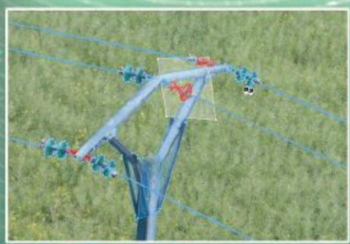
IEEE Canadian Review

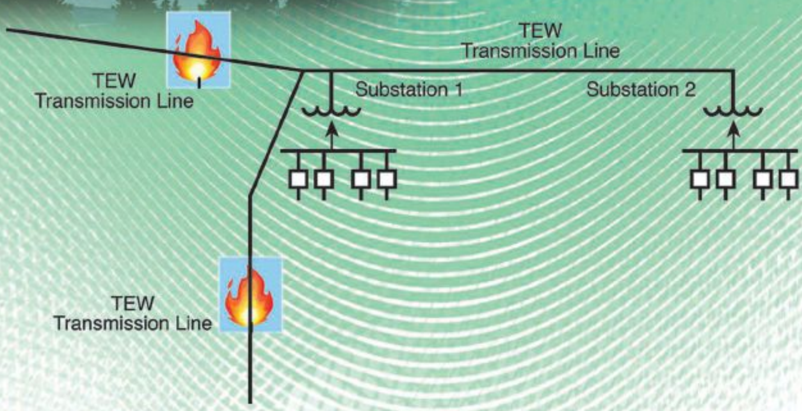
La revue canadienne de l'IEEE

Summer 2020 – No. 84

Essential Power



Resilient Response to Natural Disasters



Electric Thermal Storage

Condition–Based Risk Management

IEEE Canada

The Institute of Electrical and Electronic Engineers Inc.

Jason Gu
Ph.D., P.Eng., FEIC, FCAE

2020–2021 IEEE Canada President and Region 7 Director
Président de l'IEEE Canada et directeur de la région 7, 2020–2021

ICR 2020 Summer Issue

Greetings to all the IEEE Canada members and volunteers at this unique juncture of 2020. In this column, I will focus on the challenges and opportunities presented by COVID-19. I will also take the opportunity to announce several upcoming IEEE Canada events.

The impact of the COVID-19 pandemic has changed our daily lives, leading to major adjustments in academics, industries, and professional organizations. One of the most significant changes is how businesses function and how meetings and events are being held virtually. This will likely be the norm for the foreseeable future. With many researchers and engineers practicing social distancing and isolation, we want to emphasize our continued support for the professional community during this pandemic. IEEE Canada is fully operational despite the current challenges.

The health and safety of our members and volunteers remain our top priority; therefore, we are working remotely to ensure that we can continue to deliver the highest-quality professional services to our members nationwide. Although the COVID-19 pandemic has constrained us with many challenges, it has also brought along many new opportunities:

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Le Numéro de la RCI 2020 de l'été

Salutations à tous les membres et bénévoles de l'IEEE Canada à ce moment unique de l'année 2020. Dans cette chronique, je me concentrerai sur les défis et les possibilités présentés par COVID-19. Je profiterai également de l'occasion pour annoncer plusieurs événements à venir de l'IEEE Canada.

L'impact de la pandémie de COVIDE-19 a changé notre vie quotidienne, ce qui a entraîné d'importants ajustements au niveau des universitaires, des industries et des organisations professionnelles. L'un des changements les plus importants est le fonctionnement des entreprises et la façon dont les réunions et les événements se déroulent virtuellement. Ce sera probablement la norme dans un avenir prévisible. Avec de nombreux chercheurs et ingénieurs pratiquant la distanciation sociale et l'isolement, nous voulons mettre l'accent sur notre soutien continu à la communauté professionnelle pendant cette pandémie. L' IEEE Canada est pleinement opérationnel malgré les défis actuels.

La santé et la sécurité de nos membres et bénévoles restent notre priorité absolue, par conséquent, nous travaillons à distance pour nous assurer que nous pouvons continuer à fournir des services professionnels de la plus haute qualité

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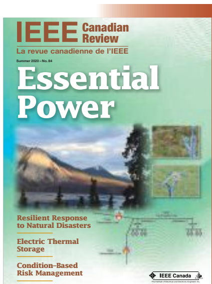

ON THE COVER

Essential Power

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- *Online meetings*: All Region, Section, and Chapter activities as well as affinity group meetings can be held online. This provides an immense opportunity for members from different time zones and provinces to come together for an active online meeting. The need to arrange logistics for travel, weather, catering, or meeting venues is nonexistent.
- *Online activities*: Technical seminars, workshops, conferences, symposiums, and forums can all be held online. This enables neighbouring sections to collaborate, giving small Sections access to technical expertise from other areas.
- *Online learning*: The IEEE Learning Network (https://iln.ieee.org/public/trainingcatalog.aspx) is providing online continuing education opportunities for our IEEE Members. The featured topics include career development, power and energy, emerging technologies, computing, telecommunication, English for engineering, and IEEE standards and transportation. The variety, breadth, and depth of online learning content continue to increase.

With many researchers and engineers practicing social distancing and isolation, we want to emphasize our continued support for the professional community during this pandemic.

I would like to draw your attention to the following several signature events that are being rescheduled or postponed due to the COVID-19 pandemic:

- *2020 IEEE Canada Conference on Electrical and Computer Engineering (CCECE 2020)*: This conference was originally scheduled to take place in London, Ontario. The date has now been rescheduled for early September 2020 and will be held completely virtual. Please visit the conference website (https://ccece2020.ieee.ca/) for the latest information. The online program is looking great. I look forward to meeting you all at the conference, albeit virtually.
- *IEEE Canada Awards Gala 2020*: This will also be held online. The 2020 IEEE Canada awards winners who would have received their awards at this year's IEEE Canada Awards Gala will be recognized through a series of specialized online promotions. These promotions will feature each recipient's contributions and their role in advancing technology for the benefit of humanity.
- *IEEE Sections Congress 2020*: This triennial in-person meeting is now cancelled, unfortunately. Details of future arrangements will be communicated to all the Section chairs and volunteers through e-communications.
- *2020 IEEE Canada Electric Power and Energy Conference (EPEC'2020)*: This conference has been moved to a virtual platform and will be held 9–10 November 2020. IEEE EPEC is IEEE Canada's premier power and energy conference and focuses on innovations in the electric power sector. We will have paper presentations, special sessions, panels, tutorials, and exhibitors. Please visit the conference website (https://epec2020.ieee.ca/) for the latest updates.

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à nos membres à l'échelle nationale. Bien que la pandémie de COVID-19 nous ait imposé de nombreux défis, elle a également apporté de nouvelles opportunités:

- *Réunions en ligne*: Toutes les activités de la Région, de la Section et du Chapitre ainsi que les réunions de groupe d'affinité peuvent être organisées en ligne. Cela offre une immense occasion aux membres de différents fuseaux horaires et provinces de se réunir pour une réunion active en ligne. La nécessité d'organiser la logistique pour les déplacements, la météo, la restauration ou les lieux de réunion est inexistante.
- *Activités en ligne*: Des séminaires techniques, des ateliers, des conférences, des symposiums et des forums peuvent tous être organisés en ligne. Cela permet aux sections voisines de collaborer, donnant aux petites sections l'accès à l'expertise technique d'autres domaines.
- *Apprentissage en ligne*: Le Réseau d'apprentissage de l'IEEE (https://iln.ieee.org/public/trainingcatalog.aspx) offre des possibilités de formation continue en ligne à nos membres de l'IEEE. Les sujets abordés comprennent le développement de carrière, l'énergie et l'énergie, les technologies émergentes, l'informatique, les télécommunications, l'anglais pour l'ingénierie, et les normes et le transport de l'IEEE. La variété, l'étendue et la profondeur du contenu d'apprentissage en ligne continuent d'augmenter.

Je voudrais attirer votre attention sur les événements suivants qui sont reportés ou reportés en raison de la pandémie de COVIDE-19:

- *Conférence 2020 de l'IEEE Canada sur le génie électrique et informatique (CCECE 2020)*: Cette conférence devait initialement avoir lieu à London, en Ontario. La date a maintenant été reportée au début de septembre 2020 et sera entièrement virtuelle. Veuillez visiter le site Web de la conférence (https://ccece2020.ieee.ca/) pour les dernières informations. Le programme en ligne a fière allure. J'ai hâte de vous rencontrer tous à la conférence, quoique virtuellement.
- *Le Gala des prix de l'IEEE Canada 2020*: Cela se tiendra également en ligne. Les lauréats 2020 des prix IEEE Canada qui auraient reçu leurs prix au Gala des prix IEEE Canada de cette année seront reconnus par une série de promotions spécialisées en ligne. Ces promotions mettront en vedette les contributions de chaque bénéficiaire et leur rôle dans l'avancement de la technologie au profit de l'humanité.
- *Le Congrès des sections de l'IEEE 2020*: Cette réunion triennale en personne est malheureusement annulée. Les détails des dispositions futures seront communiqués à tous les présidents de section et bénévoles par voie électronique.
- *La Conférence de l'IEEE Canada sur l'Énergie Électrique et l'Énergie 2020 (EPEC'2020)*: Cette conférence a été déplacée vers une plate-forme virtuelle et se tiendra du 9 au 10 novembre 2020. L' IEEE EPEC est la première conférence sur l'énergie et l'énergie de l'IEEE au Canada et se concentre sur les innovations dans le secteur de l'énergie électrique. Nous aurons des présentations papier, des sessions spéciales, des panels, des tutoriels et des exposants. Veuillez visiter le site Web de la conférence (https://epec2020.ieee.ca/) pour les dernières mises à jour.
- *La Journée de l'IEEE*: Elle est célébrée le premier mardi d'octobre. Cette année, ce sera le 6 octobre sur le thème "Tirer

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(President's Message cont'd from p. 2)

- *IEEE Day*: This is celebrated on the first Tuesday of October. This year, it will be on 6 October with the theme "Leveraging Technology for a Better Tomorrow." Please stay tuned for all the wonderful online activities.

As we welcome summer with this edition of *IEEE Canadian Review*, I thank you all for your continued support. Your comments and suggestions about any aspect of IEEE Canada's operation are welcome. Please contact me at jason.gu@ieee.org. I look forward to hearing from you.

Hope you all are staying safe and healthy. Have a wonderful summer. ■

Jason Gu, Ph.D., FEIC, FCAE
2020–2021 IEEE Canada President
2020–2021 IEEE Region 7 Director

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parti de la technologie pour un avenir meilleur." Veuillez rester à l'écoute pour toutes les merveilleuses activités en ligne.

Alors que nous accueillons l'été avec cette édition de l'Examen canadien de l'IEEE, je vous remercie tous pour votre soutien continu. Vos commentaires et suggestions sur n'importe quel aspect de l'exploitation d'IEEE Canada sont les bienvenus. Veuillez me contacter à jason.gu@ieee.org. J'ai hâte de vous entendre.

J'espère que vous restez tous en sécurité et en bonne santé. Passez un été merveilleux. ■

Jason Gu, Ph.D., FEIC, FCAE
Président de l'IEEE Canada 2020–2021
Directeur de la Région 7 de l'IEEE 2020–2021

IEEE Canadian Review
La revue canadienne de l'IEEE

IEEE Canadian Review is published three times per year: Spring, Summer, and Fall.

Its **principal objectives** are:
To inform Canadian members of IEEE on issues related to the impacts of technology and its role in supporting economic development and societal benefits within Canada. To foster growth in the size and quality of Canada's pool of technology professionals to serve our increasingly knowledge-based economy.

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Jahangir Khan
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At the time of the writing of this editorial, the global death toll from the novel coronavirus is more than 700,000, and the confirmed cases are roughly 20 million. Both of these figures are still trending upward, especially in North America, Latin America, and South Asia. In Canada, we are fortunate to have a relatively stable situation. The death toll is still staggering. Approximately 9,000 people have died, and the number of test-positive cases is around 120,000. It appears that our civilization has quietly accepted this toll as it braces for more. Although this desensitization is necessary for our survival, we cannot forget

(Continued on p. 5)

Au moment de la rédaction de cet éditorial, le bilan mondial des décès dus au nouveau coronavirus est de plus de 700,000 et les cas confirmés sont d'environ 20 millions. Ces deux chiffres sont toujours à la hausse, en particulier en Amérique du Nord, en Amérique latine et en Asie du Sud.

Au Canada, nous avons la chance d'avoir une situation relativement stable. Le nombre de morts est toujours stupéfiant. Environ 9,000 personnes sont décédées et le nombre de cas positifs est d'environ 120,000. Il semble que notre civilisation ait tranquillement accepté ce péage alors qu'elle se prépare à plus. Bien que

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(A Few Words From the Editor-in-Chief cont'd from p. 4)

that there is a deceased human being or a sick person behind every member.

With cautious optimism, we can say that the first wave of the novel coronavirus pandemic in Canada is behind us. The quiet sacrifices made by the health-care workers and essential service providers will be remembered as a cornerstone of human resilience. They shielded our communities from a major disaster and kept our society functioning. As we gradually relax the lockdown measures and aim to reopen businesses, we need to be vigilant, cautious, and sensible. In addition to maintaining social distancing and practicing good hygiene, we need to be kind to ourselves and support our peers.

George Floyd's tragic death and the "I can't breathe" movement has added another dimension to the current state of affairs. Just as the coronavirus choked the whole world with unparalleled ferocity, racism and intolerance can be a potent virus stealing breath from each one of us.

Not everything has been dark in the last few months. In early June, SpaceX launched its reflight-capable Falcon9 rocket, leaving a bright trail of optimism for a new era of space exploration. The majority of the workforce has embraced working from home.

Adjusting to the new norms, IEEE has made a number of resources available for its members and volunteers.

Adjusting to the new norms, IEEE has made a number of resources available for its members and volunteers. On the home front, *IEEE Canadian Review* (*ICR*) has found its place on the IEEE app, enabling global readership. Our editorial team is refreshed. I welcome Ahmed Farouk, Gautam Srivastava, and Nezih Mrad as associate editors. Jonathan Palmer and Adam Detillieux have been appointed as vice editors-in-chief.

This edition of *ICR* aims at "reopening" with regular themes. The column by Terrance Malkinson and Jacqueline Terlaan looks at the new normal beyond COVID-19. Dario Schor focuses on the pandemic from space. Alex Nassif's article brings the resiliency of power grids back into the spotlight. Noah Sternbergh and Eric Labrecque talk about energy storage options for the northern remote communities. Chris Bowman's article features the use of state-of-the-art artificial intelligence in bulk electric power systems.

IEEE Canada's two signature events (CCECE'20 and EPEC'20) are still on the horizon, but both will be hosted virtually. Participants are encouraged to visit the conference websites for the latest information.

ICR is actively looking for submissions, particularly in the areas of biomedical engineering, artificial intelligence, rapid prototyping, robotics, emergency preparedness, and essential services areas reflecting the lessons learned from the coronavirus pandemic. Please continue to share your stories, photos, comments, and suggestions. Please also encourage your peers to access this magazine digitally, especially through the IEEE app. I can be reached at mjakhan@ieee.org or icr@ieee.ca.

Finally, I would like to quote British Columbia's Provincial Health Officer Dr. Bonnie Henry's mantra that helped us ride through the pandemic anxiety here on the West Coast: "Be Calm. Be Kind. Be Safe." ■

(Quelques mots du rédacteur en chef suite de p. 4)

cette désensibilisation soit nécessaire à notre survie, nous ne pouvons pas oublier qu'il y a un être humain décédé ou une personne malade derrière chaque membre.

Avec un optimisme prudent, nous pouvons dire que la première vague de la nouvelle pandémie de coronavirus au Canada est derrière nous. Les sacrifices discrets consentis par les agents de santé et les prestataires de services essentiels resteront dans les mémoires comme une pierre angulaire de la résilience humaine. Ils ont protégé nos communautés d'une catastrophe majeure et ont fait en sorte que notre société fonctionne. Alors que nous assouplissions progressivement les mesures de verrouillage et visons à rouvrir les entreprises, nous devons être vigilants, prudents et sensés. En plus de maintenir une distance sociale et de pratiquer une bonne hygiène, nous devons être gentils avec nous-mêmes et soutenir nos pairs.

La mort tragique de George Floyd et le mouvement "Je ne peux pas respirer" ont ajouté une autre dimension à la situation actuelle. Tout comme le coronavirus a étouffé le monde entier avec une férocité inégalée, le racisme et l'intolérance peuvent être un puissant virus qui dérobe chacun de nous.

