsunami was totally unexpected. As a result, 15,850 people were killed, with 3,287 persons missing and 6,011 injured. An estimated 125,000 buildings were destroyed or damaged.

Moreover, the damage from the tsunami caused a level 7 meltdown at three reactors at the Fukushima Daiichi Nuclear Power Plant complex. Residents who lived within a 20 km radius of the above mentioned nuclear plant and people residing within 10 km radius of the Fukushima II Nuclear Power Plant were evacuated. As a safety precaution and also to provide time for engineers to redesign safety features, most of these reactors have now been shut down. As of January 2012, 49 of the nation's 54 reactors were offline.

But often lost in the reporting of these horrific events is the fact that, due to lessons learned from earlier earthquakes, Japan's strengthened infrastructure prevented much worse devastation: No major building collapsed because of the robust earthquake-resistant design of the newer and larger buildings; additionally, all of the Shinkansen or bullet trains were automatically stopped and hence there were no major train accidents.

In late January of this year I visited three sites near the city of Sendai that were damaged by the tsunami, a guest of colleagues from Tottori and Kyoto Universities, with whom I have had a wonderful 25-year affiliation through the student exchange programs I co-founded that encompasses these institutions and the University of Waterloo. Fortunately, this trip to Japan was less eventful than a similar trip I had made in 1995. Staying overnight with my wife at a friend's private home near Kobe, at 5:46 am on January 17, the Great Hansin Earthquake struck near that city. We thought the house was going to collapse – luckily it did not. Even though this shallow earthquake only registered 6.9 on the Richter scale, it caused extensive damage; 6,425 people killed, 25,000 injured, 300,000 displaced and 100,000 buildings damaged or destroyed. This was the worst earthquake to hit Japan since the Great Tokyo Earthquake of 1923, which recorded a score of 7.9 on the Richter scale and killed 140,000 people. Design improvements following the Kobe earthquake helped minimize quake-related damage in this most recent event.

On the following pages I've tried to convey not only a sense of the scope of the disaster, but the determination of a people to rebuild and recover.

Overlooking the tsunami-devastated city of Ishinomaki are (left to right) Shigenobu Tanaka (Public Works Research Institute), Norio Okada (Kyoto University) and Keith Hipel (University of Waterloo, Centre for International Governance Innovation). The city was established in the fourth century as a rice-shipping port.

On this tour, Tanaka was reviewing the substantial progress towards cleanup and reconstruction in his capacity as Deputy Director of the International Centre for Water Hazard and Risk Management under the auspices of UNESCO. Okada recently completed a two-year term as Director of the Disaster Prevention Research Institute at Kyoto University, the most famous risk institute in Asia. He is also a co-founder along with the author of the exchange programs that the University of Waterloo has with Tottori University and Kyoto University.

In the foreground, a concrete school Arahama is badly dammaged by the ts of Sendai in the background is on high 10 km from the sea. It was not touche nor did any major buildings collaps robust design and construction.

The tsunami over-topped the dyke along the coast-line at the former village of Arahama (means severe beach), near Sendai. Thousands died.

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The Hayate Shinkansen bullet train the author boarded at Tokyo Station. The 300 km journey to Sendai took just under 2 hours. When the quake struck the bullet trains were automatically stopped and hence there were no major train accidents.

Photo credits: Keith Hipel

The Japanese cultural response to living on shifting ground — literally — is summed up in one word: proactivtiy. Accepting the inevitability of natural hazards, they design systems to minimize their effects and expedite recovery. The process of recovery is engrained into the hearts and minds of the Japanese people, as well as in the design of their infrastructure systems. This includes the design of effective policies and governance systems, to ensure that societal systems perform according to the value systems of the stakeholders whom they are meant to serve.

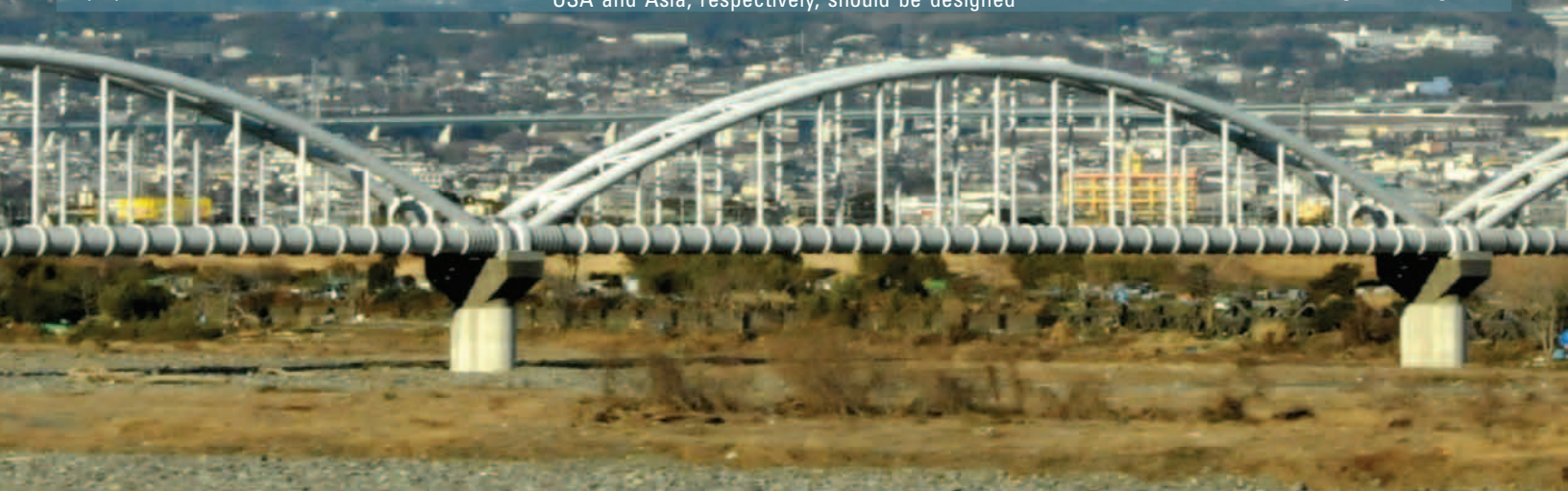
Perhaps most importantly, Japan has kept control of its industrial destiny by thinking strategically — most industry in Japan is owned by Japanese shareholders and individuals. Therefore, a large proportion of the jobs in management, and research and development, remain *in* Japan, even if some manufacturing is done in countries like China and Thailand where labor costs are significantly lower.

Canadians have been highly successful in designing many large-scale physical systems in the past to fulfill their objectives. In fact, the Canadian railway system built in the 1880s from coast to coast was the physical representation of the crazy idea that a large country in terms of territory could become a federation of a relatively small number of people that would survive and flourish — and, indeed, this dream became reality. Canadians continue to design and build great systems to serve our interests such as the St. Lawrence Seaway, the CANDU reactor and systems for extracting bitumen in large quantities from the oil sands. But the author questions whether the design of our governance systems still adequately reflects our value systems and strategic interests.

For example, is it wise for the Province of Alberta and the Canadian Federal Government to allow bitumen from the oil sands to be shipped out of Canada to be processed elsewhere, foregoing the "value-added" to this energy resource, in great demand around the globe? Currently, more than 30% of the bitumen is not being refined in Canada. This figure is expected to rise to more than 50%, according to C.W. (Clem) Bowman, Chair of the Energy Pathways Task Force, Canadian Academy of Engineering. The proposed pipeline to ship unrefined bitumen via the Keystone and Northern Gateway pipelines to the USA and Asia, respectively, should be designed and constructed for transporting only fully refined petroleum products, the author believes. Ensuring that all value-added activities take place in Canada would create meaningful widespread employment for Canadians, and generate significant wealth that could be used for supporting Canada's envied medical system and other beneficial programs, as well as reduce Canadian income taxes.

The author challenges engineers to help design effective and fair governance systems for this great country of ours that will serve the interests of every individual Canadian citizen. Our industrial, energy, water, environmental and other connected policies should be designed to deliver real meaning and prosperity to the lives of all Canadians. Although the Japanese system could be improved, the Japanese have many outstanding policies and customs from which we have much to learn.