Tout n'a pas été sombre au cours des derniers mois. Dès le début du mois de juin, SpaceX a lancé sa fusée Falcon 9 capable de réfléchir, laissant une piste d'optimisme brillante pour une nouvelle ère d'exploration spatiale. La majorité de la main-d'œuvre a adopté le travail à domicile. S'adaptant aux nouvelles normes, l'IEEE a mis un certain nombre de ressources à la disposition de ses membres et bénévoles. Sur le front intérieur, *la Revue Canadienne de l'IEEE* (*RCI*) a trouvé sa place dans l'application IEEE, permettant un lectorat mondial. Notre équipe éditoriale est rafraîchie. Je souhaite la bienvenue à Ahmed Farouk, Gautam Srivastava et Nezih Mrad en tant que rédacteurs adjoints. Jonathan Palmer et Adam Detillieux ont été nommés Vice-Rédacteurs en chef.

Cette édition de l'*RCI* vise à "rouvrir" avec des thèmes réguliers. La chronique de Terrance Malkinson et Jacqueline Terlaan regarde la nouvelle normale au-delà de COVID-19. Dario Schor se concentre sur la pandémie depuis l'espace. L'article d'Alex Nassif apporte la résilience des réseaux électriques de retour sous les projecteurs. Noah Sternbergh et Éric Labrecque parlent des options de stockage d'énergie pour les collectivités éloignées du Nord. L'article de Chris Bowman présente l'utilisation des plus récentes technologies de l'intelligence artificielle dans les systèmes électriques en vrac.

Les deux événements phares de l'IEEE Canada (CCECE'20 et EPEC'20) sont toujours à l'horizon, mais les deux seront hébergés virtuellement. Les participants sont encouragés à visiter les sites Web de la conférence pour les dernières informations.

La *RCI* est activement à la recherche de soumissions, en particulier dans les domaines du génie biomédical, l'intelligence artificielle, le prototypage rapide, la robotique, la préparation aux situations d'urgence et les services essentiels et les leçons tirées de la pandémie de coronavirus. S'il vous plaît continuer à partager votre histoires, photos, commentaires et suggestions. Veuillez également encourager vos pairs à accéder à ce revue numériquement, en particulier par le biais de l'application IEEE. On peut me joindre à mjakhan@ieee.org ou icr@ieee.ca.

Enfin, j'aimerais citer l'agente de santé provinciale de la Colombie-Britannique, Madame Bonnie Henry's Mantra qui nous a aidés à surmonter l'anxiété pandémique ici sur la côte Ouest: «Soyez calme. Gentil. Soyez». ■

by
David G. Michelson

The International Union of Radio Science (abbreviated URSI, after its French name, Union Radio-Scientifique Internationale) celebrated its centennial last year. The past 100 years have borne witness to the tremendous impact that the application of electromagnetic fields and waves have had on society, industry, and the economy.

URSI has a long history of cooperating with the IEEE to advance international cooperation in the study of electromagnetics. In this regular column, we explore how IEEE Canada members can both contribute to and benefit from URSI's mission.

In the following, we introduce the major URSI awards through which many Canadian contributions to radio science have been recognized over the years and present a focus on Canadian researchers and the achievements related to URSI Commission K—Electromagnetics in Biology and Medicine. In the next column, we will feature URSI Commission B—Fields and Waves, emphasizing Canadian achievements.

Dave G. Michelson;
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URSI AWARDS

One of URSI's important roles is to acknowledge research accomplishments in the field of radio science through various awards. URSI awards are presented once every three years at the opening ceremony of the URSI General Assembly. The selection process and criteria are described in detail on the URSI International website. Here, we summarize the background and criteria for the senior awards and identify the four Canadian recipients of the URSI senior awards to date.

APPLETON PRIZE

Edward Appleton was president of URSI from 1934 to 1952 and an honorary president from 1952 until his passing in 1965. The Appleton Prize is awarded for outstanding contributions to studies in ionospheric physics and, in particular, for the career achievements of the candidate with evidence of significant contributions within the most recent six-year period. The Appleton Prize was supported by the Royal Society from its inception in 1969 until 2008 and is now supported by the U.K. URSI Panel. Although some outstanding Canadians have been nominated, the Appleton Prize has not yet been awarded to a Canadian.

KARL RAWER GOLD MEDAL

The Karl Rawer Gold Medal honours the work and life of Prof. Karl Rawer, the father of the International Reference Ionosphere (IRI),

BALTHASAR VAN DER POL GOLD MEDAL

Balthasar van der Pol served as the vice-president of URSI from 1934 to 1950 and as honorary president from 1952 until his passing in 1959. The van der Pol Gold Medal is awarded to the scientist whose research accomplishments have substantially contributed to one of the fields of URSI activity. The medal was awarded for the first time during the Golden Jubilee of URSI in 1963.

1984 RECIPIENT—PROF. GERALD W. FARNELL

In 1984, the Balthasar van der Pol Gold Medal was awarded to Prof. Gerald W. Farnell of McGill University (Canada) "for work in physical electronics, in particular on microwave lenses, spin phonon interactions in solids, microwave acoustics, and acoustic microscopy." Prof. Farnell (31 August 1925–30 April 2015) worked at the Massachusetts Institute of Technology's Research Laboratory for Electronics (1949–1950) before joining McGill University where he initially pursued research concerning diffraction problems related to microwave lenses but later shifted to the field of solid-state physics, including paramagnetic relaxation and electroacoustic interactions in semiconductors, and the propagation of elastic surface waves.

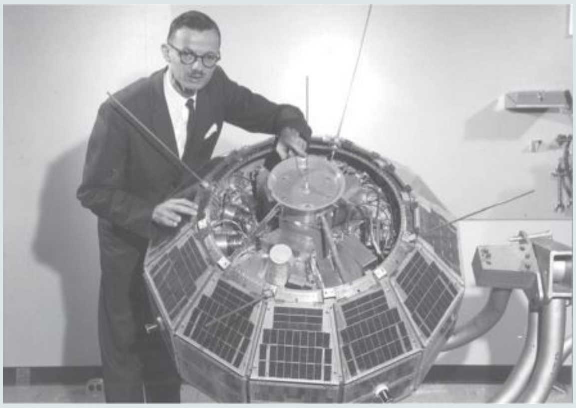
Prof. Gerald W. Farnell (Photo courtesy of McGill University; used with permission.).

JOHN HOWARD DELLINGER MEDAL

John Howard Dellinger was a vice-president of URSI from 1934 to 1952 and an honorary president from 1952 until his passing 10 years later. As a physicist at the U.S. National Bureau of Standards, he supervised the initiation and development of the WWV standard frequency broadcast service. The John Howard Dellinger Gold Medal is awarded to the scientist whose research accomplishments have substantially contributed to one of the fields of URSI activity. It was presented for the first time in 1966.

1966 RECIPIENT—DR. JOHN H. CHAPMAN

In 1966, the John Howard Dellinger Medal was awarded to Dr. John H. Chapman of the Defence Telecommunications Research Establishment (Canada) for contributions to “radio wave propagation and the *Alouette I* topside ionosphere sounder.” Dr. Chapman (28 August 1921–28 September 1979) is well known for his role in leading the development and launching of Canada’s first satellite, the *Alouette I* ionospheric topside sounder, in 1962. He later prepared the Chapman report, which provided the vision and framework that led to establishment of the modern Canadian space program. When the headquarters building of the Canadian Space Agency was completed in 1992, it was named *The John H. Chapman Space Centre* in his honour.



Dr. Chapman with the *Alouette 1* backup satellite in October 1962. (Photo courtesy of the Communications Research Centre Canada; used with permission.)

BOOKER GOLD MEDAL

Henry Booker served URSI in many capacities, including as the chair of Commission H (1963–1969) and as vice president (1969–1975). He was instrumental in the creation of the Arecibo Observatory. A strong advocate for the role of telecommunications within URSI, he was elected an honorary president in 1978. A small fund set up by his colleagues at the time supports both the Booker Fellowship and, since 2002, the Booker Gold Medal which recognizes outstanding work in telecommunications or a related science.

2002 RECIPIENT—PROF. SIMON HAYKIN (LFIEEE)

Prof. Simon Haykin.

In 2002, the Booker Gold Medal was awarded to Prof. Simon Haykin of McMaster University (Canada) “for significant and fundamental contributions to adaptive signal processing and neural networks, and their applications to radar and digital communications, the characterizations of which are dominated by nonstationary physical phenomena.”

2017 RECIPIENT—PROF. LOT SHAFAI (LFIEEE)

Prof. Lot. Shafai.

In 2017, the Booker Gold Medal was awarded to Prof. Lot Shafai of the University of Manitoba (UM) “for outstanding contributions to antenna miniaturization by electromagnetics and numerical techniques, small satellite terminals, planar antennas, invention of virtual reflectors, low loss engineered conductors, and dielectric film components and antennas.” Prof. Shafai chaired URSI Commission B (Fields and Waves) from 1985 to 1988. He was elected an IEEE Fellow in 1988 “for contributions to the analysis of electromagnetic problems in antenna design” and received IEEE Canada’s Fessenden Medal in 2002.

FOCUS ON

URSI Commission K—Electromagnetics in Biology and Medicine

Alexandre Legros
Canadian representative to Commission K Member, Canadian National Committee

Puyan Mojabi
Early career representative to Commission K (2017–2019)

Dr. Alexandre Legros is a principal investigator and director of the Bioelectromagnetics and Human Threshold Research Facility within the Imaging program of the Lawson Health Research Institute (London, Ontario). He is also an associate professor in the Departments of Medical Biophysics, Medical Imaging, and Kinesiology at Western University. His research interests mainly relate to the effects of specific electric and magnetic stimuli (DBS, transcranial magnetic stimulation, and time-varying magnetic fields) on human brain processing, motor control, and cognitive functions. He is currently the secretary of the BEMS board of directors, cochairs a subcommittee 6 IEEE-ICES working group (EMF dosimetry modeling with application to human exposure standards), and leads an IEEE-ICES task force working on C95.6 future revisions. Dr. Legros is managing an international industry-partnered scientific program with academic support from Mitacs.

Puyan Mojabi is an associate professor and a Canada research chair (Tier 2) in the Department of Electrical and Computer Engineering at the University of Manitoba (UM). He is a recipient of UM's Falconer Emerging Researcher Rh Award for Outstanding Contributions to Scholarship and Research in the Applied Sciences category and an Excellence in Teaching Award from UM's Faculty of Engineering. He also received three Young Scientist Awards from URSI and recently served as an Early Career Representative of URSI's Commission K and as the chair of the IEEE Winnipeg Waves Chapter. Dr. Mojabi's research is focused on electromagnetic inversion for characterization and design with applications in the areas of imaging, remote sensing, antenna measurements, and design

URSI Commission K—Electromagnetics in Biology and Medicine promotes research and development involving

- the physical interaction of electromagnetic fields (from static to optical) with biological systems
- the biological effects of electromagnetic fields
- the mechanisms underlying the effects of electromagnetic fields
- the exposure systems of experimental electromagnetic fields
- the assessment of human exposure to electromagnetic fields
- the medical applications of electromagnetic fields.

Medical imaging is an important focus of both Canada's Electromagnetics in Biology and Medicine community and URSI Commission K. Techniques such as magnetic resonance imaging, computerized tomography (CT), ultrasound, and others have become indispensable tools for diagnosing diseases, planning treatment, and monitoring patients' responses to treatment. The significance of medical imaging technology is underscored by the size of the annual global market for diagnostic medical imaging equipment and software: US$32 billion and growing by 7% each year.

Canadian academic centres have developed some of the world's leading imaging research programs, with the three largest located in Toronto, London, and Vancouver. Considerable public and private investments have led to significant imaging innovations, many of which have already been licensed to and developed further by spin-off companies. Key challenges include the need to bridge islands of expertise and pool resources, the effort required to conduct clinical trials and pathological validation, and the effort required to prepare regulatory filings and manage the business aspects.

Among many other contributions, Canadian researchers have advanced the understanding of biological responses to electromagnetic stimuli in humans, generated 3D ultrasound imaging (Fenster et al., 1999), created digital mammography (Yaffe et al., 2003), and developed Canada's first positron emission tomography-CT scanner at Lawson Health Research Institute in 2002. Other organizations with an interest in this area that have a significant Canadian presence include the IEEE Engineering in Medicine and Biology Society and the Canadian Medical and Biological Engineering Society.

In April 2014, Canada's Electromagnetics in Biology and Medicine community marked a notable achievement with the Royal Society of Canada's release of their Expert Panel Report on the Review of Safety Code 6: Potential Health Risks of Radiofrequency Fields. Dr. Frank Prato, the URSI Canada chair at the time and a past international chair of URSI's Commission K, served as a member of the panel. The Expert Panel was established at the request of Health Canada, the federal department responsible for regulations in this area.

The panel's mission was to determine whether Health Canada's proposed changes to Safety Code 6 provide adequate protection from established adverse health effects, whether there are other potential health impacts that should be considered, and whether additional precautionary measures should be recommended. The panel concluded that "the balance of evidence at this time does not indicate negative health effects from exposure to RF energy below the limits recommended in the Safety Code. However, research on many of these health effects is ongoing and it is possible that the findings of future studies may alter this balance of evidence." The panel recommended that Health Canada continue to monitor the literature for emerging evidence and that it aggressively pursue scientific research aimed at clarifying the radio-frequency energy-cancer issue and at further investigating the question of electromagnetic hypersensitivity, in particular. The report has since served as an important reference for both policy makers and researchers.

Through this wide range of activities, Commission K serves to facilitate communication and collaboration with its involvement in scientific and technical meetings and is already starting to prepare its URSI GASS 2021 scientific program.

who chaired the COSPAR/URSI Inter-Union IRI Working Group from its inception in 1968 to 1976, and remained an active mentor for two decades thereafter. The Karl Rawer Gold Medal was only recently introduced and has not yet been awarded to a Canadian.

THE PRESIDENT'S AWARD

This award was just introduced in 2017 and honours outstanding contributions to the work and mission of URSI.

The National Research Council of Canada is the adhering body for Canadian membership in URSI and appoints the members of the Canadian National Committee. For more information about URSI International, please visit http://www.ursi.org/. For more information about URSI Canada, please visit http://www.ursi.ca/. ■

About the Author

David G. Michelson is chair of the Canadian National Committee of the International Union of Radio Science (2018–2021). He has led the Radio Science Lab at the Department of Electrical and Computer Engineering, University of British Columbia (UBC), since 2003. His current research focuses on short-range/low-power wireless networks for smart utility, smart transportation, and natural-resource applications; millimetre-wave channels and systems; and satellite networks for communications and remote sensing. Prof. Michelson serves as a member of the Board of Governors of the IEEE Vehicular Technology Society, as a member of the steering committee of the NIST-sponsored 5G mm-Wave Channel Model Alliance, and as director of the AURORA Connected Vehicle Technology Testbed at UBC.

Two weeks into the COVID-19 lockdown, my grandmother questioned my devotion to space technologies. She sounded very disappointed that I was not applying my engineering skills to solve problems that could have a direct impact on people's lives. Although I do not disagree that I could do more, I explained to her that satellite images are not just pretty pictures but, rather, important tools used by health officials to fight the pandemic. In this issue, I elaborate on that response and describe some of the ways in which Earth observation data have played and continue to play an important role in the fight against COVID-19.

Ad adstra,
Dario Schor; schor@ieee.org

From the ultimate vantage point, space-based technologies help us see the big picture, distill patterns, and make decisions in the fight against a global pandemic. This relatively new field known as *tele-epidemiology* enhances the information collected on the ground by using Earth observation (EO) images to monitor the spread of diseases [1]. Needless to say, the space assets are not tracking individual vectors for a disease. Instead, large remotely sensed data sets collected over multiple years are used to look for temporal signatures in the physical, chemical, and biological environment that correlate to a particular health hazard. For example, within Canada, *RADARSAT-2* images are used to monitor the changes in forests conducive to the spread of Lyme disease and the environmental conditions that can disseminate the West Nile virus [2], [3]. In recent months, even without explicit signatures to track the novel coronavirus, engineers and health officials relied on EO data to monitor the other social and economic factors affecting global health. This article highlights a few uses of space technologies to fight COVID-19 and how you can play a role in this fight.

Using NASA's *Terra* spacecraft, the International Water Management Institute plotted degrees of ripened crops in the Indo-Gangetic Plains region.

As news of COVID-19 emerged from Hubei province, China, space agencies began imaging the area to collect data that could help understand the disease and its impact. Shortly thereafter, the European Commission released EO data from the *Sentinel-5 Precursor* spacecraft showing a decrease in nitrogen dioxide emissions in the region coinciding with factories shutting down as the province entered a lockdown [4]. By some crude estimates from the Copernicus Atmosphere Monitoring Service, the decline in air pollution equated to roughly a 60% reduction in road traffic and a 30% reduction of industrial activities in the area [5]. Similar data were collected over other epicenters (e.g., in Figure 1) to see if there was a correlation between the spread of the virus and air pollution (i.e., whether fine-particulate matter is a vector for COVID-19).

By late March 2020, Northern Italy was the focus of the pandemic. Struggling to manage limited health resources, the municipality of Turin requested EO data from the Copernicus Emergency Management Service [6]. Officials combined 50-cm resolution images from the *Pleiades* satellite showing the temporary hospital infrastructure with population data to successfully optimize the deployments of health personnel and

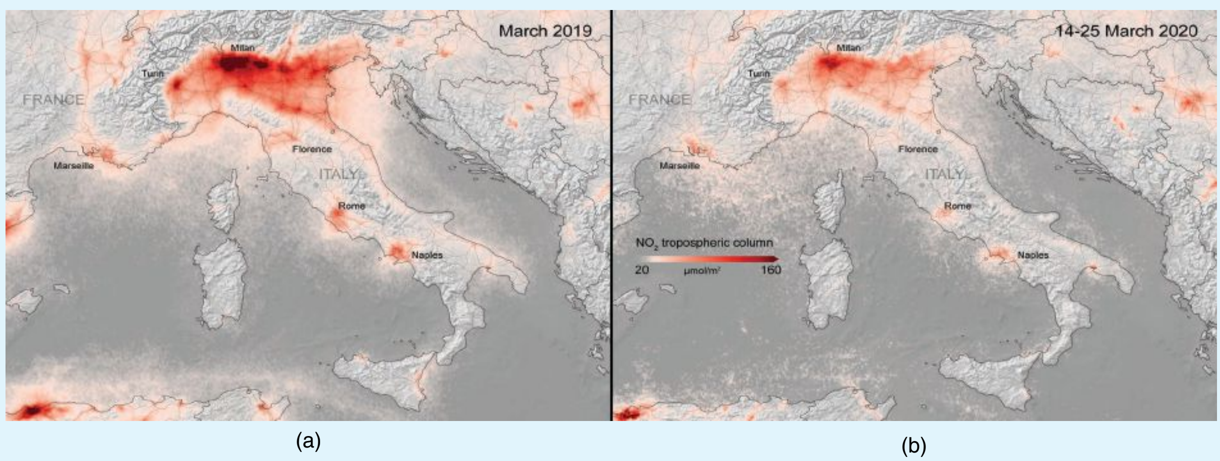


Figure 1: The processed Copernicus *Sentinel-5 Precursor* images of Italy showing a decrease in nitrogen dioxide (NO_2) levels when comparing (a) March 2019 to the COVID-19 lockdown in (b) March 2020. (Credit: KNMI/ESA.)

Figure 2: The Copernicus Emergency Management Service (EMS) images from (a) 2018 and (b) 2020 showing changes in the use of outdoor markets and the installation of new hospital tents in Italy. (Credit: Copernicus EMS © 2020 EU.)

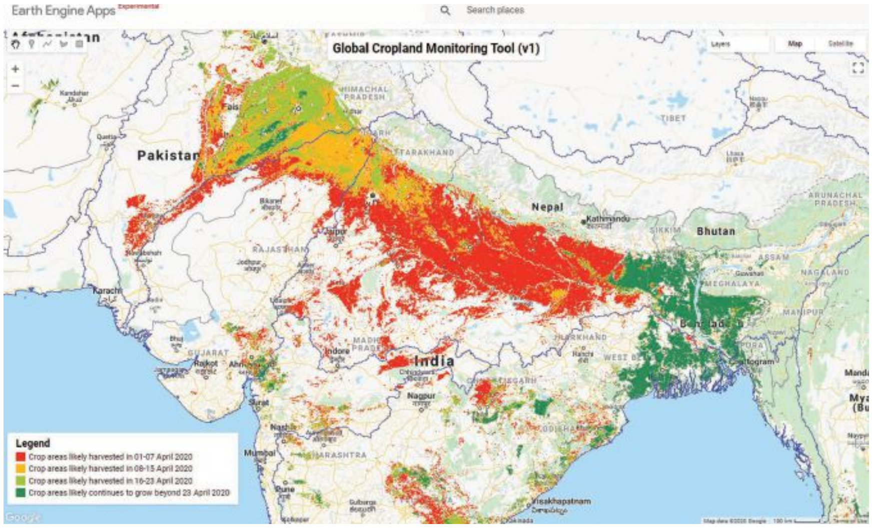


Figure 3: A map showing the maturity of crops in the Indo–Gangetic Plains region as estimated from NASA's *Terra* satellite images. (Credit: International Water Management Institute.)

resources, as shown in Figure 2. At a later stage, similar images were collected from street markets and green spaces to help drive policy decisions on how to gradually ease the lockdowns without risking more outbreaks.

As the virus spread throughout the world, other indirect consequences of local lockdowns began to emerge. For example, using NASA's *Terra* spacecraft, the International Water Management Institute plotted degrees of ripened crops in the Indo-Gangetic Plains region [7], [8]. The information, presented in Figure 3, was used to influence officials in India to ease COVID-19 lockdown restrictions and allow farmers in the region to harvest the crops [8]. Beyond food security issues and the risk of produce going bad, officials were also afraid of cascading effects, like waterborne diseases that could develop if there was a significant change in the demand of water used for irrigation [7].

The aforementioned examples are only a few examples of how EO data is being used to fight COVID-19. For other applications, check out the United Nations Space-based Information for Disaster Management and Emergency Response (also known as UN-SPIDER) website [9]. You can also look at the solutions from the NASA Space Apps COVID-19 Challenge [10]. In this 48 h hackathon, 15,000 participants from 150 countries used data provided by various space agencies to derive solutions to develop innovative uses of space data to help track the spread of the virus and its impact on society. More importantly, with all the data sets still available online, you can help develop new EO tools to help fight the spread of the virus. ■

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About the Author

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Scanning Toward Better Condition-Based Risk Management for Electric Power Utilities

By Chris Bowman, P.Eng.
Principal Product Manager, GE Digital, Saanich

This article provides a broad overview of converged global trends in remote sensing and artificial intelligence (AI) that enable improved data feeds for electric power transmission and distribution (T&D) assets and vegetation risk management.

Asset managers maintain our livelihoods

Canada's 19th-century goal of achieving mass electrification has been attributed to creating our middle class and, by extension, locking us in as a top-10 country by gross domestic product. However, due to our enormous land mass, abundant trees, harsh weather, and the distant locations of hydro and thermal generation plants, Utility 1.0 has meant endless challenges for T&D asset and vegetation managers. Today, new remote sensing technology, surveying methods, and AI-enabled data management solutions are available. This offers electric power utilities a clear upgrade path from their legacy inspection and risk management programs. Needless to say, 2020 has already proven to be a unique year marked by the COVID-19 pandemic. Electric power still remains an essential service to our society. Sooner or later, we are predicting a big acceleration in the area of digital transformation. Utilities that adopt the new solutions will see improvements in reliability, traceability, costs, and better service to our society in general.

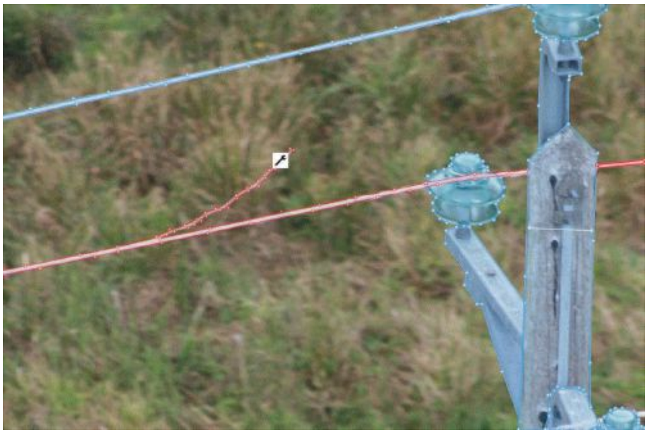

Figure 1: Conductor damage detection using image AI. (Photo courtesy of GE; used with permission.)

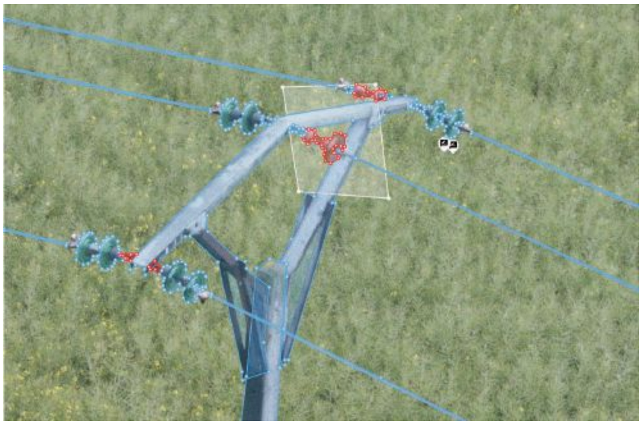

Figure 2: Insulator damage detection using image AI. (Photo courtesy of GE; used with permission.)

Why are these programs so important?

To understand the scale and criticality of these programs, consider that BC Hydro, Hydro One, and Hydro-Québec combined have more than 80,000 km of high-voltage transmission lines to manage. Canada is also electrically connected to the United States, something that both sides usually enjoy, except for the odd incident. We nearly claimed the world record in power outages when in August 2003, 10 million people in Ontario and 45 million in the United States suffered a sustained blackout. This outage is believed to have been initially triggered by part of a transmission line that sagged and contacted a tree that was allowed to grow too close to the line. It is for good reason that both countries are regulated by the North American Electric Reliability Corporation, which mandates periodic routine inspections of all transmission infrastructure and nearby vegetation. Slightly less frequently, utilities must also conduct a comprehensive visual inspection that goes right down to each individual line span, tower, nut, bolt, and even cotter pins that ensure that the insulator strings remain locked together.

The data that support current asset and vegetation risk calculation

Risk models are usually implemented according to the type of asset. This utilizes various attributes sourced from a utilities' enterprise asset management system and includes age, category, operating voltage, and installation configuration. These data are often supplemented by inspection data, which vary by a utility's practice and budget. However, most utilities maintain a reasonably rich database distributed across many types of assets. In countries and regions that have a wider financial reach and more regulatory requirements, a typical inspection data portfolio would include digital red-green-blue (RGB) photographs, forward-looking infrared (FLIR) images, or video (thermal imaging) and LiDAR (pulsed-laser imaging) (see Figure 1). In addition, utilities often record manual observations by tagging the database with indicators such as "Yes," "No," or "1-2-3-4" against issues like corrosion, structural defects, and danger trees. The size of the digital information can be measured in tens or hundreds of petabytes per year.

The challenges of legacy survey methods (fixed-wing aerial survey and land-based line patrol) are that they are very expensive, time-consuming, and can have unacceptable liability risk (especially with helicopter operation). Often, the images collected using this approach have a lot of variation and integrity issues due to inconsistent perspectives, focal accuracies, and distance from the target objects. Another major challenge with the legacy method is data management. This includes how to efficiently centralize and process the raw data, associate images (or point cloud blobs) with specific assets or trees, and extract the risk classifications so that asset managers can optimize their overall condition-based asset and vegetation risk management programs (see Figure 2).

Inspection data management 1.0

For any T&D asset or vegetation manager, the following inspection data management story should sound familiar.

We typically gather and process our inspection data manually, sometimes not even starting until the entire inspection program or at least a major phase completes.

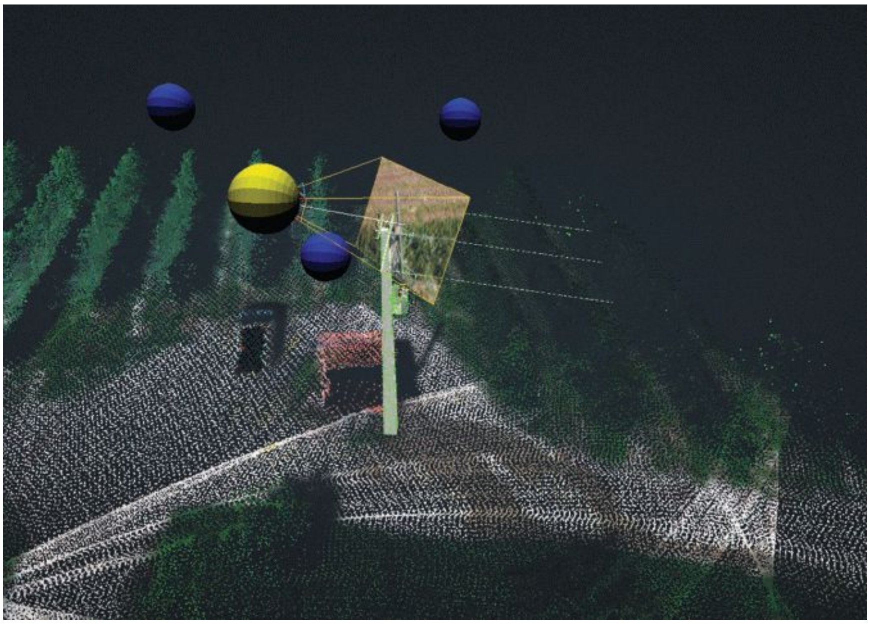

Figure 3: Pole and conductor classification using LiDAR. (Image courtesy of GE; used with permission.)

Figure 4: Vegetation encroachment calculation using LiDAR. (Image courtesy of GE; used with permission.)

We use teams of low-cost human resources, sometimes student employees. It takes them about five months to get through the analysis until we can get it all translated into our asset health and vegetation risk-calculation spreadsheets. From there, our asset and vegetation managers need to spend another few weeks or months trying to correct some data integrity issues caused either by poor or incomplete image collection, incorrect association to assets, and incorrect risk classifications. Finally, we can create next year's risk-based mitigation strategy using the cleansed and harmonized data.

Given the current situation, it's no surprise that asset inspection data management 1.0 has found itself staring down the barrel of digital disruption (students will enjoy their next summer job more anyway, so don't even start!).

What new approaches have emerged?

A recent global trend is that most electric power utilities are suddenly more open to changing their inspection processes and survey data portfolio so long as the new options are techno-economically superior, meaning that they can maintain or improve reliability for less money. For example, until recently, innovation had been too narrowly focused on incrementally better FLIR and LiDAR sensors (see Figures 3 and 4). However, so many other important aspects were not being examined. It is fair to say that we have now hit a critical convergence of innovation in multiple areas that can remove the pain points associated with surveying, managing inspection data, and efficiently analyzing data to generate business intelligence. This paradigm shift is being enabled by the following market trends: significant advancements in the commercial satellite industry, a new generation of drones that are purpose built for industrial infrastructure inspection, a leap in the maturity of AI-based image processing, unmanned aerial vehicle operation programs, and special applications of AI in utility data management.

At GE Digital, we have recently pulled all of these specific programs and innovations together to offer a complete managed solution. We brought in resources and technology from GE Aviation, GE Global Research's AI group, and GE Digital's Grid Analytic software and from strategic partnerships with commercial satellite companies, software companies, and cloud infrastructure providers. We are busy proving the value of our solutions as we speak with some of the largest and most progressive utilities in Europe, North America, and South America. The early adopters are all indicating the desire to prove to their regulators that the new methods are superior so that they can move toward full-scale production rollout. Prior to this, many utilities had been experimenting for years with different parts of the emerging approach. They are now signaling their intent to move from small pilots to full-scale enterprise programs to take full advantage without having to staff internally or integrate and manage disparate pieces.

A few specific improvements

A key aspect of our new program at GE Digital involves investments in multisensor data management. The starting point being a distribution of inspection data (RGB, LiDAR, satellites, and so on). We needed to streamline and generalize a data-ingestion pipeline so that asset and vegetation risk calculations can be made more automated. We are leveraging a federated image-classification AI engine that automatically identifies many of the important T&D asset types as well as critical defect types. The asset- and defect-classification framework is extensible, and we plan to continue implementing more inspection use cases by leveraging our GE Global Research team, customers, and partners. A final critical aspect to automated multisensor data management is our ability to associate assets identified from the 3D image maps correctly back into a utility's geographic information system of record. This "auto association" is critical to enable efficient data processing and risk calculation. This has been a problem for many of the companies that have pioneered this new technology.