Acknowledgements: The author expresses his appreciation for being invited by editor-in-chief Amir Aghdam to contribute to the *IEEE Canadian Review*. He also extends his gratitude to Bruce Van-Lane and his organization Communication Matters, for assistance in editing and design.



Keith W. Hipel is *University Professor* of Systems Design Engineering and *Coordinator* of the Conflict Analysis Group at the University of Waterloo. He is *Senior Fellow* at the Centre for International Governance Innovation and *Chair* of the Board of Governors of Renison University College. His major research interests are the development and application of conflict resolution, multiple objective decision making, and time series analysis techniques from a system of systems engineering perspective, with applications in water resources management, hydrology environmental engineering and sustainable development. Keith is the recipient of the 2011 IEEE Canada Outstanding Engineering Educator Award, the IEEE Systems, Man and Cybernetics Norbert Wiener Award (USA) and Sir John William Dawson Medal (Royal Society of Canada). In February 2012 he was named recipient of the *Japan Society for the Promotion of Science (JSPS) Eminent Scientist Award*, bestowed upon "foreign researchers who possess a record of excellent research achievements and who are mentors and leaders in their respective fields." Generally four scientists are granted this award each fiscal year. Three of the four 2011 recipients are nobel laureates, and all three in 2010 are.

Limitations of Distance Protection Associated with the Integration of Renewable Sources

By Alexandre B. Nassif, Fenghai Sui and Miroslav Kostic
Hydro One Networks Inc.

Abstract

Renewable energy sources have received widespread promotion in a drive to offset their polluting counterparts. In Ontario alone over 1.2 GW of renewable energy sources are going to be connected to the transmission grid. Installation of these sources in such dispersed fashion results in system performance degradation, which creates challenges for the transmitter. Power system protection dependability and security can be seriously compromised unless mitigating measures are adopted. Protection and Control planning studies conducted by Hydro One assessed the prevalence of excessively enlarged apparent impedance and current outfeed (current reversal) as being the main culprits of power system protection challenges. A simple criterion is presented to examine current reversal issue in this paper. The paper also presents a case study that encompasses these challenges, along with the solutions that were required for the system to tolerate the new generation. Detailed studies reveal that the required solutions, unanticipated by the proponents as well as by the transmission planners, would be costly. Protection engineers should be aware of these problems and how prevalent they can become as programs such as the Feed-In-Tariff (FIT) program, which in various forms exists in many countries, are adopted.

Sommaire

Les sources d'énergie renouvelables ont fait l'objet d'une large promotion afin de se démarquer de leurs contreparties polluantes. Seulement en Ontario plus de 1.2 GW de sources d'énergie renouvelable vont être reliées au réseau électrique. L'installation de ces sources de façon dispersée a comme conséquence la dégradation de la performance du système, qui représente des défis pour la transmission. La fiabilité et la sécurité de la protection du système d'alimentation peuvent être sérieusement compromises à moins que des mesures d'atténuation ne soient adoptées. Les études de planification de la protection et de la commande entreprises par Hydro One ont évalué que les principaux coupables reliés aux défis de protection de système d'alimentation étaient la prédominance d'une impédance apparente excessivement grande et le courant de sortie (inversion de courant). Un critère simple est présenté pour examiner le problème d'inversion du courant dans cet article. L'article présente également une étude de cas qui englobe ces défis, avec les solutions qui ont été exigées afin que le système tolère la nouvelle génération. Les études détaillées indiquent que les solutions exigées, non anticipées par les partisans et par les planificateurs de la transmission, seraient coûteuses. Les ingénieurs en charge de la protection devraient être au courant de ces problèmes et de quelle façon ils peuvent devenir importants pour des programmes tels que le programme Feed-In-Tarif (FIT), qui sous diverses formes existent dans beaucoup de pays et sont adoptés.

1.0 Introduction

Over the years, protection design philosophies for transmission systems have evolved and diversified. Each utility may apply its own protection practices independently. Large generation plants and the buses connected thereto have always been vital assets that deserved the utmost care from protection engineers. In the past, transmission-connected plants were centralized and connected to the transmission facilities via lines that are connected to station buses, or alternatively tied directly into the buses in adjacent transmission switchyards. From the protection engineering perspective, this traditional configuration is very robust.

Nowadays, however, there has been a rapid change of the transmission grid's configuration and its operating conditions. With the objective of increasing the usage of cleaner sources and diversifying the supply, renewable generation has been installed on large scale, propelled by government initiatives such as the FIT programs [1]-[2]. In Canada, this number is expected to continue increasing at an even steeper rate [3]. The province of Ontario alone is expected to connect over 1.2 GW of renewable sources between 2011 and 2014, the vast majority consisting of solar and wind farms. This number is expected to multiply before 2025. While many of these new generation stations consist of relatively small plants (<50MW), a significant number of medium- to large-sized (50MW-300MW) wind and/or solar plants are being connected to Ontario's transmission lines [4].

However, most of the existing protection philosophy and relaying schemes were created for the earlier grid configuration. In many cases, they do not offer satisfactory performance for the reconfigured system nor for the operational conditions that new connections and renewable technologies are influencing. Due to wind and solar generators being installed in a wide range of locations, and their relatively small size, building a new switching station for each of these plants is simply not regarded as economical by most transmission utilities. It would also impose additional, many times prohibitive, costs on the proponents.

In Ontario, most newly approved generators are allowed to connect to transmission lines up to 230kV by simply tapping off the circuit via a circuit breaker. Connections to 500kV are more complex and the type of connection is presently under consideration. Line sectionalization and building a new switching station is typically required only if the conventional connection is proven not feasible due to transmission/stability limits, protection or operational considerations. This practice creates protection challenges, one of which is that the instantaneous distance coverage (Zone 1) may be reduced not to reach into the customer's tap line or transformer. Consequently, Zone 1 steps at different terminals would no longer overlap and part of the line would be protected by timed Zone 2 steps only.

As one can see, this practice can introduce significant system degradation, which is not limited to, but includes extended fault clearing times. This paper reports and analyzes challenges associated with new wind and solar farms that are being connected in the Hydro One system. Some cases are leading to changes in present protection philosophy or applications. A case study is presented to illustrate some of these problems, along with Hydro One's solution for allowing the generator to be connected.

This paper is structured in the following manner. Section 2 presents the key protection challenges that cover the variations of large apparent impedance and current outfeed. Section 3 explains the adopted solutions, along with their applicability and limitations. Section 4 presents a case study, the problems encountered and implemented solutions. Section 5 concludes the paper.

2.0 Apparent Impedance and Current Outfeed

Excessively large apparent impedance caused by additional infeed is not a new phenomenon [5]-[6]. However, due to large penetration of dispersed generation in transmission systems, large apparent effects are becoming commonplace and deserve increasing care from transmitters. Current Outfeed (also referred to as Current Reversal), conversely, even though reported in literature [7]-[8], is not a commonly observed fact and for this reason it has not been widely reported by utilities. Both phenomena are concisely explained in this section following a brief background on distance protection of transmission lines.

2.1 Protection of Transmission Lines

Due to space limitations, this paper will only address schemes related to distance protection. Distance-based tele-protection schemes can vary greatly. Fig. 1 illustrates the most typical case, where two protection

zones are implemented (instantaneous Zone 1 and timed Zone 2) between two terminal stations. Zone 1 stages at both terminal stations typically overlap and therefore faults occurring within the overlapping zones are cleared instantaneously. However, if a fault such as that shown in Fig. 1 occurs outside of Terminal Station 1 Zone 1 coverage, the relay at Terminal Station 2 senses the fault, trips instantaneously and transmits a transfer trip (or remote trip) signal to open the breaker(s) at Terminal Station 1 with little or no time delay.

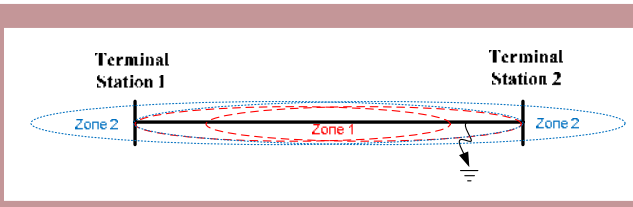


Figure 1: Typical Two-Terminal Line Distance Protection.