Another innovative aspect we have been working on is the use of free and commercial satellite data as a means for generating relatively inexpensive wide area vegetation risk maps of entire T&D territories. A benefit of satellite data is that historic vegetation levels can be calculated, against which a utility's vegetation fault history can be used to generate insight on current and improved trim programs. The trend in the commercial satellite industry is clearly toward lower cost, improved spatial resolution (30 cm and decreasing), and more frequent and pervasive coverage. We have developed a flexible approach that combines orthoscopic 3D modeling, automated tree segmentation, and risk calculation. We are proving this in trials right now. We believe that satellite data will, for example, greatly improve overall inspection programs by displacing the need for complete LiDAR surveys. This is important because today, utilities spend roughly \$1 million for a 100 × 100-km^2 area using fixed-wing aerial LiDAR surveys. ■

About the Author

Chris Bowman is the principal digital product manager of grid analytics and asset performance management for GE Digital. He is a registered professional engineering physicist in British Columbia. He is a Member of the IEEE and the IEEE Power & Energy Society. He started his career in the power industry in 2008 at Powertech Labs—the R&D, testing, and consultancy subsidiary of BC Hydro. Over the past decade he has worked on a wide variety of transformative technology including electric vehicles, renewable generation, microgrids, AMI, IEC 61850-based protection and control, ADMS and FLISR, big data analytics, edge computing, artificial intelligence, and machine learning.

A Technical View on Deploying Emergency Generators for a Resilient Response to Natural Disasters in Alberta

by Alexandre Nassif

Alberta has recently experienced many natural disasters. Wildfires and floods have become frequent occurrences. Past events have resulted in transmission line damage, leaving areas temporarily separated from the Alberta Interconnected Electric System until one or more of the affected lines could be repaired and restored. Modern-day utilities have been transitioning from a reactive response, often involving bringing generator buildings and diesel tanks to a site after a disaster has struck or is imminent, to a more proactive and efficient measure.

Background

Major natural disasters, such as earthquakes, tropical storms, tsunamis, ice storms, flooding, and wildfires, have caused severe power outages around the world in the last few years. Recent events in Alberta include the 2011 Slave Lake fire, 2016 Fort McMurray fire, 2017 La Crete floods, and 2019 Northern Alberta wildfires that affected High Level, La Crete, and Wabasca.

Natural disasters have enforced a paradigm shift in many electric utilities. When a secure state changes to an alert state, the focus shifts to curtailing the impact of disasters and carrying out recovery actions to reduce supply disruptions. Electric utilities provide one of society's most critical services. Therefore, the recent focus has been on becoming more resilient. The IEEE Power & Energy Society's Industry Technical Support Task Force defines resilience as "The ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event" [1]. It stipulates that electric utilities must be able to endure stress and recover as quickly as possible with justifiable costs. It is, however, impossible to completely avoid performance degradations when a disaster occurs. Adequate

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This article summarizes the technical challenges and practices developed to tackle natural disasters in rural Northern Alberta by employing mobile emergency generators.

countermeasures and response plans can certainly help with system restoration.

In light of recent events, many utilities have provided an in-depth look at their emergency preparedness. For example, Xie and Zhu [2] reviewed the damages to the Chinese electric power grid infrastructure caused by natural disasters. The lessons learned from the 1994 earthquake in California have been discussed by Schiff [3], and those from the 2010 Chilean earthquake were presented by Rudnick et al. [4]. The recovery from severe weather-related water damage in Missouri in 1993 was presented by Abi-Samra and Henry [5]. An overheating-related weather event in New Zealand was described by Chakrabarti et al. [6].

Emergency preparedness has, in fact, been a long-standing practice for most electrical utilities, as demonstrated in research published in 1955 [7]. More recently, Lei et al. [8] presented an approach to pre-position generation assets in anticipation of a natural disaster and allocate them in real time. This work was focused in densely populated urban areas. In [9], Ortmeyer et al. present strategies to harden the distribution grids by sectionalizing feeders into microgrids. This future-looking approach may, indeed, become relevant once microgrids are widely deployed.

Meanwhile, rural areas in Canada present a unique challenge, with little shared experience available. This article summarizes the technical challenges and practices developed to tackle natural disasters in rural Northern Alberta by employing mobile emergency generators. It addresses asset specification, system sectionalizing, generator allocation, and safety.

Energy-Balancing Challenges

The operational challenges in running an electrical system during an emergency are described in this section.

The Balance of Load and Generation

Load Classification

To make effective use of all available generation resources, a thorough load plan must be developed. The goal is to categorize each load under at least three tiers:

- *tier 1—critical*: hospitals, fire stations, police stations, grocery stores, pharmacies, water treatment plants, and telecommunication towers and facilities
- *tier 2—desirable*: residential dwellings, farms, and schools
- *tier 3—nonessential*: industrial processes and less essential commercial establishments.

Supply Continuity

It is imperative to ensure that all of the critical loads are continuously supplied. This may involve transferring loads to feeders emanating from other substations. If supply from another substation is unavailable, mobile generators must be employed. The reconfigured system may require each feeder to be supplied by one or more generators. Furthermore, each feeder may need to be separated into even smaller islands that are supplied by their own generator sets.

Commercial load flow programs, such as CYME, can be employed to ensure the following:

- The generators are sized appropriately.
- The protection philosophy is reliable.
- The system voltage is adequately maintained.

It can be noted that power-quality requirements may often be relaxed during an emergency.

Generator Sizing

Adequate generation needs to be available in each of the distribution grid sections. This translates into having generator sets large enough for all critical loads and, at least, the majority of the less critical loads. Load imbalance needs to be factored in, ensuring that the generator rating is not exceeded. Furthermore, any critical load must be served with a predetermined degree of reliability and availability, even though the system is under contingency. Relevant standards can be adjusted to fit the system needs under such conditions.

Fuel Security

Generators are typically mounted along with fuel tanks. In each of the feeders or portions thereof, there must be enough fuel stored at the generator locations to ride through the event, or there must be open road networks to bring in additional fuel. Given the temporary and mobile nature of the supply, it is almost certain that the generators will be internal-combustion, diesel fueled as opposed to natural gas fired. However, if there are gas facilities near the intended generator installation location, consideration should be given to employ gas-fired generators. Having a mix of diesel and gas-fired generators (where multiple units are needed and available) has the added benefit of hedging against supply issues. Other forms of generation (e.g., photovoltaic and wind) are not yet an integral part of most utilities' mitigation plans.

Reliability and Availability

The best effort shall always be employed to serve critical and desirable loads most of the time. During an emergency, target values for the System Average Interruption Duration Index and System Average Interruption Frequency Index become less relevant and are excluded from periodic reporting to utility commissions.

Distribution System

The distribution infrastructure must have enough capacity to supply any power system islands created due to the emergency. Planning engineers need to consider topological information, such as conductor sizes, when determining where to site the generators. Distribution conductors tend to have less ampacity away from a substation. As such, a generator set installed too far from the substation on a feeder may result in conductor overload or excessive voltage drops. While it is not feasible to reinforce distribution networks based on possible emergency events, consideration should be given to plan the distribution system with increased capacity if an area is prone to disasters.

Opportunities to Reduce Consumption

During an emergency, some of the less critical loads can be dropped. Time of year also plays a factor. For example, it is unlikely that residential consumption would be reduced in winter. However, the heating load is likely to decrease during summer. A utility may serve many industrial customers in its territory, such as sawmills, oil fields, and pump stations. If a disaster is imminent, these customers should be directed to schedule an outage.

System Configuration Requirements

The discussions and configuration requirements presented in this section are intended to ensure system operability and supply reliability.

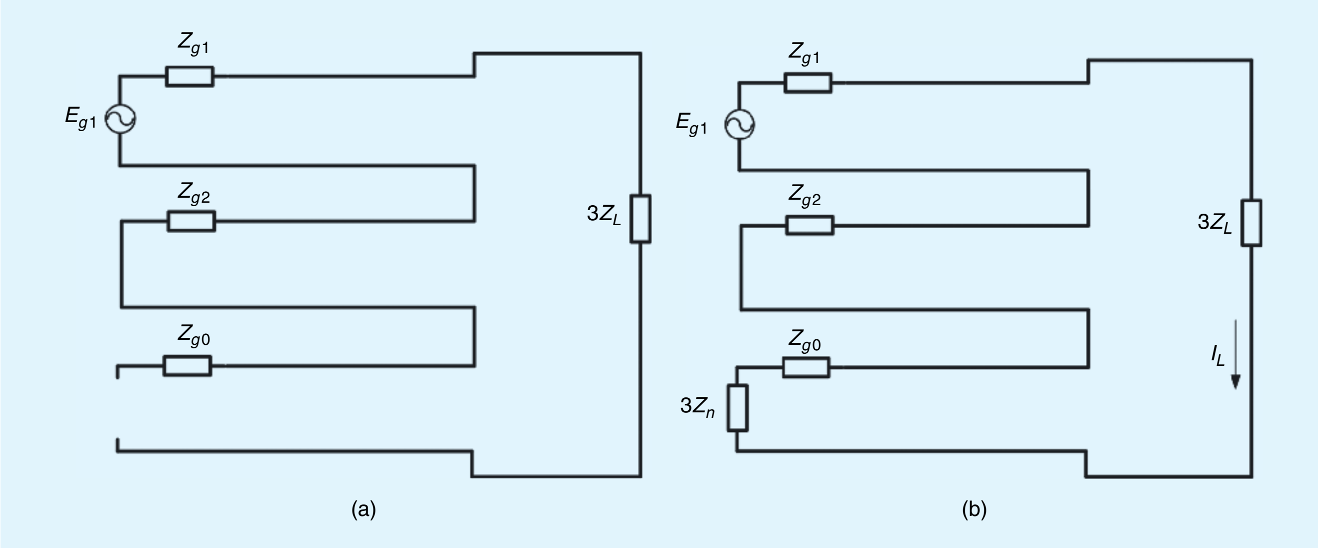

Figure 1: The sequence network of a three-phase generator supplying a single phase-to-ground load: (a) an ungrounded wye generator and (b) a grounded wye generator.

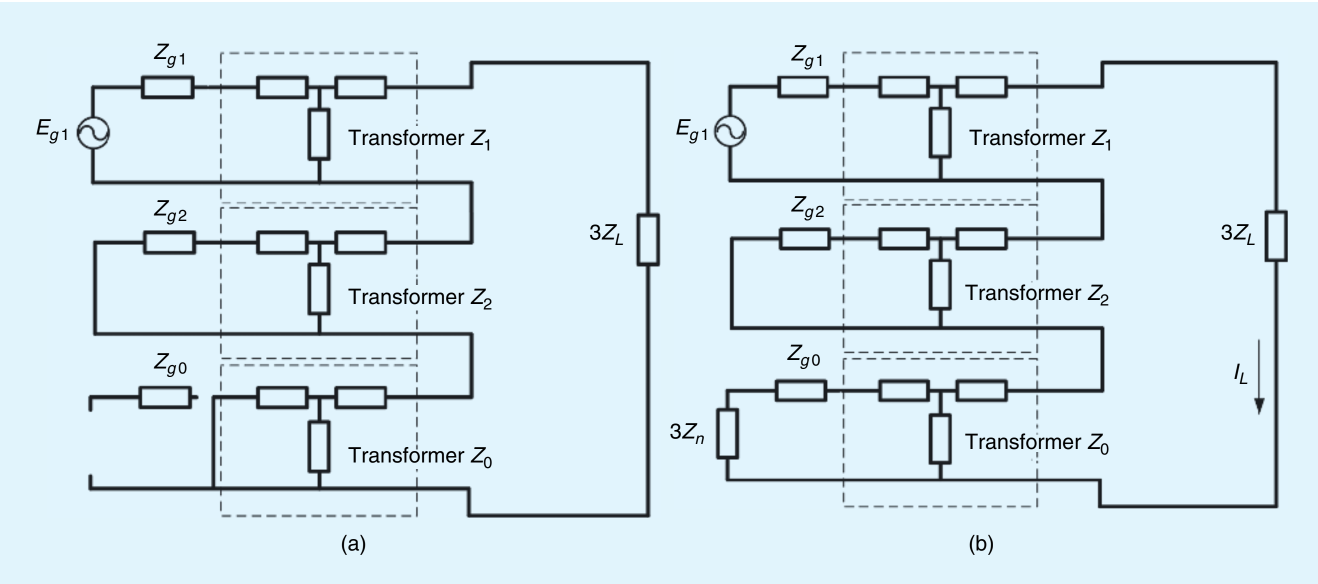

Figure 2: The sequence network of a three-phase generator supplying a single phase-to-ground load: (a) an ungrounded wye generator and delta-grounded wye step-up transformer and (b) a grounded wye generator and grounded wye-grounded wye transformer.

Generator Winding Configuration

Most diesel generators available for this purpose are configured either as delta or ungrounded wye. This configuration often allows for better reliability, as the generator does not contribute to ground faults, issuing alarms rather than tripping.

When coupled with grounded wye-wye transformers (typical distribution transformers), a delta or ungrounded wye generator is not suitable to supply phase-to-ground connected loads or any zero-sequence imbalanced current. The equivalent sequence network of this configuration is illustrated in Figure 1(a). As a result, ungrounded wye- or delta-connected generators require an external ground source. Figure 1(b), on the other hand, illustrates the sequence network of a three-phase, wye-grounded generator supplying a single phase-to-ground load. Z_{g1}, Z_{g2}, and Z_{g0} are the positive-, negative-, and zero-sequence source impedances of the generator, respectively. E_{g1} is the positive-sequence equivalent source voltage, Z_L is the equivalent load impedance, and I_L is the load current. Finally, Z_n is the neutral grounding impedance of the generator (zero if solidly grounded).

Transformer Winding Configuration

The transformer winding configuration also plays an important role in the supply suitability. For example, if the generator does not supply a ground source (ungrounded wye or delta configured), then a transformer that provides a high-side ground source is required. Figure 2(a) illustrates this configuration. Figure 2(b) shows another suitable configuration, where the generator is configured as a grounded wye, and the step-up transformer is configured as a grounded wye on both windings. A simplified representation of a transformer's sequence network is shown in the dashed boxes.

An alternative to the described configuration is shown in Figure 3. Here, a grounding transformer, such as a delta-grounded wye (the low-side delta winding can be

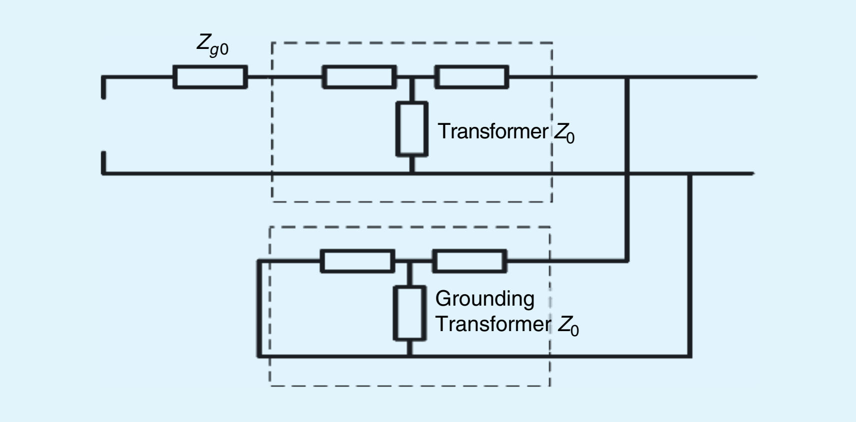

Figure 3: The zero-sequence network of a three-phase ungrounded wye generator coupled with a grounding transformer.

Table 1: The allowable generator–transformer configurations.