Zone 2 is typically set with 400-600ms delay, depending on the utility practice and performance requirements, and serves as a supplement for Zone 1. In order to accelerate Zone 2 operation, a tele-protection scheme involving permissive signals (Permissive Overreaching Transfer Trip, or POTT) or blocking signals (Direct Comparison Blocking, or DCB) can be implemented [9]. The POTT scheme works such that, in the presented case, Terminal Station 2 senses the fault and sends a Permissive signal for Terminal Station 1 to trip upon receiving, reducing the Zone 2 operation time to the intrinsic telecommunication signal transmission latency. Alternatively, the DCB scheme works by implementing a reversed protection zone (Zone 3), which typically covers the "over-reach" of opposite station Zone 2. For the case of Fig. 1, since the fault is in the forward direction of Terminal Station 2, no blocking signal would be sent to Terminal Station 1 and it would trip upon lapse of time delay of 2-3 cycles. Should a fault be in the reverse direction of Terminal Station 2, and sensed by the Zone 2 of the terminal Station 1, it would also be sensed by Terminal Station 2 reverse-looking Zone 3 and a blocking signal would be sent to Terminal Station 1 to avoid tripping.

As explained above, this typical case is straightforward and represents no challenge to protection engineers. However, present practices for accepting large generation by a simple tapping on a transmission line represent a new scenario with many setbacks.

2.2 Non-Overlapping Zone 1 Protections

Consider the system illustrated in Fig. 2. A new generator is connected at the line via a simple tap connection. In order to maintain selectivity, it is undesirable to trip the terminal stations instantaneously for a fault on the customer's line, since the new generator has a HV interrupter. Such an action would result in the unnecessary disconnection of the whole line and of the other customers connected to it.

Therefore, in these cases, it has become the transmitters' practice to shorten Zone 1 in order to block short of the customer tap, as shown in Fig. 2. This will of course result in non-overlapping Zone 1 reaches for the relays located at line terminals. When there are overlapping Zone 1 stages with transfer trips, the Zone 2 protections are only required for the conditions of the line end open or transfer trip communication failure. However, now that the Zone 1 stages no longer overlap, Zone 2 becomes the primary line protection that covers the entire line. Non-overlapping Zone 1 stages due to new generation infeed are one of the root-causes for protection challenges, as using the extended reach of Zone 2 can become difficult and is dependent on communications.

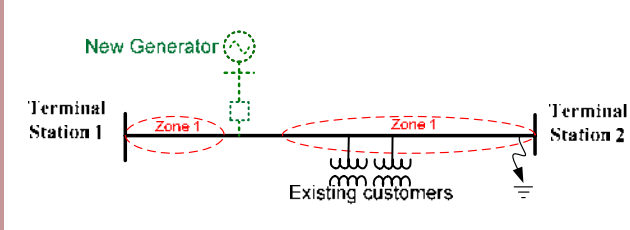


Figure 2: Line Protection for a Two-Terminal Line with Tapped Generator.

2.3 Excessive Increase of the Apparent Impedance

The apparent impedance is a well known concept to power system protection engineers. It is used to describe a phenomenon typically resulting from additional infeed from a third terminal connected to a transmission line having effect on impedance-based relays. In this paper, the focus is on enlarged apparent impedance due to new generation connections. The apparent impedance can be explained by using Fig. 3.

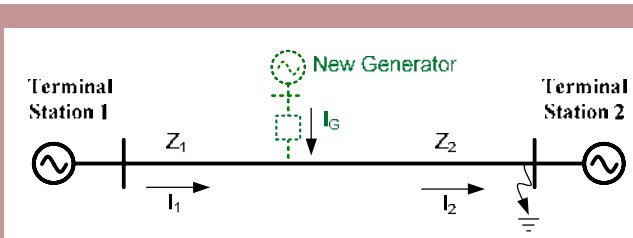


Figure 3: Current Infeed Resulting in Enlarged Apparent Impedance.

As shown in Fig. 3, the actual impedance to the fault at the end of the line close to Terminal Station 2 is the line impedance $Z_L=Z_1+Z_2$ and the total current through Z_2 is $I_2=I_1+I_G$. The apparent impedance seen at terminal station 1 is given by:

$$Z_{App} = V_1 / I_1 = (Z_1 I_1 + Z_2 I_2) / I_1 = (Z_1 I_1 + Z_2 [I_1 + I_G]) / I_1 \quad (1)$$
$$= ([Z_1 + Z_2] I_1 + Z_2 I_G) / I_1 = Z_L + Z_2 I_G / I_1,$$

Therefore, (1) shows that the impedance seen at Terminal Station 1 is increased by a factor of $Z_2 I_G / I_1$. Two problems may arise if the apparent impedance value is too large. The first problem is that the timed distance element shall be set according to the maximum apparent impedance to clear the fault on the entire line. As transmitters are increasingly accepting solar and wind farms, which are predominantly intermittent sources, the settings may be reaching past several stations beyond Terminal Station 2 when the infeed sources are outputting low power or are off-line. The second possible problem is that it may not be possible to change Current Transformer (CT) ratios to cover the required settings with acceptable relay accuracy. Clearly, these might impede utilities to promptly accept a new connection without conducting detailed studies and/or imposing constraints on the manner in which it will be connected.

2.4 Current Outfeed (Current Reversal)

Current Outfeed (Current Reversal) is present when the current flows in the reverse direction into one terminal station as a fault occurs. The Current Outfeed is an occurrence that is not often observed in transmission systems, as it normally takes place when the source behind one terminal station is weak, and when a generation connection is being proposed on the circuit. A criterion is suggested in this section to examine whether a current reversal exists.

2.4.1 Positive Sequence Current Outfeed

The positive sequence current reversal can be explained by using Fig. 4, which shows the positive sequence network of a double-circuit transmission line where a three-phase-to-ground fault occurs at the end of line L_1 close to Terminal Station 2.

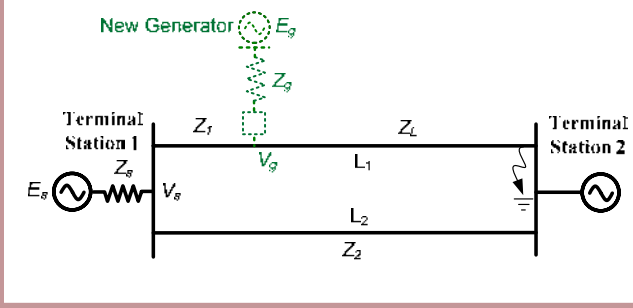


Figure 4: Positive Sequence Current Reversal.

From the parameters presented in Fig. 4 and according to electric circuit theory, the condition for positive sequence current reversal (as both lines are in service under the fault condition) is:

$$V_g > V_s, \tag{2}$$

where V_g and V_s are the open circuit voltages at the new generator connection point and at the bus of Terminal Station 1, respectively, when the circuit between the connection point and terminal 1 is opened, and can be written as

$$V_g = E_g \frac{Z_L}{Z_g + Z_L}, \tag{3}$$

where E_g is the equivalent generator voltage, Z_L is the positive sequence impedance of the line segment between the new generator and Terminal Station 2, and Z_g is the generator internal impedance,

$$V_s = E_s \frac{Z_2}{Z_s + Z_2}, \tag{4}$$

where E_s is the equivalent source voltage, and Z_s and Z_2 are the positive sequence impedances of the source impedance behind Terminal Station 1, and of line L_2, respectively. Substituting (3) and (4) into (2), and noticing that $E_g = E_s$, the inequality can be written as

$$E_g \frac{Z_L}{Z_g + Z_L} > E_s \frac{Z_2}{Z_s + Z_2}, \tag{5}$$

and simplified as

$$Z_g / Z_s < Z_L / Z_2, \tag{6}$$

which is ultimately the condition for positive-sequence current reversal. Inequality (6) shows current reversal is likely to appear when the connected generator is stronger than the source behind the Terminal Station 1 or line L_1 has higher apparent impedance. For the latter case, an existing tapped generation or three-terminal circuit will represent the same result.

2.4.2 Zero Sequence Current Outfeed

The condition for zero sequence current reversal can be assessed in a similar way and is explained by using Fig. 5, which shows the zero sequence network of a double-circuit transmission line where a single-line-to-ground fault occurs at the end of line L_1 close to Terminal Station 2.

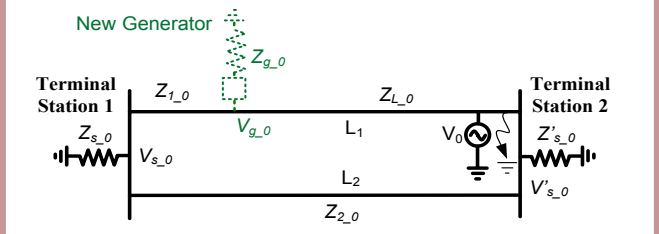


Figure 5: Zero Sequence Current Reversal.

From the parameters presented in Fig. 5 and according to electric circuit theory, the condition for zero sequence current reversal (as both lines are in service under the fault condition) is:

$$V_{s\_0} > V_{g\_0}, \tag{7}$$

where V_{s_0} and V_{g_0} are the open circuit voltages at the bus of Terminal Station 1 and at the new generator connection point, respectively, and can be written as

$$V_{s\_0} = V_0 \frac{Z_{s\_0}}{Z_{s\_0} + Z_{2\_0}}, \tag{8}$$

$$V_{g\_0} = V_0 \frac{Z_{g\_0}}{Z_{g\_0} + Z_{L\_0}}, \tag{9}$$

where Z_{L_0}, Z_{g_0}, Z_{s_0}, Z'_{s_0}, Z_{1_0} and Z_{2_0} are the zero sequence impedances of the line segment between the new generator and Terminal Station 2, internal impedance of the generator, of the source impedance behind Terminal Station 1, of the source impedance behind Terminal Station 2, of the line segment between Terminal Station 1 and the new generator, and of line L_2, respectively. Substituting (8) and (9) into (7), the inequality can be written as

$$V_0 \frac{Z_{s\_0}}{Z_{s\_0} + Z_{2\_0}} > V_0 \frac{Z_{g\_0}}{Z_{g\_0} + Z_{L\_0}}, \tag{10}$$

and simplified as

$$Z_{g\_0} / Z_{s\_0} < Z_{L\_0} / Z_{2\_0}, \tag{11}$$

which is ultimately the condition for zero-sequence current reversal. Inequality (11) shows that zero sequence current reversal will exist if the zero sequence impedance of the tapped generation branch is low. It normally represents a relatively large generation capacity. However, if the new generators are connected on the transmission line via an ungrounded transformer at the high voltage side, the zero sequence impedance of the tapped generation will be indefinite. Inequality (11) will not be met and the zero sequence current reversal will never happen.

2.4.3 The Current Outfeed and Generation Infeed

Fig. 6 shows another case of current outfeed (either positive-sequence or zero-sequence). In this case, there is an existing generator connected to the line when the second generator is being connected. The situation would be similar if rather than an existing generator a third line terminal were present. The existing generator or third terminal would increase the apparent impedance represented by Z_L. In addition, assume the circumstance that the source behind Terminal Station 1 is weak relative to the new generator on the line (large Z_s or Z_{s_0}), and the new generator is connected close to the bus of Terminal Station 1 further increasing the apparent impedance of Z_L. These conditions clearly make the current reversal situation more likely to happen, as shown by (6) and (11).

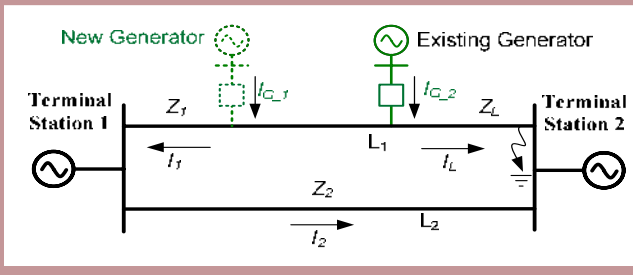


Figure 6: Typical Current Reversal Situation.

If the current direction reverses, the phase angle of the current I_1 will become positive (with reference to the voltage phase angle, considered equal to zero). The relays at Terminal Station 1 will be unable to see the fault because the apparent impedance will fall in the third or fourth quadrant of the impedance characteristics plane, as shown in Fig. 7.

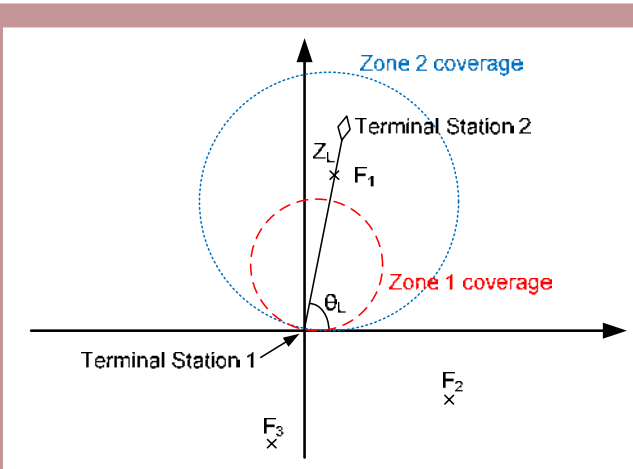


Figure 7: Impedance characteristics of a Relay at Terminal Station 1. Current reversal - Fault may be seen at either the third (F_3) or fourth (F_2) quadrants.

In Fig. 7, Z_L and $\emptyset_L$ are the line impedance magnitude and angle, respectively. F_1 represents a typical fault impedance seen by the terminal without the outfeed effect, and F_2 and F_3 are faults seen by the terminal as if they had struck backward due to current reversal condition.

Therefore, protection coverage will be provided only by Terminal Station 2 and by the backup protection of the new generation station, which will transfer trip Terminal Station 1 via telecommunication channels, a situation that is unacceptable as per most transmitters' practice (including Hydro One's).

3.0 Mitigation Measures

Some utility practices or system modifications can be adopted in order to mitigate or eliminate the problems explained in Section II. This section explains the related measures and their effects from a power system protection standpoint.

3.1 Change the Generator Connection Point

From the theoretical standpoint, this solution method is the simplest and most straightforward option to avoid a range of problems. However, from the practical standpoint, this proposed solution is difficult to implement because it may either affect the geographical location of the customer or imply that the customer must build or extend his transmission line. Therefore, this option can only be used in special cases and greatly depends on the aforementioned factors.

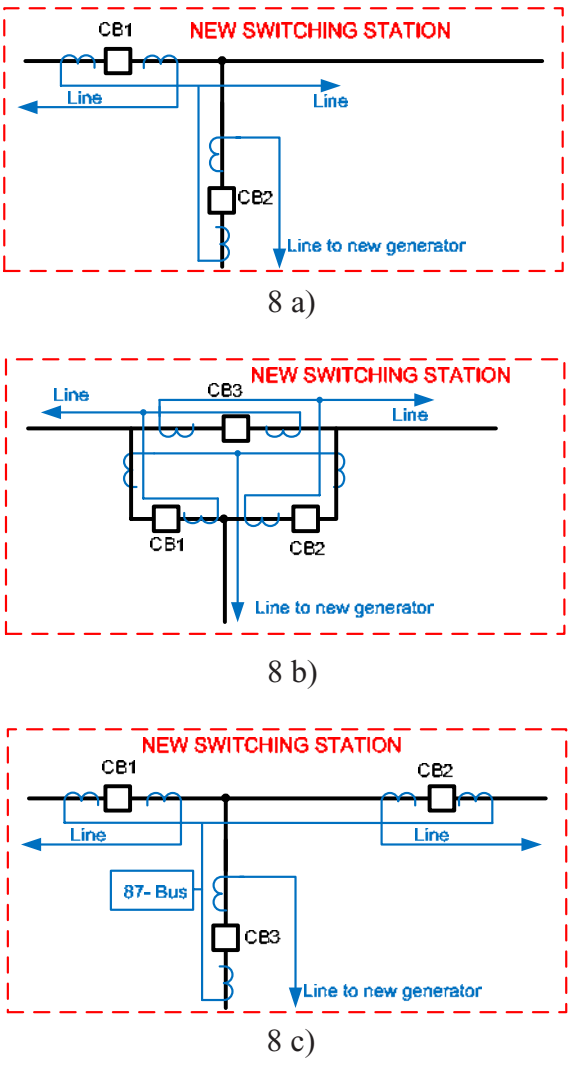


Figure 8: Switching Stations (SS) for Line Sectionalization: (a) Split-line SS, (b) Ring Bus SS, and (c) T-Tap SS.