Generator		Transformer Configuration								
		Yg–Yg	Yg–Y	Yg–D	Y–Yg	Y–Y	Y–D	D–Yg	D–Y	D–D
	Y	No	No	No	No	No	No	Yes	No	No
	Yg	Yes	No	No	No	No	No	Yes	No	No
	D	No	No	No	No	No	No	Yes	No	No

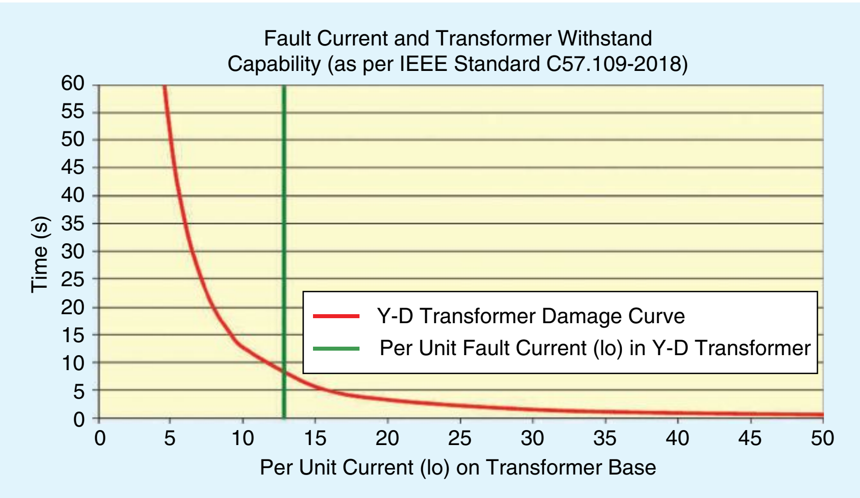

Figure 4: The transformer damage curve and ground-fault contribution.

kept unloaded), is used. Only the zero-sequence network is presented in the figure. The grounding transformer provides a low-impedance path for ground currents, which allows supply of single phase-to-ground loads. Table 1 summarizes all of these combinations and indicates their suitability to supply single phase-to-ground loads.

Grounding Transformer Design

A grounding transformer provides a zero-sequence, low-impedance path, allowing a ground source to serve single phase-to-ground loads. It also supplies the ground-fault current during a ground fault. Where appropriate, a grounding transformer can be designed with readily available transformer tanks (stored in a utility's warehouses). Care shall be taken to size the grounding transformer appropriately. The transformer tanks should be configured as delta-grounded wye (wye on the high side).

IEEE Standard C57.109 [10] prescribes the minimum design requirements for through faults of liquid-immersed transformers (i.e., the transformer damage curve). The damage curve of a typical 225-kVA grounding transformer (obtained from short circuit analysis software) using the method described in [10] is illustrated in Figure 4 (red decaying curve). The fault contribution obtained from a short circuit calculation is shown in the green vertical line. In this case, the transformer contributes about 12.5 times its rated current to the ground fault, and it will suffer damage if the fault persists for longer than approximately 8 s.

Generator Ground-Fault Detection

Because of the emergency nature of these systems, an automatic disconnect in the event of a ground fault at the generator terminals is not required by code [11]. However, the detection of such a fault is necessary. It is a good practice to provide an audible and visual signal device to indicate a ground-fault condition. Instructions should be provided to advise what course of action should be taken in the event of a ground-fault alarm.

Most generator sets will include ground-fault detection in their protection suite. For ungrounded wye- or delta-configured generators, this element is very sensitive. Typically, it could generate just alarms or initiate a trip. It may be necessary to ground the neutral point of the generators that are configured to operate as an ungrounded wye. In such a case, the protection system may set off alarms excessively or trip a unit even under normal system conditions, such as energizing a transformer.

Fault Current Considerations

A small generator will have short circuit characteristics (magnitude and duration) very different from those of a source provided by a substation. From a protection perspective, the most critical concern is whether the fault current magnitude and duration would be sufficient to selectively activate the overcurrent devices in a properly coordinated manner. In most cases, these generators do not produce high fault currents and should be connected as close as practically possible (physically and electrically) to the loads.

It is necessary to determine the magnitude and duration of a fault current and its changing characteristics. During the planning stages, much of this information can be obtained from generator specification sheets and type tests. It is an incorrect assumption that the speed of the generator prime mover will remain unchanged during a fault. The frequency variations and the prime mover load are interrelated. The coordination of the mechanical and electrical stored energy in a generator and the type of excitation system will determine how long the engine and generator would sustain a fault current and how rapidly this fault current would decay. Often, the initial power to a fault is several times higher than the prime mover power rating, resulting in a rapid deceleration. Such prime mover overloading is more likely to happen in small generator sets than in larger power systems because the *X*/*R* ratios of both the generator windings and distribution circuits in small systems are lower [11].

Fusing and Generator Protective Devices

Small generators often do not provide enough short circuit current to allow the distribution system protection to operate as it was designed. This means that inline reclosers may have to be reconfigured and fuses replaced. Alternatives include the following:

- Enable undervoltage and underfrequency protection elements on the generator. This would allow the generator to trip in case of a fault on the distribution system. However, selectivity will be lost, and difficulty will increase in discerning faults from events, such as transformer energization inrush or motor starts.
- Split the distribution system into smaller islands, effectively planning the generator physically and electrically closer to the load center so that reliance on its undervoltage and underfrequency protection can be increased.

It is inevitable that any such system will likely operate at a lower protection reliability and selectivity.

Motor Start Considerations

Motor starting using a generator requires that the motor develop enough torque for its driver's load and the system voltage be maintained above critical limits. Typically, a motor behaves as a constant impedance load during start. This means that the starting torque is proportional to the square of the terminal voltage. The purpose of a motor start study is to obtain the maximum voltage drop that will be experienced across the generator terminals as well as the motor terminal and determine if this poses a problem to the generator or motor. The starting power factor is typically low (15–40%), resulting in, mostly, reactive starting power demand [11].

Depending on the relative sizes of the motor and generator, the motor start can present itself as a small or large disturbance to the generator. During a start, the generator reactance will suddenly change from its steady-state value to its subtransient value. After a few cycles, the reactance changes to its transient value and then gradually changes back to its steady-state value. To capture this behavior, the generator model shall include its field and damper windings so that the transient and subtransient behaviors are captured adequately. The time constants need to be included to represent the effect of speed on the rotor reactance and resistance, implying that, to accurately represent this behavior, a transient stability

Small generators often do not provide enough short circuit current to allow the distribution system protection to operate as it was designed.

program is required. The models of the generator exciter and governor systems are also needed. However, to simplify the study, a worst-case scenario can be captured by using commercial short circuit software that includes simplified models of the generator and motor. In this case, the generator is modeled as an equivalent Thevenin network (classic model) consisting of a constant voltage source behind its transient impedance (X_d'). The starting motor shall be modeled using its locked rotor impedance.

Generator manufacturers often provide a guide to calculate how large a motor load can be. The aim is to start the motor without resulting in nuisance to a generator. Two rules of thumb are frequently used:

1. motor size-to-generator size ratio: 0.5 hp/kW [11]
2. minimum voltage across generator terminals during motor start: 0.75 per unit.

Shunt Capacitor Bank Considerations

Many electric utilities liberally employ shunt capacitor banks to support system voltage. When connected to the grid, these capacitor banks aid the voltage along a feeder. These are typically sized for a feeder's peak load condition.

During an emergency, it is expected that the feeder loading will be reduced because the industrial loads are likely to be partly or completely curtailed. In addition, many residents may have evacuated, reducing residential loads. This means that surplus reactive power may be available. For the case of a system supplied by emergency generators, this excess reactive power will be absorbed by the generator, potentially leading to an underexcited operation and creating generator field instability. It is recommended that all of the shunt capacitors be disconnected from the system under emergency.

Arc-Flash Considerations

It is important that the generators have all their motor control center (MCC) cabinets assessed for arc-flash incident energy and minimum approach distances. Where field personnel need to access the MCCs, they need to wear proper personal protective equipment and follow required procedures.

Breaking the System Down Into Smaller Islands

Suggestions have been made to use microgrids for powering islanded, small power systems. True microgrids would, ideally, enable the distributed energy resources to seamlessly switch from the primary source to an emergency one. While there are major differences between a microgrid and the islanded operation of a backup system, it is also important to recognize their interrelationship. Microgrid-supported resiliency has been an active area of research [9], [12], [13]. True microgrids, however, have been mostly limited to isolated (remote) off-grid communities or in demonstration projects. Generally, these have not been part of the restoration plans to date.

The main benefits of sectionalizing a large system into smaller islanded portions are

1. reduced physical space required to house the temporary generators
2. limiting distribution system faults into smaller sections
3. more flexibility to manage the load demand
4. increased controllability, especially for load shedding
5. increased dependability, security, and selectivity for protection and grounding schemes.

The disadvantages of such sectionalizing are as follows:

1. There is less available margin for excess or deficit in generation, as the units are sized to match the expected peak load.
2. Smaller (consequently, less resilient) generators need to be deployed.
3. Larger excursions in voltage and frequency need to be allowed due to the reduced regulating capability of the generation.

Allocation of Generators

The problem of emergency generator dispatch can be addressed by sensible allocation only to restore critical loads. Current practices generally follow an ineffective pattern that results in underutilization of these assets for the following reasons.

1. Even though they are prepared in advance, major dispatch efforts are conducted after a natural disaster is in progress.
2. The assessment of needs for matching generation with load is often not carried out rationally: generators are sized based on historic loading rather than real-time needs.
3. It is difficult to completely assess the site accessibility.

Ideally, a more efficient dispatch strategy should identify the potential areas for generator pre-positioning and dispatch.

Mobile Emergency Generator Pre-Positioning

Resource pre-positioning is a strategy recently implemented and still being refined by electric utilities around the globe. Pre-positioning of mobile generators essentially places them in staging locations prior to a natural disaster. The objective is to minimize the outage duration should the disaster occur. Ideally, pre-positioning should be done via a scenario-based approach by solving an optimization-like problem that considers the potential damage to the distribution system as well as the site accessibility after the disaster. By effective planning, faster service recovery can be achieved by reducing the transportation and travel times.

In practice, pre-positioning could imply that a utility will have a fleet of generators permanently stationed in areas deemed prone to disasters. An alternative is to have rental contracts that ensure generating units will be quickly delivered and commissioned as soon as a disaster is deemed to be imminent.

Real-Time Allocation

As soon as a disaster is in progress, the emergency generators are to be sent from the staging locations to the allocated position. They are then connected to the grid, which forms the islanded system to pick up the emergency loads.

Grounding Considerations

Grounding requirements for emergency power systems are subject to special code stipulations. Grounding conductors and connections must be arranged so that unacceptable levels of stray neutral currents do not exist. Adequate grounding must be provided such that ground-fault currents flow in a low-impedance and predictable path, protecting the personnel from electrical shock and guaranteeing proper operation of the protective equipment.

Performance Grounding

The suitable transformer and generator configurations discussed earlier are conducive to conditions that will allow acceptable performance grounding, per [14]. Generally, a case-specific performance grounding assessment during an emergency is not required.

Apparatus Grounding

Apparatus grounding systems consist of interconnected grounding conductors and grounding structures (such as rods). They perform the following basic functions [11].

- They limit the ground potential that may transfer to the exposed metal parts of equipment (such as raceways and other conductor enclosures), reducing the touch potential hazard.
- They safely conduct ground-fault currents for the fast operation of protective devices.
- They reduce electromagnetic interference, common mode noise, and other electronic interference.

Touch and Step Potential

Touch potential is the hazardous voltage between a hand (in contact with an energized object) and the feet of a person. Conversely, step potential is the voltage between the two feet of a person who is standing on energized ground [14]. A ground fault may cause a ground potential rise near a structure, which decays with distance. If a transformer or a generator undergoes a fault, any personnel working near the equipment will be exposed to this hazard.

The most practical measure to contain these risks is to prevent public access. Inexpensive wood fencing or barricades may serve the purpose during an emergency. A cost/benefit analysis suggests that the overall risk is manageable, as the likelihood and duration are low. Furthermore, if the area has been evacuated, there will be less foot traffic in the vicinity of a generator.

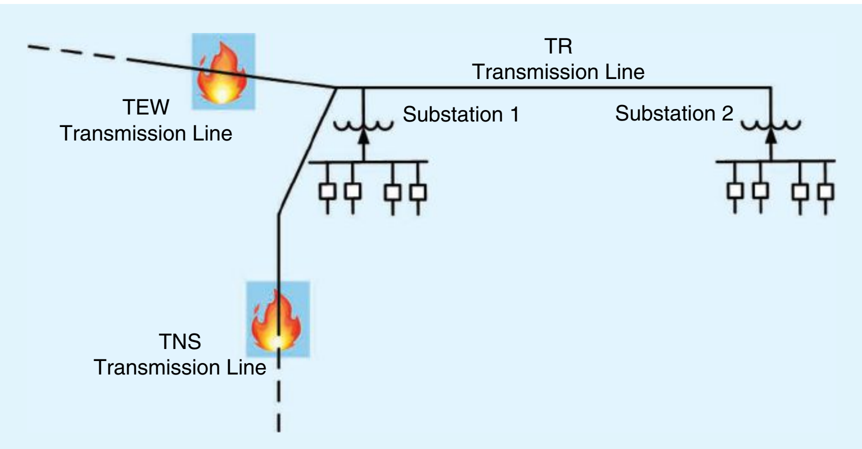

Figure 5: The transmission configuration of the affected system.

Case Studies

This section illustrates two examples of generator mobilization during the 2019 wildfire season in Alberta. The affected areas were exposed to potential prolonged outages, as multiple transmission lines that supply the upstream substations were impaired. Substation 1 lost two transmission lines (the west–east line [TEW] and the north–south line [TNS]; both lines were made of wood poles and damaged by the fire), whereas Substation 2 had a radial feed from Substation 1 through a separate transmission line (TR). Figure 5 illustrates the transmission network configuration. The TEW was quickly restored, even after being severely damaged. It was energized while portions of the line were still leaning as the utility crews worked to repair the TNS. After the TNS was repaired, the TEW was then taken off service for further repair. The wildfires raged out of control and burned sections of both lines over a period of several days. During this time, the utility tried to keep at least one line energized.

Substation 1

Substation 1 mainly feeds a town and its surrounding areas. Figure 6 illustrates the system and the corresponding emergency generator placements. The generators were allocated near the substation. The ground grid of the generators was tied to the substation grid. The high side of each generator's transformer

It is important that the generators have all their motor control center cabinets assessed for arc-flash incident energy and minimum approach distances.

was coupled with fuses sized marginally larger than the feeder's historical peak load. Without major industrial customers and with some of the residents prepared to evacuate, the load experienced a reduction.

Substation 2

Figure 7 illustrates the configuration of the system supplied by Substation 2. The substation has four feeders. Two feeders are extremely long, supplying four communities and many industrial, commercial, and rural customers. The customer count at each feeder is also shown in the diagram. The generators were placed near the substation. The utility had access to this land, which is primarily farmland. The generator ground grid was connected to the substation grid. Furthermore, the generator buildings were barricaded to avoid public access.

Because of the decreased short circuit levels from the emergency diesel generators, it was not expected that any of the inline protective devices would activate during a fault. The main protection was at the generator protection (overcurrent, undervoltage, and underfrequency). Fuses were installed at the distribution feeders at each connection point with the generators. These were sized marginally larger than the historical peak load. At the same time, the customers were encouraged to conserve electricity through public announcements. All industrial customers were directed to stop operation.

One feeder supplying three communities is 164 km long. Community 2 is 122 km away from the substation, which used to be an isolated load. It was interconnected in the early 2000s. It retained its diesel plant as a backup asset due to reliability issues, as the system is not accessible year round (winter road access only). Community 3 is about 162 km away from the substation. This was interconnected in 2018 to the distribution grid. Its original diesel plant was dismantled. Community 2 was to be disconnected from the feeder during the emergency scenario to allow better voltage management.

The feeder that supplies the main load center was broken down into three smaller islands. It was decided that two of these islands could be better supplied using diesel generators placed in two locations. This option resulted in better voltage management.

Lessons Learned

Before the real-time allocation and installation of emergency generators, the utility tried to maximize the usage of its existing fleet of generators and transformers. While warehouse-ready equipment was employed, the equipment was often found to be unfit for its intended purpose.

Technical Requirements for Transformer–Generator Sets

The following transformer–generator sets are recommended for emergency applications.

1. A ground source is required at the distribution feeder level. The generator–transformer configurations must be one of the options shown in Table 1. The use of generator or transformer neutral ground resistors must be avoided.
2. A grounding transformer may be required, which can be used to detect faults by monitoring its high-side neutral.
3. Primary protection is provided in the generator's voltage and frequency elements. Hence, fuses can be used at the high side of the transformer as backup protection.

Rental equipment may need to be secured as complete sets equipped with step-up transformers to meet these specifications.

Technical Requirements for Grounding and Safety

Where possible, the ground grid of the generators shall be connected to that of a larger grid. For example, if placed near a substation, the generator ground grid should be bonded with the substation grid to improve performance grounding. Foot traffic restrictions need to be applied by installing wood and tape barricades around the installations to discourage public access. A grounding study is recommended to determine safe distances for the public.