3.2 Convert the Distance Protection Scheme into Line Current Differential Scheme

Refer to Fig. 6. In this case, if the line distance protection scheme is replaced with a line current differential protection scheme, the problems of positive- and/or zero-sequence current reversal would not be an issue. However, a line current differential protection has very stringent telecommunication requirements. For stations classified as critical by the Northeast Power Coordinating Council (referred to as NPCC impactive stations), the requirement is to have dual paths geographically diverse. However, if those are not already in place, the solution requirements become costly. Additionally, as per some utilities' standards, line current differential is usually designed to encompass up to three terminals. Even though relay manufacturers have developed hardware that allows multi-terminal line differential, these relays require very robust telecommunications [10]-[11], which if not already in place would require a very large investment.

Therefore, for lines with more than three terminals or subject to NPCC requirements, even though it is possible to change the protection scheme to a line current differential, a very large investment is usually required if infrastructure is not already in place. For this reason, it is not a solution easily justifiable.

3.3 Line Sectioning

Line sectionalization by building a new switching station is, from the technical interconnection standpoint, the best solution, as it offers perfect asset protection zoning. It is also the most expensive one. Therefore, the solution is adopted when no other solution can effectively mitigate the problem, because of stability issues or protection limitations (such as too large an apparent impedance or occurrence of either positive- or zero-sequence current reversal). Line sectionalization can be achieved by one of three ways. An in-line breaker and customer tap breaker can be installed as shown in Fig. 8.a. As one can see, this topology will create a three-terminal protection zone on the right hand side of the tap. The second topology is installing a ring bus on the line between the terminal stations as shown in Fig. 8.b. Alternatively, a T-tap can be installed as shown in Fig. 8.c. Among the three solutions, those two presented in Fig. 8.b and Fig. 8.c provide better operational protection opportunities, as opposed to the first topology presented in Fig. 8.a which creates a third line terminal.

Among the two topologies shown in Fig. 8.b and Fig. 8.c, both require the addition of three HV circuit breakers and six new relays for the ring bus (at each of the three new station terminals with two protection groups each) or eight new relays for the T-tap connection (two protection groups for each of the three new line terminals and for the bus current differential). These two options can effectively create a new configuration such that the challenges associated with large apparent effect and current reversal would become immaterial. Either one of them has advantages and disadvantages as compared to the other. It is not in the scope of this paper to discuss the choice between them because in addition to the technical features, this choice depends also on the utility practices and ownership agreements. Whether or not to sectionalize the line is, however, dependent on the need and cost for the investment.

3.4 Change of Transformer Connection

The idea behind the change of transformer connection is to avoid additional zero-sequence flows on line due to the ground source. If only zero-sequence current reversal is present, the change in transformer connection can mitigate the problem. This can be achieved by demanding the customer provide an ungrounded primary winding on the step-up generation station transformer.

This practice is not an intuitive strategy to transmission planners during planning stages due to the fact that generator step up transformers must generally be ground sources. The simple change of connection can avoid the zero-sequence reverse flow on the primary side and save a great deal of investment if detected in the early stages, but will not provide the desired ground source. Due to the fact that it contradicts the requirement for an effectively grounded primary, it is a solution that may be considered when it is impossible to configure the protection system to accommodate the new generation, as it makes the system more susceptible to transient overvoltages for single-phase-to-ground faults. Ideally, the need for this change should be identified very early in the planning stage. However, some utilities' standards may not allow such a transformer configuration.

3.5 Sequential Tripping

Consider the systems shown in Fig. 3 and Fig. 6, and the respective situations of excessively large apparent impedance and current reversal.

In the first case (Fig. 3), assume it is not possible to set Terminal Station 1, Zone 2, to be as large as the maximum apparent impedance. In that case, Terminal Station 1 will only trip upon receiving a transfer trip signal. Planning is done assuming a single contingency, in this case communication failure. The scenario is that only after Terminal Station 2 had tripped and sent transfer trip to the new generators, the apparent impedance seen at Terminal Station 1 will be reduced and Zone 2 will "see" the fault.

Now, consider the case shown in Fig. 6, where a fault occurs on line L_1 close to Terminal Station 2, as shown in the figure. Assuming communication failure, once Terminal Station 2 trips and the tapped generators trip, the circuit will open and current reversal will no longer exist. Consequently, Terminal Station 1, Zone 2, will "see" the fault and trip.

In both cases, the fault will be cleared sequentially. The problem with this approach is the fault clearing time, which is greatly extended to a scale that is unacceptable for any bulk station, as the remote terminal station has to trip first and transfer trip tapped generators. The event of any additional contingencies could lead to serious consequences.

4.0 Case Study

The system chosen to be analyzed in this paper is presented in Fig. 9. A FIT application was submitted to accept a customer to connect 240 MW of combined wind and solar generation to a 230kV line at Point A (L_c = 27% of the total line length L_1) from Terminal Station 1. To determine the feasibility of accepting the new customer connection, a thorough short-circuit study was conducted. When conducting fault studies, the practice is to consider the situation of minimum infeed from the opposite terminal stations (maximum source impedance).

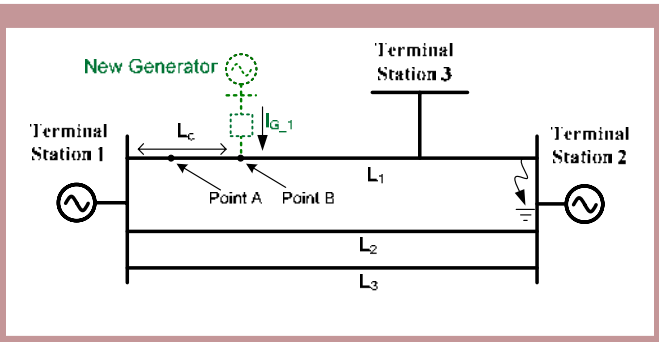


Figure 9: New 240 MW Combined Wind and Solar Farms Connection.

4.1 Study with the Customer-Proposed Connection at Point A

A three-phase-to-ground, close-in fault (fault at the end of the line before the circuit breaker opens) was applied at Terminal Station 2. With the new 240 MW renewable generation, the positive-sequence apparent impedance measured by the relay on line L_1 at Terminal Station 1 is 3 times the actual line impedance. Since Zone 2 is usually set at 125% of the maximum apparent impedance, this represents a reach of almost 400% of the actual line length. In this case, the line is about 45 km, resulting in a somewhat large reach which might cause coordination problems with the protections of adjacent stations. Even though coordination problems could arise, no problem was observed related to reversed phase angle of the fault currents.

Next, a single-line-to-ground fault was applied at Terminal Station 2. For this case, both the phase and zero-sequence fault currents have reverse direction as seen from Terminal Station 1. In addition, in the single-line-to-ground fault, the apparent impedance increases to 5 times of the line impedance with opposite phase angle of the line impedance. This represents Zone 2 settings reaching over 600% of the line impedance, a situation that is even worse than that encountered for the case of the three-phase-to-ground fault. Due to the reversed current, it is impossible for the distance relay at Terminal Station 1 to operate on this fault. The only way of clearing this fault would be via transfer trip from Terminal Station 2. Due to the importance of both of these stations (they are NPCC impactive), transfer trip only or sequential tripping are not acceptable fault clearing methods.

When simulating a fault at Terminal Station 1, no apparent problem was observed with Terminal Station 2 relay settings, for both single-line and three-phase faults.

4.2 Study with the Transmitter-Suggested Connection at Point B

In an attempt to avoid the current reversal condition, a connection further down the line (44% of the total line length L_1 from Terminal Station 1) was tested. This distance was suggested because of the availability of the transmitter tower and shorter distance to the actual wind/solar farm. The three-phase fault was simulated at Terminal Station 2. The apparent impedance became 2 times the line impedance and current outfeed was not observed. Next, a single-line-to-ground fault was tested at Terminal Station 2. As a result, the apparent impedance had a very large magnitude and opposite phase angle from the line angle. Therefore, the distance relay would not be able to operate on this fault due to reverse direction of the current. After the circuit breaker is tripped at Terminal Station 2, the current outfeed disappears. The apparent impedance seen at Terminal Station 1 is, however, still much higher than the line impedance, until the generator removes itself from the line upon transfer trip received from Terminal Station 2. After all generation trips, the impedance seen at Terminal Station 1 becomes the same as that of the actual line impedance, allowing for sequential tripping. Even though still unacceptable, the situation has improved as compared to that encountered when the new generator is connected at Point A.

As in the previous case, no apparent problem was observed with Terminal Station 2 relay settings, for both single-line and three-phase faults.

4.3 Suggestion for Changing the Customer Transformer Connection

To mitigate the above problem, it was suggested, in addition to moving the geographical location of the HV tap, to use a transformer with an ungrounded primary winding in order to reduce the zero-sequence current contribution that caused the current reversal for line to ground faults.

With this change, the zero-sequence current reversal did not occur. This detailed analysis helped avoid some more expensive solutions. In addition, because the assessment was completed in a timely manner, the transformer connection change recommendation was released before the customer had finalized procurement, and therefore resulted in insignificant financial impact on them. With the new location and transformer connection, the situation became acceptable and it was possible to accommodate the customer connection on the line. Table I shows all steps adopted in this study and their effects on the measured apparent impedance and current reversal.

	Yg-Δ 27%	Yg-Δ 44%	Δ-Yg 44%
Three-phase Max App Z (Ω)	65∠80°	45∠83°	45∠83°
Single-phase Max App Z(Ω)	92∠−80°	242∠−55°	60.7∠83°
+ seq. Current Reversal?	NO	NO	NO
0-seq. Current Reversal?	YES	YES	NO

Table 1: Maximum Apparent Impedance seen by Terminal Station 1 (Fault at Terminal Station 2).

The change of transformer connection, plus the additional 17% of line span (about 8 km) to connect the generators resulted in a position where the existing protection scheme can adequately protect the line. The solution resulted in lower cost for the customer and transmitter, as no line sectionalization was required. The only large investment demanded from Hydro One was to bring the buses in the terminal stations up to NPCC requirements. This involved upgrading of line protection and duplication of breaker failure protection – but this investment would have taken place anyways, as the acceptance of the new customer triggered the requirement.

5.0 Conclusions

The connections of renewable sources have proliferated in many countries with various forms of the FIT program. These new connections represent not only cleaner generation, but also new challenges in several aspects of the power system. A simple criterion was presented in this paper to identify potential conditions of current reversal. Protection challenges encountered in the Hydro One transmission system were also presented. Mitigating measures used by our protection engineers have been reported and strategies on how to employ them have been presented. Finally, a representative case study was presented. Challenges encountered by protection and control planners could have been circumvented in a few different ways, but only the most economical solutions were actually implemented in our transmission grid. The presented experience should be useful for other utilities with similar configurations to spot the potential difficulties associated with new connections early.

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About the Authors

Alexandre Nassif received his B.Sc. and M.Sc. degrees in Electrical Engineering from State University of Campinas, Brazil, in 2002 and 2004, respectively, and the Ph.D. degree in Electrical Engineering from the University of Alberta, Edmonton, AB, Canada, in 2009. From 2009 to 2012 he was a Protection and Control Planner with Hydro One Networks Inc., Toronto, ON, and also worked as a Post-Doctoral Fellow at Ryerson University from 2010 to 2011. Dr. Nassif joined ATCO Electric, Edmonton, AB, in 2012 as a Senior Engineer, Power Quality. He is a licensed Professional Engineer in Alberta and a Member of IEEE.

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Remembrances of Anthony Brown Sturton—(1926–2010)

By Bill Kennedy

When I joined The Shawinigan Engineering Company in 1970, I was sent to Winnipeg for an initial 18-month assignment. While in Winnipeg, we were occasioned with visits from an engineer who had a twinkle in his eye and mercilessly teased the secretarial pool in a very good-natured way. A short man, he was dressed in a grey suit, white shirt and a Manitoba tartan tie. I was told that was Andy Sturton, Shawinigan's leading expert in power systems engineering.

Sometime later, I was assigned to the commissioning staff at the Dorsey HVDC Station outside of Winnipeg. I was given the job of commissioning the synchronous compensators, over/under excited synchronous machines. In the course of my work, I discovered that the droop circuit had been incorrectly sized. I informed senior people of my findings. One of the owner's representatives stated flatly I was too young and too inexperienced to understand this. He insisted that Andy Sturton come to the site to prove me wrong. I was instructed to pick Andy up from the Winnipeg airport the following morning. "I hope you're correct," one of the more senior engineers remarked as we left the site that day. I didn't sleep much that night. I gathered Andy from the Winnipeg airport in the morning and we drove to the site.

All day we looked at the machine and its excitation system. Throughout the day Andy talked of other power system apparatus: about how the machines fitted into the power system, how you ran them in parallel, transformer configurations, tapchangers, why switchyards were laid out the way they were, the dangers of operating breakers in a bang-bang mode, protection applications and their settings. As I wrote things down, he would ask for my pencil and jot down other formulae along with sketches, stating this is how you calculate this or that. I took copious notes and studied them for many weeks afterwards. I was in total awe of his encyclopaedic knowledge. At the end of the day, he gave me the news – I was correct, the droop circuit was incorrectly sized. However, he cautioned me that I was not to gloat on this.

Andy as a young graduate of the U. of Toronto in 1948.

Next day at a hastily convened meeting because of Andy's plane connections, the engineer again stated – "So Andy, Bill was wrong. The circuit works correctly." Andy replied, "No, Bill is correct." I remember looking down at the floor. Shortly afterwards, the meeting broke up and I drove Andy to the Winnipeg airport and he caught his plane and was off to solve another problem.

Anthony Sturton (left) receiving the 2005 McNaughton Award from then-IEEE Canada President Bill Kennedy. The citation was "For sustained contributions to electric power systems in Canada and the world, especially for Single Pole Trip and Re-Close operation of High Voltage transmission lines and Elliptical distance relaying."

After six years in Winnipeg, we returned to Montreal and I renewed my acquaintance with Andy. He gave regular seminars to those of us interested in power systems. But our learning couldn't be entirely on the company's nickel—a half hour of our time and half an hour on company time. His teaching method was simple; "Understand the physicals," he would say. Once again, I took copious notes and studied them later. Andy always gave freely of his knowledge and I learned quickly that you didn't take his word as given, but needed to understand the underlying concepts. I pestered him with many questions. "It's in the Westinghouse Blue Book," he would reply and I would go looking. Many years later, my well-worn Blue Book sits on my book shelf and is still consulted regularly.

One afternoon, the lights in the Montreal office dimmed and got bright again. Andy stood in his office door and started naming the Hydro Quebec stations as one by one they went off line. Finally, the building was in darkness along with a large portion of downtown Montreal. "No more work today," he stated. He put on his hat and coat and said, "See you fellas tomorrow." Next day, the papers carried news of the power system failure. A bushing had failed on a 735 kV shunt reactor near Quebec City, isolating Churchill Falls from the Quebec system. The Hydro Quebec generators then started going off line one by one, as the system frequency reduced. The generators had dropped in exactly the sequence that Andy had stated from his office door.

He took me to Newfoundland to work on a problem with one of his clients. The system was unique. It was a generating facility generating at 50 Hz and 60 Hz and tied to a pulp mill, some 50 km away via a double-circuit 69 kV line. We visited the generating facility first. As we passed by the double circuit line, he remarked that each line carried the sum and difference of the frequencies, in addition to the fundamental. A rotating frequency converter coupled both systems at the pulp mill. One side of the pulp mill operated at 50 Hz and the other at 60 Hz. There had been some unexplained outages at the pulp mill and each side thought the other was to blame. Andy assigned me the task of sorting it out. As it turned out neither side was to blame—a number of protective devices at both ends needed some minor adjustments. A power system study was required to solve the problem and Andy insisted that I use Shawinigan's model power system to do the study. "You won't understand the problem if you use a computer," he told me. Once again, I heard one of his favourite paradigms: "understand the physicals." The model power system was a hands-on device that looked and operated very much like an old fashioned telephone switch board. I learned a lot from using it. Once the system was set up, you could pull a plug, take a line of service, and apply a fault and read the resulting milliamp output, converting it directly to the desired quantities (see photo at top right of opposite page).