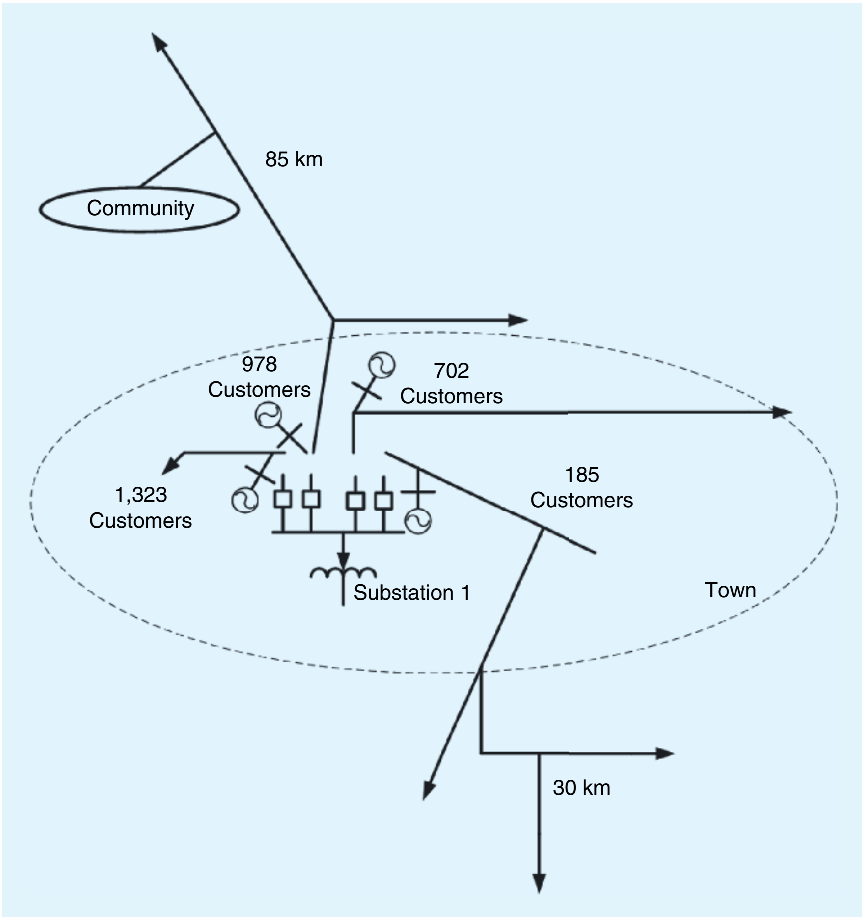

Figure 6: The Substation 1 system configuration.

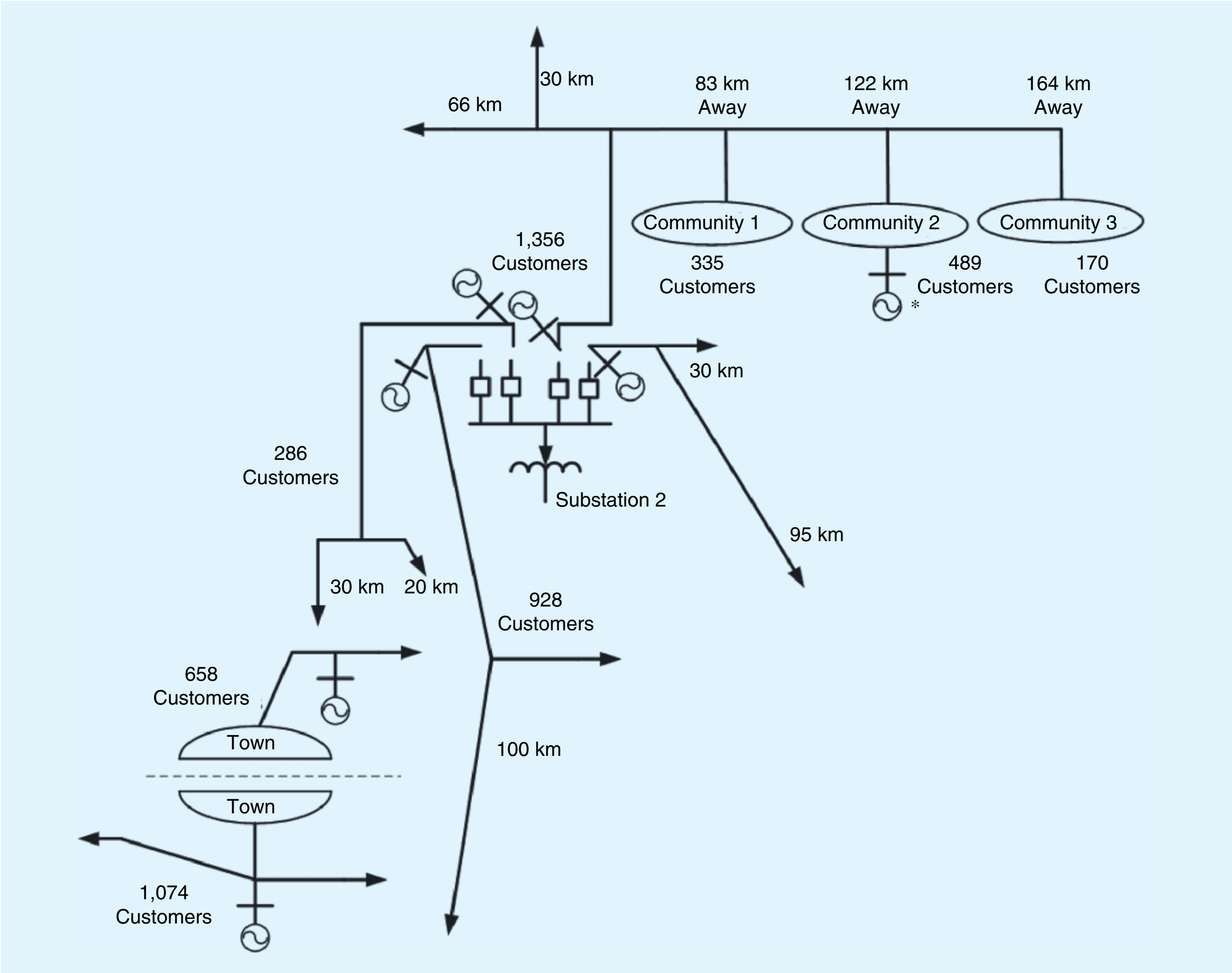

Figure 7: The Substation 2 system configuration.

Road Accessibility

Emergency conditions, such as wildfires, may affect the roads adversely, and accessibility can be compromised. This may affect the delivery schedule, requiring a longer, secondary routing. Such a contingency situation should be factored into the overall planning and management of an emergency response. ■

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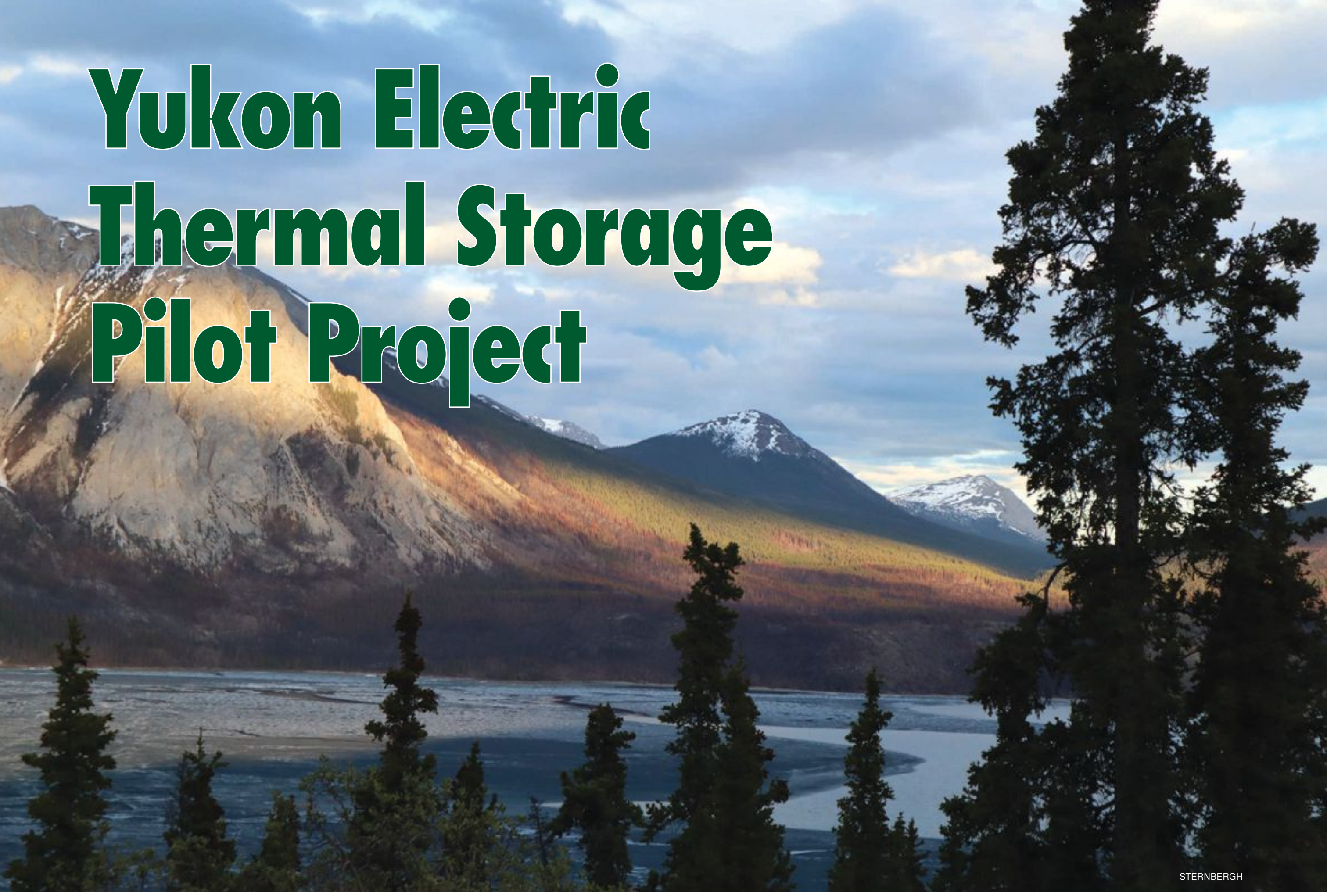
Yukon Electric Thermal Storage Pilot Project



STERNBERGH

By Noah Sternbergh and Eric Labrecque,
Yukon Conservation Society

Yukon Territory, located in Canada's far northwest and just east of Alaska, is home to approximately 35,000 people and 70,000 moose [1], [2]. Its mountainous and treed natural beauty with magnificent winding rivers may be why Yukoners have a history of pursuing green technology innovations. There has been a push in recent years to pursue the electrification of Yukon's home heating, reducing the use of fossil fuels to keep Yukoners warm through our frigid winters. Given that 92% of Yukon's electric demand was met by hydro in 2018, the electrification of heating appears, on the surface, to be an improvement over fossil fuel-based heating solutions like oil or propane furnaces [3]. However, unlike most of southern Canada, Yukon's grid (called the Yukon Integrated System, which is connected to most Yukon communities) is entirely cut off from the rest of the North American electrical grid [3]. To manage the isolated territorial grid and its communities, local utilities ATCO Electric Yukon and Yukon Energy must carefully control limited resources to achieve and maintain power balance. In the territorial capital of Whitehorse, increasing the adoption of electric heat in the territory has resulted in a growing demand on the electric power grid. The resulting winter peak has necessitated the use of supplementary greenhouse gas-emitting diesel and natural gas generators by Yukon Energy [3].

Spikes in electricity consumption from electric heating, which are particularly severe on the coldest winter mornings, are hard on the grid and generally not desirable from a utility control perspective. One way of shifting such a spike, more commonly referred to as a *peak*, is to use energy storage. Energy storage technology shifts peaks by storing electricity while energy consumption is lower, such as during overnight hours, and releasing stored electricity later during peak demand times. Longevity is an essential factor in the economic viability of energy storage technologies. This also is a common weakness of conventional battery technologies. Although there are always new chemical batteries in development, this shortcoming is ubiquitous. One technology that does not suffer from this problem is electric thermal storage (ETS). In the isolated grid of Yukon Territory, where the heating season often lasts from September to May, that makes ETS a hot topic.

Yukon Conservation Society is a grassroots environmental nonprofit organization established in 1968.

Yukon Conservation Society (YCS) is a grassroots environmental non-profit organization established in 1968. Through a broad program of conservation education, input into public policy, and participation in project review processes, the organization strives to ensure that Yukon's natural resources are managed wisely and that development is informed by environmental considerations. With a board and volunteer group composed of many long-time Yukoners, the society is a trusted voice with a vested interest in the well-being of the territory whose role in the community cannot be overstated. YCS advises government in the development of environmental, land use, and energy policies. It works with First Nations on landscape-scale conservation initiatives and acts as a bridging organization that brings together governments, the public, and other groups to facilitate communication and growth for a better future. YCS addresses energy concerns in the territory by contributing to any energy-related public and stakeholder engagement efforts by any level of government in Yukon. The society's history allows its work to set a precedent and act as a knowledge base for nongovernmental organizations across the country.

When an opportunity arose to spearhead a demonstration project that could impact the future of electricity generation and storage in Yukon, YCS jumped at it. The venture, now called the Yukon Electric Thermal Demonstration Project, will be led by YCS over the next two years. The project will involve the installation and monitoring of ETS units in at least 40 homes in and around the Whitehorse area (see Figure 1). Various usage data will be collected from all of the installed units over the course of two heating seasons (2020–2021 and 2021–2022). The Northern Energy Innovation (NEI) research team at Yukon University, in partnership with YCS, will conduct research to assess the suitability and viability of ETS for widespread use in Yukon and other northern jurisdictions.

As a storage technology, ETS acts as a temporal transport from when energy is not needed to when it is.

YCS is also working closely with the Yukon government's Energy Branch (also known as the Energy Solutions Center) to assess the energy efficiency of project applicants' homes and to harness their extensive energy program experience in support of our ETS project. This will ensure that our participants have home-heating systems that are representative of the heating mix currently in use in and around Whitehorse. Most importantly, in terms of shifting peak energy use, YCS is partnering with Yukon Energy, which will vary the preferred charging periods for participants' ETS units. This will allow Yukon Energy to identify the best ETS control approaches and practices for the territory. If, at any time, the amount of heat stored during the utility-set preferred charging periods is insufficient to meet the occupant's heat demand, the ETS units will charge outside of the preferred periods as necessary to maintain occupant comfort. If and when this occurs, it will be critical to NEI's research efforts for assessing ETS's feasibility for peak-shifting in northern climates.

Figure 1: An Ecombi ETS unit used to replace baseboards. (Photo courtesy of Coldbrook Electric Supply; used with permission.).

Building on success

ETS is an energy storage technology whose many benefits have been demonstrated in Europe since the 1940s and in North America since the 1970s [4]. Compared to other mature storage technologies such as flywheels and pumped hydro, ETS can be implemented grid wide, which allows for dynamic control when paired with smart grid technology [5]. It is also easily scalable, making it suitable for a wide variety of buildings ranging from small residences to large institutions [5], [6]. ETS technology has been used to expand wind energy penetration in Summerside, Prince Edward Island (PEI), and in Nova Scotia, to reduce strain on the grid by allowing consumers to shift their use to off-peak hours. It has also been used in remote Alaskan communities to support energy autonomy by decreasing reliance on diesel fuel, improving grid stability, and increasing the penetration of existing wind resources [5].

Potential benefits of ETS

Renewable energy sources are rarely available both where and when we need it. A relevant example of this is the availability of solar energy, which is plentiful during Yukon summers (hence Yukon's moniker, the "Land of the Midnight Sun") but limited during the dark winter months when we need it most. As a storage technology, ETS acts as a temporal transport from when energy is not needed to when it is. Although ETS is not capable of seasonal storage, which would be incredibly beneficial to address the lack of solar energy during the winter, the technology nonetheless offers remote grids like the Yukon Integrated System several potential benefits.

Peak-shifting

When consumer demand for electricity spikes, it can cause strain on multiple power grid components (i.e., transmission lines and transformers). These spikes in demand usually occur in Yukon during bitterly cold spells in December and January [3]. ETS could shift the electricity demand from residential heating systems throughout the day when less electricity is being drawn from the grid, smoothing out the daily electrical demand curve [5]. This would reduce strain on grid components and facilitate Yukon Energy's resource management efforts.