Andy's decision to leave Shawinigan in late 1978 influenced me to leave in mid 1979. We moved to Saskatchewan where I assumed responsibility for the protection department of SaskPower, soon learning that there was a major protection issue. SaskPower relied on single phase trip and reclose for its 230 kV transmission system. The success rate was below 50%. I consulted with Andy and he told me it should be at least 90% and that it was easily achievable. Over the next few years, with Andy's guid-

ance, I tackled a myriad of problems associated with the protection and reclose system. Finally, in the mid 80s I felt all the problems had been fixed. The next year, single phase trip and reclose success rate rose to 95% - there was only one failed reclose attempt. The next year it was 100%. To my knowledge, it has remained above the 90% success rate ever since.

One of the concerns people had regarding single phase switching was the effect of negative and zero sequence currents flowing in the system during the open phase condition. In response, Andy would relate the following story. The Shawinigan Water and Power Company had to change the insulator on one phase of a double circuit line. The pulp mill at the other end couldn't be taken out of service. Nor could one line be switched out to change the insulator. Andy did some calculations and determined that you could take one phase out of service for a protracted length of time to change the broken insulator. Arrangements were made with the pulp mill and the line was switched to single phase. A number of hours later, with the broken insulator replaced, the line was ready to be put back in service. Andy phoned the pulp mill to tell them they were ready to re-energize the line. The mill responded that they were still waiting for the line to be switched out. His story illustrated a number of things. The effect of negative and zero sequence currents on the rest of the power system was negligible—power transfer during the single phase of our operation was sufficient to keep the pulp mill running. "You need to do your homework first," Andy said. "It's just 'grunt work,'" he would add.

When I was with SaskPower I was visited by an engineer from Westinghouse who, upon learning I knew Andy well, related the following story. As a young engineer he was told to pack his bags because they were going to Shawinigan to see some modifications to one of their distance relays, the K-DAR. When they arrived, a demonstration was given and the engineer leading the demonstration was Andy. Andy had modified the relay's circular characteristic to an elliptical one. "He wasn't much older than me," my guest stated and went on to say, "In those days, young engineers were seen and not heard!" Later Andy told me he needed to modify the circular characteristic to avoid load encroachment on a long line they were single phase switching.

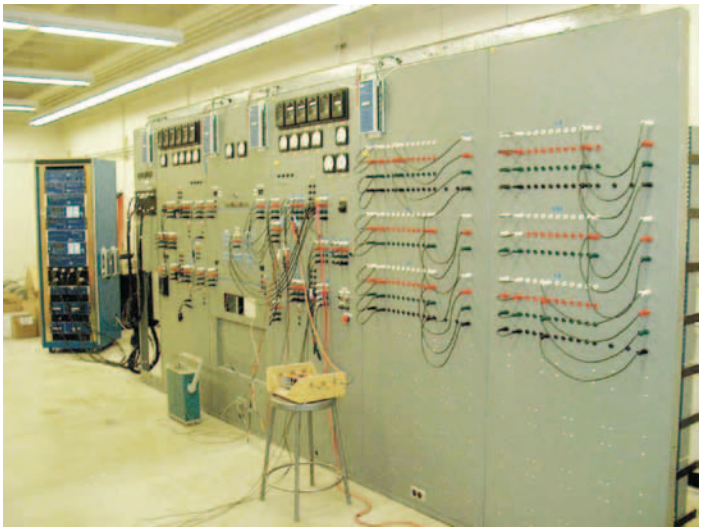
His stories and personality were like a magnet to the younger engineers who hung on every word.

One of Andy's more eccentric characteristics was his collection of provincial tartan ties. When he came to see me in Saskatchewan, he wore his Saskatchewan tartan tie. He had others and wore them when he visited the Maritime Provinces. One of my classmates, who worked for Energie New Brunswick Power remembers the New Brunswick tartan tie and his greeting, "Allojeunehommes," as he entered their offices.

I left SaskPower in the mid 90s and we moved to Calgary. I went to work for an Irish company. It was a brand new company and new staff. We brought Andy in to do an intensive four-day seminar on power systems. One of the objectives was to get all the engineers on a common footing. In addition, I wanted to expose the engineering staff to Andy's way of thinking and—more importantly—his shortcut methods for power system estimation and analysis. Andy came and we structured the seminar for a Thursday/Friday with a facility tour on Saturday morning, resuming Monday/Tuesday of the next week. The seminar was a great success and it achieved what I wanted it to do.

On the Saturday night, we hosted a get together and Andy sat in a comfortable chair regaling the younger engineers with stories from his career. His stories and personality were like a magnet to the younger engineers who hung on every word. On learning of Andy's passing, one of the engineers spoke to me fondly of Andy's reminiscences that evening. He was still in awe of Andy's encyclopaedic knowledge of power systems. Andy worked into his early 80s. He often remarked that the "young fellas need to understand that the fundamentals of power system engineering don't change—just the tools." He had a number of rules of thumb and he used to tell me, "Use those first. But, remember you're just ballparking and the ball park is a big place."

Andy's shortcut methods were myriad and ranged from how to estimate the reactive capability of a synchronous machine to how much reactive power a line consumed or generated. A colleague of mine was involved in a project where Andy had been brought in to do the power system work. Andy worked out the "particulars" (another favourite phrase) in just three pages. The utility wanted some assurances that Andy's work was correct and hired a consulting firm to check his work. A report of nearly 1,000 pages was produced. It confirmed Andy's results!



In the foreground, an analog model power system similar to the one Andy Sturton used to such good effect at The Shawinigan Engineering Company. The unit above was built in the 80s by the Idaho Power Company, and later donated to the University of Idaho. Since then, the University has extended its capability with the addition of digital technology, as seen by the equipment cabinet to the far left, and the four blue rectangular digital protective relays mounted near the top of the main cabinet. Photo Credit*: University of Idaho.*

After Andy retired, I would phone him occasionally and we would discuss power system issues. His extensive travels were beginning to take their toll. A bad fall on the ice a few winters earlier had contributed to deteriorating health. As always, he gave freely of his knowledge. Although he complained he was slowing down, his encyclopaedic knowledge was still there and his instantaneous recall never ceased to amaze me. As I enter the back end of my own career, I remember his dictum to share my knowledge freely. As part of my work, I have developed a power system seminar for non-engineers. The seminar concentrates on the "physicals" of the power system and owes a lot to Andy's tutoring.

In 2005, IEEE Canada recognized Andy's pre-eminent power system contributions by awarding him the AGL McNaughton Gold Medal. Andy lived with his wife, Irene, for 55 years and they were blessed with five children and an equal number of grand children. He died peacefully in the early hours of January 1, 2010 at the age of 83. Born in Quebec City, Andy was a 1948 graduate of the University of Toronto, and a Life Senior Member of the IEEE.

I learned a lot of engineering from Andy. Three lessons stand out: Understand the "physicals"—the math comes second. Use shortcut methods to understand the problem; but remember, you're just ballparking, and a ball park is a big place. Always share your knowledge freely; it's the best way to know you understand the problem.

A classmate of mine who had met Andy when working on the construction of Churchill Falls, upon learning of Andy's passing, stated: "Andy was a gentleman, and a gentle man." I can think of no better tribute.

About the Author

Bill Kennedy has 40 years of professional experience in the electric industry in Canada. He runs a consulting practice that helps companies solve problems related to their power supply, interconnection to their utility, and energy usage. Previously, he was a principal engineer for Alberta Electric System Operator (AESO), where he was responsible for identifying and solving transmission-related issues. Prior to AESO, Bill worked at ESBI Alberta as its director of measurement and protection, at Saskatchewan Power Corporation in Regina, and at the Shawinigan Engineering Company Ltd. in Montreal.

A registered professional engineer in the four western provinces, in 1998 Bill was elected a Fellow of the Engineering Institute of Canada. He is a member of IEEE Southern Alberta Section, serving as IEEE Canada President (Region 7 Director) for 2004-2005. He is Chair of the 2014 IEEE Electrical Power and Energy Conference (EPEC) to be held in Calgary.