In remote power grids primarily powered by hydroelectricity-supplemented fossil fuel-based generation like Yukon's, the smoothing out of the daily electrical demand through the introduction of residential ETS systems is expected to reduce the amount of fossil fuels consumed to generate electricity. Here in Yukon, the magnitude of the daily spikes in electrical demand due to the territory's heating needs and the reduced capacity of the territory's hydroelectric facilities during the winter have necessitated the rental of temporary diesel generators during the winter months. Even with rented diesel generators, Yukon Energy's capacity was tested this past winter when the peak demand hit record levels of 95 MW, well exceeding the utility's forecasts [7]. ETS's demand-smoothing capabilities are expected to allow Yukon Energy's hydroelectric facilities to meet a larger portion of the territory's electrical demand during the winter months and reduce the need for rented diesel generators.

Intermittent renewables

Intermittent renewables, like solar and wind power, often produce electricity in excess of demand at different points throughout the day [5]. This is problematic because power must be balanced instantaneously, especially in remote grids like Yukon's. In other words, to prevent damage to equipment and blackouts, the demand must always precisely match the supply in electrical power systems. A solution to the problem of unpredictable renewable resources is energy storage. With a heating season that lasts nine months of the year, ETS represents a potentially ideal technology to help the territory incorporate more intermittent renewables onto its grid. This has been demonstrated in Summerside, PEI. Summerside is now able to provide electricity to residents that is an astonishingly 46% wind generated [8]. It has plans to add a 21-MW solar power farm and a 10-MW battery storage system to their grid, thanks in large part to their successful ETS program [9].

Grid stability

Both peak-shifting and the increased, intermittent renewable-penetration benefits of ETS touch on a key perk of the technology, namely, bolstered grid stability. ETS units can be controlled by utilities to act as dispatchable loads when charging and as dispatchable resources when discharging [5]. Certain utility control methodologies for ETS systems, such as radio-frequency control and frequency-based system operation, could provide auxiliary services such as frequency and voltage control [5].

To prevent damage to equipment and blackouts, the demand must always precisely match the supply in electrical power systems.

Potential challenges of ETS

Although there are many potential benefits of ETS integration with the Yukon grid, the technology is not without its drawbacks. For homeowners with functioning heating systems, the cost of purchasing and installing ETS units may be a deterrent, especially when time-of-use rates are not available in the territory. Local contractors who are less familiar with ETS will also need to undergo training and capacity building to ensure the safe and proper installation of the technology. The current electrical infrastructure in many Whitehorse and southern Yukon homes is not set up for the amperage demands of ETS heating systems and may require costly upgrades to at least 200-A service. Finally, although there are important reasons to switch to electrical heating over fossil fuels, more consumers heating their homes electrically means more demand on the electrical grid. That is, even though ETS systems are expected to lower the winter peak demand on Yukon Energy's electrical grid in terms of power (in megawatts), they will raise the annual demand for electricity (in kilowatt hours). The former (lowering the winter peak demand) is more critical than the latter (minimizing the increase in annual energy demand) based on Yukon Energy's recently released draft 10-year renewable resource plan [10]. This increase in annual demand would nonetheless need to be considered in Yukon Energy's medium- and long-term resource planning, especially if ETS systems become more popular in Yukon following this project.

These drawbacks to ETS are not insurmountable. The early adopters of ETS technology will be the first to see the financial benefits if Yukon's electricity utilities embrace time-of-use rates, as they are wont to do. Furthermore, capacity building, although potentially costly up front for employers, pays dividends in the areas of autonomy, expertise, and the general employability of any given business. Similar benefits are gained when investing in infrastructure. Although grid improvements can be expensive for utilities, they allow for a long-term growth that keeps up with the demand. Lastly, increasing demand on the electrical grid may require infrastructure improvements, but it also represents an increase in revenue for utilities, and it is inherent to the nature of our current economic system.

Conclusions

Looking forward, the Yukon Electric Thermal Storage Demonstration Project has the potential to show that this promising technology is the right fit for Yukoners. This could lead to the introduction of programs and policies for more Yukoners, well beyond the 40 or so who will participate in this pilot project. This will contribute to the territory's efforts to build a greener and more reliable electrical system. Barring that happy conclusion, the project will still shed greater light on the details of ETS's function in cold climates, contributing to the global knowledge base concerning the electrification of space heating. It will also contribute to the efforts of communities across the circumpolar region to reduce their reliance on fossil fuels while building a more resilient grid. ■

Acknowledgments

Eric Labrecque is the corresponding author.

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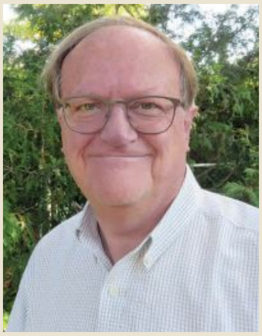
About the Authors

Noah Sternbergh is passionate about northern issues, environmental protection, and energy autonomy in the circumpolar north. She brings her experiences as an engineering student at Camosun College and her time as a research assistant on Yukon University's Northern Energy Innovation team to her role as an intern on the Yukon Electric Thermal Storage Demonstration Project. When Noah isn't working or studying she can be hard to find, as she makes the most out of living in one of the most beautiful places in the world. Contact her at noahwdsternbergh@gmail.com.

Eric Labrecque received his B.Eng. degree in sustainable and renewable energy engineering at Carleton University and his M.Sc.E. degree in mechanical engineering at the University of New Brunswick. Having decided to devote his career to assisting remote northern communities in their efforts to reduce their reliance on fossil fuels, early into his undergraduate studies, he moved to Whitehorse, Yukon, in 2019 to begin that career. Under a year later, he found himself at the helm of an exciting pilot project that will directly reduce the territory's fossil fuel consumption and reliance. He now lives in a "tiny house" with his girlfriend and loves to get out into the Yukon wilderness whenever he can. Contact him at eric.sree@gmail.com.

Philanthropy in a Time of Pandemic—The IEEE Canadian Foundation Continues to Serve



This is a difficult time for our community, whether you are a student, academic, industry practitioner, or retiree. Right now, the volunteer team at the IEEE Canadian Foundation is working to ensure that our mission continues even as social distancing guidelines and restrictions have caused some of our supported activities to shift the way they operate.

Scholarships will be increasingly important, as student work opportunities are in temporary decline.

Special grants can support virtual events and activities or be preparatory for new initiatives and ways of leading learning, innovation, and achievement.

McNaughton Learning Resource Centres, although perhaps operating under social distancing rules at the present time, will step up in importance as students want to round out and enhance online learning with practical hands-on experience.

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If you are able, please consider a gift to our $25 for 25 Years campaign in recognition of the formal launch of IEEE Canada in 1995. This was a result of the merger of IEEE Region 7 and the Canadian Society of Electrical and Computer Engineering. Twenty-five years ago, and after much volunteer effort, those two organizations combined, with the main goal to create one strong Canadian organization and more effectively serve and represent the interests of electrical and computer engineers in Canada. The IEEE Canadian Foundation, established as a separate and incorporated Canadian registered charity in 1993, was active then and continues to align with the interests and aims of IEEE Canada by supporting student and educational activities, including McNaughton Centres and scholarships, and other special ventures benefiting electrical and computer engineering in Canada.

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Thanks, as always, for your continued support of the IEEE Canadian Foundation. We wish you and your loved ones safety, comfort, and all our best as we face the times ahead together as a community.

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Our Governance Framework

The IEEE Canadian Foundation is a non-profit organization incorporated in Ontario and a national public foundation registered by the Canada Revenue Agency. We operate with 12 directors (IEEE Senior Member or higher, three-year terms, staggered, renewable), one of whom is the past IEEE Canada president for the duration of that position. Directors are chosen at the Annual General Meeting by the 30 members of the IEEE Canadian Foundation (IEEE Canada members or higher, five-year terms, staggered, renewable, at least one from each Section). The IEEE Canadian Foundation president is ex-officio on the boards of IEEE Canada and the IEEE Foundation, a charitable organization in the United States only but with some worldwide activities.

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Elena Uchiteleva

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My journey with the IEEE started as a master's student while volunteering for the Specialized Programming Activating Rich Kinds of Experiences and Discoveries (SPARK) Conferences held in 2013 by the IEEE London Section in collaboration with local schools. This program, led by Murray MacDonald of the London Section, is aimed at introducing engineering to school students. One day, I received an e-notice from Murray that had been sent to all of the IEEE London Section members with a call for volunteers for SPARK. I decided to sign up and replied. Seemingly uneventful, yet this is how my IEEE volunteering begun.

Following my wonderful experience at SPARK, Murray encouraged me to join the IEEE London Section's Executive Committee as the chair for the Women in Engineering (WIE) group in 2014. This role seemed challenging at first, as I had never held a leadership position or been on an executive committee before. However, it resonated a lot with my views on supporting women in science, technology, engineering, and mathematics (STEM). With an excellent mentorship from Murray and other senior volunteers in the Section, it turned out to be an interesting and rewarding experience. I worked on expanding the group in London, and I organized professional events aimed at promoting women in STEM. Following that, I was appointed to the position of the IEEE WIE Canada Committee chair (and regional coordinator), which involved leading the group nationally and representing it internationally. This interesting and dynamic role afforded me the opportunity to engage with WIE groups from all across Canada. I worked on regional WIE activities such as WIE sessions and panels at the IEEE conferences hosted in Canada (IEEE Canadian Conference on Electrical and Computer Engineering 2016–2017, IEEE Canada Electrical Power and Energy Conference 2016–2017, and IEEE International Symposium on Electromagnetic Compatibility, Signal, and Power Integrity 2016–2017), led the 2016 WIE Canada Congress, and participated in global WIE Committee discussions and meetings. Next, I was nominated for and subsequently appointed to be the chair of the IEEE Canada Member Services Group Committee. In this role, I was a part of the IEEE Canada Executive Committee and had a chance to engage more with Young Professionals, Student Activities, Life Members, Membership Development, and History regional committees. I also had the privilege to be in the core team bringing the IEEE WIE International Leadership Summit (WIE ILS) to Canada in 2018. Last year, I joined the organizing team of the IEEE Sections Congress as a member of the program committee. Currently, I am serving in this capacity, and I look forward to supporting the IEEE in the future.

Volunteering enables me to make meaningful contributions to society and to my profession.

When I reflect on my motivations for volunteering with the IEEE, a few come to mind.

- Volunteering enables me to make meaningful contributions to society and to my profession. I worked on increasing diversity in engineering through WIE initiatives, facilitated professional development for students and young professionals while engaging with Student Branches and YPs, and motivated young students to study engineering through local outreach events. A contribution is truly meaningful and rewarding when it helps someone else. I also learned from volunteering that leadership is one of the best ways to make impacts on issues that matter.
- Volunteering helps me improve myself and become a better leader. The IEEE provides an abundance of opportunities for leading teams and taking new initiatives. This is essential for students and young professionals who may not have an exposure to leadership roles. With passion and the capability to grow, one can thrive even under very challenging situations, given the opportunity. While volunteering and giving back to others, I developed a number of soft skills that are invaluable for my career and professional growth. The IEEE also has great learning tools available for members and volunteers such as the IEEE Center for Leadership Excellence and Volunteer Leadership Training Program.
- While volunteering, I meet people, and this helps me build my personal and professional networks. The IEEE is a large and vibrant community. It is a perfect venue to connect with peers and find mentors. I have met many inspiring people through the IEEE. Volunteering is also a great way to spend time with like-minded individuals and build lasting relationships.

To conclude, the experience I obtained over the years by volunteering for the IEEE is rewarding in a multitude of ways. It is undoubtedly worthy of the time I have invested. Volunteering can be challenging at times, but it is always fun. I believe that, while being part of such a diverse organization as the IEEE, anybody can find an activity that fits his or her interests and objectives. All one needs is to show up with passion and commitment. ■

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"Power Systems in Transition"

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Reflections on the "New Normal"

by Terrance Malkinson and Jacqueline Terlaan

There is a "new normal." We have all heard this phrase again and again. The rapid spread of the novel coronavirus has affected everyone. It has disrupted every aspect of our lives, creating unimaginable business, employment, physical, socialization, and mental hardships for everyone throughout the world. We are fortunate in Canada to have one of the best public health systems in the world; outstanding scientists, engineers, and citizens; abundant resources; and the wealth to implement government programs to assist our most vulnerable and those who have temporarily lost their employment.

Although not everything has gone smoothly, we must all realize that this is a new challenge and evolving rapidly and unpredictably. We will be challenged for many months and, perhaps, even years. A second wave of infection (or even more waves) later this year and continuing into the future is a very real possibility. National debts are growing with the unexpected expenditures required to fight this enemy and are added onto national debt accumulated prior to COVID-19. The IEEE and its members are playing an active role in flattening the curve, providing leadership and professional expertise. The IEEE has created an information-rich resource for you: "COVID-19: Your IEEE Resources," available at https://spectrum.ieee.org/static/covid19-ieee-resources.

This article is based on information as of 15 May 2020, and it will focus primarily on realistic forecasts for our future new normal, providing insights into how we can best prepare ourselves for career and personal success. The opinions expressed are those of the lead author and not necessarily those of the IEEE.

There are a plethora of opinions about the origins of the new coronavirus, ranging from the possible to the too ridiculous to be believable. The answer remains elusive. Even the world's best virus experts do not know its origin for certain. Previous experience with other emerging pathogens suggests that the coronavirus may have jumped from animal to human, a phenomenon known as *zoonotic spillover*. Research is suggesting that the 2019 novel coronavirus is 96% identical at the whole-genome level to a bat coronavirus.

Peter Daszak, a preeminent virus hunter who has been working in China for 10 years and is president of EcoHealth Alliance, a nonprofit health organization that tracks zoonotic spillover, has stated, "We're very confident that the origin of COVID-19 is in bats… We just don't know which bat species exactly, and we don't know how many others there are out there that could emerge in the future." The reality is that humans are biological creatures and subject to the rules of the natural world. Considering the complexity of the human body, it is indeed amazing that the billions of cells that make up our bodies function as well as they do.

By applying good science and engineering, we will, in time, overcome this challenge and emerge even stronger and, likely, better as a result of the experience. Changes that are now occurring and positive lessons from this experience may well become a permanent component of our culture. Now is the time to ponder changes in our society—the new normal—and position yourself for personal and career success as a positive coping mechanism. Indeed, entrepreneurial opportunities are opening up to those with vision, tenacity, and the courage to take risks.

Redesign of Our Cities

Over the past few decades, there has been a planned transition of increasing density in our urban centers, encouraging large numbers of people to now live and work closely together in condominiums and office towers, travel via crowded public transit, and walk closely together on narrow sidewalks. New York Governor Andrew Cuomo blames the severity of COVID-19 in his state's capital city, in part, on urban density. "There is a density level in New York City [NYC] that is destructive," he tweeted. "It has to stop and it has to stop now. NYC must develop an immediate plan to reduce density." Additionally, the world's population continues to grow as the concept of global population management, popular several decades ago, has been cast aside. Data from a Harris poll revealed that nearly a third of Americans are considering relocating to less-crowded places as a direct result of COVID-19.

Urban leaders and planners throughout the world have implemented changes to flatten the curve that may become permanent. Where previously citizens had to fight for space left over by automobiles, many streets are now being closed to cars, opening up space to bicycles and widening sidewalks to encourage walking and facilitate social distancing. Cities in the United States, Canada, and Australia have reconfigured traffic lights so that people no longer need to touch crosswalk "beg" buttons.

Keeping people apart contradicts the emphasis planners have traditionally placed on human interaction, including overcrowded mass transit and public spaces. We have valued nearness and meeting places as sources of collaboration, inclusion, and community building. "That contradiction is very interesting," said Jordi Honey-Rosés, associate professor at the University of British Columbia, who coauthored one of the first academic studies into the potential impact of COVID-19 on public space, "The Impact of COVID-19 on Public Space: A Review of the Emerging Questions."

Contactless Interfaces and Interactions

Social interaction tells us and confirms who each of us is as a person. Social isolation is currently causing considerable mental anguish for many. Regrettably, the very young who cannot play with their friends and the elderly who cannot have visitors are collateral damage. COVID-19 has made most of us acutely aware of every touchable surface that could transmit the disease. Fewer touch screens but more voice, machine vision, and new innovative interfaces will emerge and provide numerous entrepreneurial opportunities. Changes are as basic as elevator buttons, motion-controlled switches, door openers, plexiglass barriers, and contactless options to pay for goods and services. Population-tracking and surveillance technologies present myriad questions related to privacy.