Engineering Management: What's New in the Literature?

by Terrance Malkinson

- Thomas Malone, Robert Laubacher and Tammy Johns in the July-August 2011 issue of *Harvard Business Review* discuss the concept that employees will in the future become hyperspecialized ["The Age of Hyperspecialization," pp. 56-65. www.hbr.org]. Projects and tasks previously done by one person will be divided into highly specialized small pieces, each completed by a highly skilled hyper-specialist — at times an outside contractor sourced locally, nationally or internationally. The authors describe the advantages, disadvantages and implications for managers of this vision of the future.

- Cloud computing represents a significant change in the way that companies use technology. "What Every CEO Needs of Know about the Cloud" is an article by Andrew McAfee in the November issue of *Harvard Business Review* [89(11):124-132, November 2011]. McAfee discusses three basic categories of cloud computing, debunks commonly expressed concerns and discusses its benefits. He concludes by outlining how companies can get started on the path to the cloud.

- Publishing is an important professional activity. Today, the majority of journal articles in many fields are co-authored. Deans of 440 accredited colleges of business were surveyed on their views on undeserved authorship in business journals and the impact of these undeserved authorships upon the faculty performance reward system ["College of Business Deans' Views on Undeserved Authorships in Business Journals," Edgar Manton and Donald English. *Journal of Faculty Development*, 25(2):5-11, May 2011, www.newforums.com]. Their finding? Many Deans were aware of the problem with 41% believing that the practice is "somewhat extensive."

- Douglas Fox discusses the laws of physics that might prevent the human brain from evolving into a more powerful thinking machine, and muses on how humans might still be able to collectively achieve higher intelligence. Technology might enable us to expand our mind outside the confines of our body. ["Can We Get Any Smarter? The Limits of Intelligence," *Scientific American* 305(1):36-43. July, 2011, www.scientificamerican.com].

- The July-August 2011 issue of *Harvard Business Review* [89(7/8)] spotlights the topic of building a culture of trust and innovation through collaboration. A series of five articles (Are You a Collaborative Leader? The Unselfish Gene, Bringing Minds Together, Building a Collaborative Enterprise, and Who Moved my Cube?) discuss how to change organizational culture from individual achievement to an environment of collaboration.

- The New Science of the Teenage Brain is the cover story of the October 2011 issue of *National Geographic* ["Beautiful Brains". 220(4): 36-59. www.ngn.com]. David Dobbs discusses how teenagers' "most exasperating traits may be the key to success as adults." Adolescents are "works in progress" as their brains mature and as they discover their identity and place in the world.

- Today's competitive employment environment requires many workers prove their value to the organization perhaps even to the point of convincing your employer that you are indispensable. John Zenger Joseph Folkman and Scott Edinger in their article "Making Yourself Indispensable" [*Harvard Business Review*. [89(10):85-92. October 2011] provide strategies that you can use to promote your value to the organization. A step-by-step process to identify your strengths, selecting complementary skills and development of those skills is described.

- A transition in cinematography from traditional film to digital motion picture cameras took root in 2000 with George Lucas' production of *Star Wars Episode II*. In "The Status of Cinematography Today" [*Motion Imaging Journal,* 120(6): 39-44, September 2011, www.smpte.org], Curtis Clark provides a historical perspective on the transition to digital motion picture cameras. Clark describes the evolution of this technology and future directions.

- William Norton and Dena Hale introduce and develop teaching protocols to guide aspiring entrepreneurs behaviors in searching for and discovering innovative ideas that may have commercial potential in their article "Protocols for Teaching Students How to Search for, Discover, and Evaluate Innovations". [*Journal of Management Education* 35(6):808-835. December 2011]. A series of six, structured modular learning sessions are described. A framework is introduced that permits a viability assessment of all discoveries.

- The theme of the November issue of *Harvard Business Review* [89(11) pp.66-104, www.hbr.org] is What Great Companies Do Differently. Four authoritative articles (How Great Companies Think Differently, Why Don't We Try to be India's Most Respected Company? It's Hard to be Good, and The For-Benefit Enterprise) take a fresh look at the meaning of "good." Complementing the research findings are short profiles of five companies that are believed to have achieved a level of goodness by excelling in key areas of employee relations, community engagement, supply-chain management, environmental protection and corporate governance.

- Most employees are enthusiastic when they start a new job, however, morale declines over time. David Sirota et al. provide eight practices for maintaining a motivated and enthusiastic workforce in "Why Your Employees are Losing Motivation and What to Do about It" [*Nonprofit World,* 29(4):20-21, July/August 2011, www.snpo.org]. Despite the plethora of historical information on employee motivation, the reality is simple: poor management is generally to blame. The authors conclude, *"there may be no single motivational tactic more powerful than freeing competent people to do their jobs as they see fit."*

- Government policy-makers often do not understand science and its importance when they make decisions that affect all of our lives, usually lacking a background in this area. A special report on science in America is the cover story in *New Scientist* [212 #2836, October 2011, www.newscientist.com]. Shawn Otto in his report "Decline and Fall," [pp. 38-41] explores the roots of why the status of science in public life has declined. A report by Peter Aldhous, "Don't Tell It So Straight," [pp. 42-45] challenges scientists to learn to effectively communicate the importance of their work to policy-makers and the public.

- A discussion on how technology and humanity are co-evolving and how this creates new societal tensions and cultural clashes is provided by Braden Allenby and Daniel Sarewitz who provide their insights on "the Accelerating Techno-Human Future" in *The Futurist.* [45(5):30-33. October, 2011. www.wfs.org]. The magazine has published its annual forecasts for next year in "Outlook 2012" 45(6)-9 page inset, November-December 2011 . The editors are not attempting to predict the future but rather to *"provoke thought on how we may begin to shape our own tomorrow's today".* In the January-February 2011 issue the editors provide their assessment of what are some of the best predictions for the world's future [46(1):28-39,].

- The January 16, 2012 issue of *FORTUNE* provides a portrait of what the world might be like in ten years. ["*FORTUNE'S* Guide to the Future," 165(1) pp.44-74, 2012 www.fortune.com]. Interviews with futuristic researchers, forecasters, security experts and analysts reveal their visions that provide a mostly optimistic view of the future in spite of current challenges. However, the introduction does note "the coming changes will be uncomfortable for some" [pg. 46]. Management practices will most certainly change as non-conventional sources and methods of innovation will be the birthplace of the important major breakthroughs.

***Author biography*: see page 8**

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- Energy Storage
- Energy Conservation and Efficiency
- Nuclear Energy
- Renewable Energy - Generation and Integration
- Electrification of Transportation and its Impact
- Integrated Energy System Planning and the Energy - Water Nexus
- Asset Management and Condition Based Maintenance
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- Computational Methods
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Paper Submission:

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APPEL POUR PUBLICATIONS

CEE IEEE 2012

Conférence sur l'énergie électrique

Systèmes robustes d'énergies vertes pour une société viable

10-12 octobre 2012, London, Ontario, Canada

La conférence annuelle sur l'Énergie électrique (CEE 2012) aura lieu à London, Ontario, Canada du 10 au 12 octobre 2012. London est située au coeur du sud-ouest de l'Ontario à mi-chemin entre Toronto et Detroit. La conférence est une occasion pour des experts en matière d'Énergie électrique et de systèmes énergétiques de l'industrie, du milieu universitaire, et de d'autres organismes intéressés de discuter des derniers développements dans le domaine. Ceci pouvant inclure la discussion sur l'impact potentiel de ces développements incluant des discussions sur des aspects réglementaires et politiques.

http://www.ieee.ca/epec12/

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La conférence CEE 2012 accueille des publications reliées à beaucoup de sujets reliés au thème de la conférence, des systèmes robustes d'énergies vertes pour une société viable, incluant, mais non limitées à:

- Résilience des systèmes de puissance électrique
- Réseaux intelligents incluant HVDC et FACTS
- Aspects communications des réseaux intelligents
- Microréseaux
- Emmagasinage de l'énergie
- Conservation de l'énergie et efficience
- Énergie nucléaire
- Énergie renouvelable—Production et Intégration
- Électrification du transport et son impact
- Planification de système énergétique intégrée et l'Énergie—Water Nexus
- Gestion de l'actif et Maintenance basée sur la condition
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