Changes in How We Care for the Elderly

In this pandemic, the vast majority of deaths (more than 80%) have occurred in our extended-care facilities. As health-care practitioners and others have stated, this is a result of overcrowding and, although well-meaning, poorly trained and paid staff. This must change. More and new designs for these facilities, effective staff-training programs, and appropriate compensation must occur.

Another important consideration that has emerged for many is the concern of preparing in advance for the event of illness. An updated last will and testament, designated power of attorney, personal directive, and type of remembrance celebration are essential tools that everyone should take the time to prepare. A frequent comment in the coronavirus chatter is that family members do not know the final wishes of an elderly parent or loved one. Did the individual wish to be kept alive by a ventilator and/or medications, or did he or she prefer to be allowed to pass naturally?

Work Site Redesign

Second only to the elder-care facilities, the largest outbreaks of coronavirus are also occurring in overcrowded worksites where workers make the minimum wage and work long hours. These employees are often fearful of being terminated should they speak up to their supervisors about company practices that put them at risk for illness. Many are new Canadians and not familiar with our culture and values. This must also change through corporate leadership. Employers must provide information and effectively listen to their employees who believe that their workplace is unsafe. Business and risk-management plans will need to be updated.

Expansion of Digital Infrastructure

COVID-19 has proven that it is possible to use innovative digital solutions to maintain meetings, education, physical workouts, and contact with friends and loved ones when restricted to our homes. Many workers are reporting that they value the home office employment arrangement. This will have a significant effect on public transit, roadways, and business travel. Is it really necessary to travel to an office or distant countries for a meeting? A video call for meetings can be more effective and is environmentally responsible. New housing is now incorporating a home office as a critical or even mandatory marketing strategy for new home buyers and opportunity for home renovation. COVID-19 will sweep away many of the artificial barriers to moving more of our lives online; however, not everything can become virtual. Face-to-face interaction is important and essential for organizational cohesion and other in-person activities. We can be selective and choose options that best meet circumstances.

To reduce visit traffic at hospitals, pharmacies, and other health-care practitioners' offices, many are implementing consultations that can be done through technology, such as video. The development of remote diagnostic and monitoring technology provides incredible opportunities for entrepreneurs. With the pandemic, the majority of shopping and delivery has moved online. Those business that did not have an online option faced financial ruin, and those who had some capabilities ramped up offerings. Businesses that want to remain competitive will enhance their online services even if they maintain a brick-and-mortar location. Robots, drones, and automation support us today and will play an increasingly important role after COVID-19.

Reduced Demand for Fossil Fuels

The world population wants and is learning to live with less oil. The coronavirus pandemic, along with foreign national politics, has destroyed the demand for fossil fuels. Investors are dumping oil assets. There is no indication that this industry will ever recover to previous levels despite low energy commodity prices. There will always be a need for oil and oil-based products and services but likely not at levels previously enjoyed. Additionally, a product for which we have no control over the price or market is not a good basis for an economy.

Employees are working from home. International travel is plummeting. After this experience, will anyone want to travel in a crowded airplane or take an ocean cruise? People in once-polluted cities are now accustomed to blue skies and clear water, enjoying it, and demanding tougher emissions controls and increased efforts to tackle the climate crisis. The fossil-fuel industry has served society well for many years; however, as history has proven, it most likely will decline as new technologies emerge. Many creative people are working at innovative alternatives to fossil fuels.

Encouragement of a Healthy Lifestyle

The best defense against illness is well known to be regular exercise, which stimulates the body and, specifically, the immune system naturally to overcome illness. Being overweight, smoking, consuming alcohol, and using nonprescription drugs all make the body susceptible to infection and present difficulties with treatment should an individual become ill. Exercise is known to have a significant impact on the normal functioning of the immune system, including improved immune responses to vaccination, lower chronic low-grade inflammation, and improved markers of disease states including cancer, HIV, cardiovascular disease, diabetes, cognitive impairment, and obesity.

It is important that we find innovative ways to exercise while maintaining social distancing and good hygiene. The authors envision opportunities for providing mandatory education on healthy lifestyles, the epidemiology of disease, and regular participation in professional-led fitness programs. Fitness centers will need to be reconfigured with more space between equipment. Perhaps, as is the case with a home office, a home gym might become a valued asset. It is important for all workers to save a portion of their income for emergencies, such as unexpected temporary or permanent loss of income.

Greater Respect and Support for Our Scientists, Public Service Workers, and Health-Care Providers

Leaders who deny or discount science are a liability to the public good. Well-educated professionals who have the benefit of historical and current knowledge have, in general, been discounted and dismissed when they expressed an opinion contrary to government or industry thinking. In Canada, funding for our best scientists has been significantly reduced over time, resulting in the best and brightest having left the country for better opportunities. The motivation is, in most cases, not financial but rather respect for their mentality and work ethic. Those who remain do not in general receive the respect or financial support necessary to conduct important basic and applied research that will have long-term benefits. This must change.

National Supply Chain Self-Sufficiency

In recent years, the practice of globalization has been the basis of industry. Dependence on imports from foreign corporations is increasingly seen as not being in any nation's best interest. The fragility of food, fuel, and medical supplies, in particular, to global supply chains has been exposed with the pandemic. There is no reason why a country, such as ours, cannot manufacture and supply most of our own supplies and services. It was always a source of amazement to the lead author, when working for a North American logistics organization, to see container after container of consumer goods being shipped to Canada over long distances—goods that could easily be manufactured within Canada.

National Emergency Planning and Preparation

The lack of and delays in international cooperation have weakened the world's response to this challenge. Organizations, such as the World Health Organization and United Nations, must have the unencumbered funding and independent strong leadership to monitor, forecast, communicate, and mitigate risks to the world's population. No one country or group of countries should have the power to influence or interfere in any way with the independence of this important work. Jurisdictional disputes within a country should not be allowed to interfere or delay action.

In Canada, it is a national embarrassment that we did not have even a minimal level of personal protective devices and medical equipment within our borders to cope with this or any medical emergency. The authors believe that Canadians have the ability to manufacture, for example, our own high-performance medical masks and diagnostic technology. Why did we need to purchase them from other countries? Many agile and innovatively thinking Canadian manufacturers have redesigned their facilities to produce needed supplies. The leadership of these companies needs to be applauded, and they should be encouraged to continue this in the future. We can do this.

Digital (Virtual) Events

Organizers of and participants in in-person events that were forced to switch to electronic formats realize there are benefits. An example is the Canadian House of Commons, which is now holding virtual sessions, supplemented with periodic in-house sessions. The pandemic has had a tremendous effect on sporting events. Owners, athletes (professional and amateur), and fans have had to deal with the reality of their activities in large venues being put on hold or seasons entirely canceled due to COVID-19. By employing innovative broadcasting methods, sports enthusiasts can view events close up in the comfort of their homes and with fellow enthusiasts. Is there really any need to construct larger and larger event centres?

Conclusion

With unprecedented scientific collaboration, researchers around the world are racing to create an effective coronavirus vaccine and treatment options for those who become ill. Regulators are examining methods of fast-tracking testing and approval processes to ensure that a potential vaccine is effective and also safe for mass immunization. That is the best-case scenario—but it is far from certain. Would a vaccine for the new coronavirus wind up offering long-lasting immunity, potentially wiping out COVID-19 across Canada? Or will the virus prove to be a shape-shifter, mutating quickly enough that people will need annual vaccinations, like those for seasonal strains of influenza? To create long-lasting protection, researchers need to pinpoint a piece of that structure that is likely to remain stable over time and then isolate and deactivate it. This could require a traditional method, such as using a chemically killed virus, or genetically modifying viral information so it cannot infect humans.

Infectious disease expert Dr. Matthew Miller, an associate professor at McMaster University's Department of Biochemistry and Biomedical Sciences, warns the new coronavirus—or other similar, undiscovered strains—could wind up causing seasonal infections in Canada long after this pandemic. "This is much more likely to be a long-term battle for us," he said. "It's unlikely that we're going to be able to eradicate this thing."

Even if we are successful in creating an effective vaccine, change will occur. Lessons from the current experience may well become a permanent component of our culture. Game-changing events, such as the one we are now experiencing, result in loss to some and opportunities to others. One thing is clear: those who become informed, are entrepreneurial, think futuristically, and have the courage to embrace change will be successful. In a rare message to the Commonwealth, Queen Elizabeth addressed the COVID-19 pandemic early on and said, "I hope in the years to come everyone will be able to take pride in how they responded to this challenge." Queen Elizabeth offers an enduring and reassuring voice, urging resilience in the face of the COVID-19 crisis. ■

About the Authors

Terrance Malkinson is the author of more than 500 peer- and editorial-reviewed publications and is now retired. However, in retirement, he vigorously continues research and journalism, with an extensive portfolio of basic and applied research projects, journalism, philanthropy, and mentorship. His diverse career path includes 26 years in medical research as a founding member of the Faculty of Medicine at the University of Calgary as well as a three-year appointment as a manager with the General Electric Company followed by a one-year applied research appointment with SAIT Polytechnic. During his long career, he has advanced both basic and applied medical, health and wellness, scientific, and engineering knowledge. He has trained and mentored undergraduate, graduate, and postdoctoral students as well as staff in the business sector and government. He is a 45-year, long-term member of the IEEE and, over the years, has served in many IEEE governance and publication roles. His current research interest in health and wellness extends to being an accomplished multisport triathlete, including, among other events, the completion of 11 long-distance Ironman triathlons. He is a Senior Life Member of the IEEE.

Jacqueline Terlaan recently completed her bachelor of arts degree in philosophy (honors) from the University of Alberta. She is the recipient of several student achievement awards and competitive scholarships. She has contributed her expertise in writing to outreach at the University of Alberta as well as with industrial leaders in Alberta.

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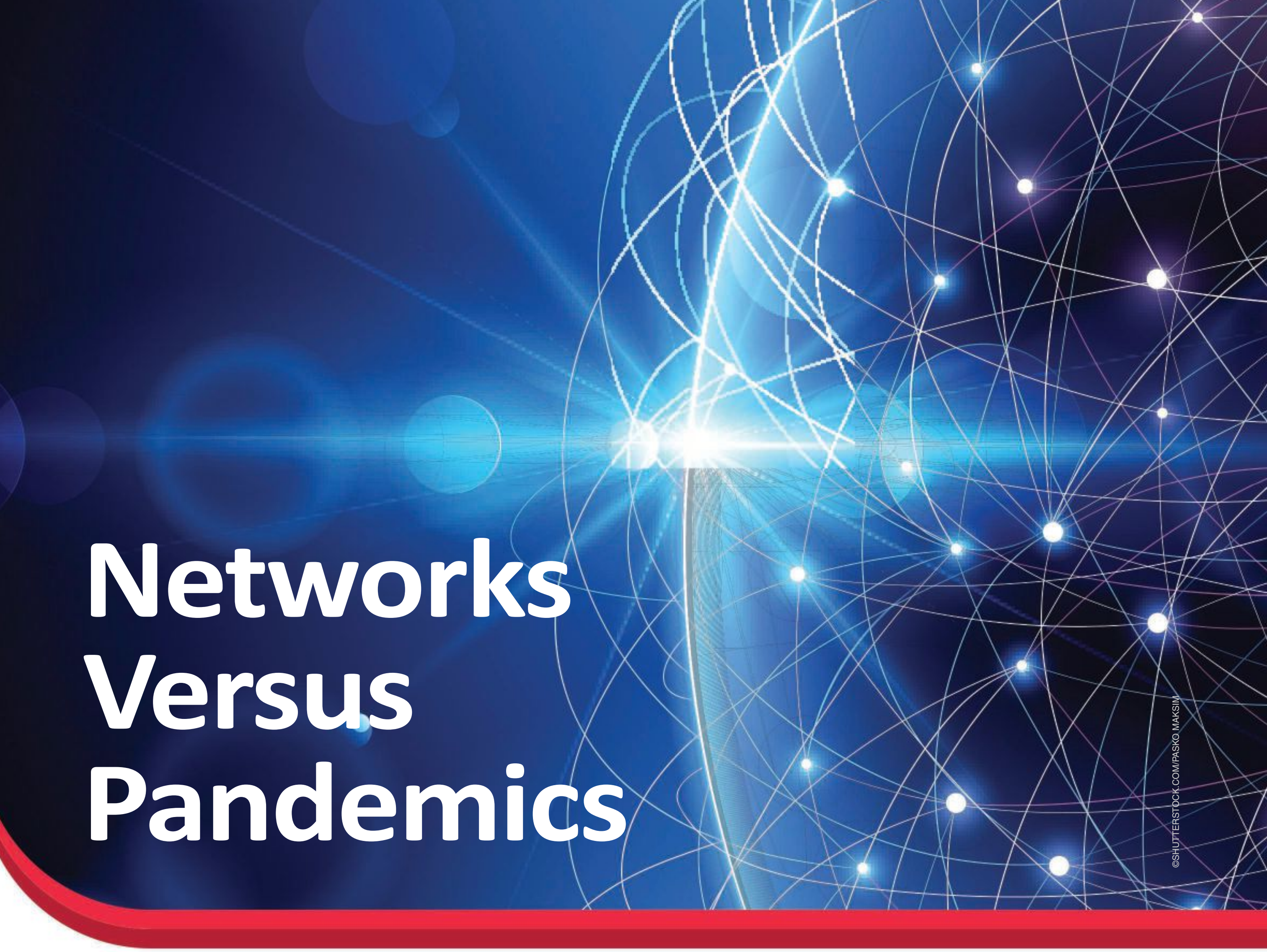
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Networks Versus Pandemics

by Matthew Wilder

In 1918, the Spanish flu took hold of Europe during the First World War. This deadly war claimed a staggering 20 million lives by the time it ended. The Spanish flu would turn out to be just as deadly, if not more. Estimates range between 17 million to more than 50 million lives lost to the pandemic between 1918 and 1920.

Nearly exactly a century later, we find ourselves facing a similarly aggressive pandemic in the novel coronavirus disease COVID-19. Although the absolute numbers of infections and fatalities of COVID-19 have been lower than those of the Spanish flu, the early rate of spread of COVID-19 seemed poised to sweep the population just like the Spanish flu.

It goes without saying that COVID-19 has sent the world into a disorienting series of unprecedented societal reactions and recalibrations as governments have sought to slow this pandemic down as much as possible. The exponential growth of contagious diseases is defined by R_0 (pronounced "R naught"), a number representing the number of people who will become infected by each presently infected person. The aim of any measures taken to combat the spread of a pandemic is to suppress R_0 to one or fewer to keep the growth linear at worst or even turn active infections into a decay curve.

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Social Distancing and Physical Distancing

As our awareness of the global pandemic came into focus in March 2020, we began hearing the term *social distancing* from government and health officials the world over. Early examples of limiting physical contact included foot taps and elbow bumps to replace handshakes. It did not take long for these gestures to fade away as officials urged us to keep at least 2 m from others at all times.

A better phrase emerged over the following weeks. The term *physical distancing* replaced *social distancing* as the preferred phrase to describe that we must keep from physical contact while recognizing just how important social contact is to each and every one of us.

Networks: Then and Now

By 1918, telephones were present in one out of every three homes in North America. When the Spanish flu hit, businesses accepted orders by telephone to limit physical contact. Students in some areas took part in early distance education by talking with instructors over the phone to review work they were performing at home. Unfortunately, as the flu swept through the population, the highly trained switchboard operators were just as susceptible to the Spanish flu as anyone else in the population. This left telephone companies with less capacity to direct telephone calls. Consequently, many operators were left with no option but to urge their customers to use the phone only for the most urgent of calls.

As Canadians have had limited access to hospitals and clinics, citizens of British Columbia, Alberta, and Ontario have been able to speak with physicians by way of video chat.

Today's networks are much more sophisticated and capable than the telephone network of the early 1900s. The Internet accommodates entertainment, video chats, distance learning, working from home, e-commerce, and even health. Since March, we have been watching more Netflix, and many of us heard of Zoom for the first time. Our children are learning at home, facilitated by technology, as many of us work from home. We order the goods we need online and even contact physicians over video chat.

Internet usage from February to March jumped approximately 25% (Figure 1). The peak usage of mobile messaging and multimedia messaging rose 30% and 50%, respectively. Phone traffic has risen 45%. Through all of this growth in our network usage, Canadian networks have kept up because of the significant investments being made in network facilities in our borders. These investments are paying dividends for the social fabric of

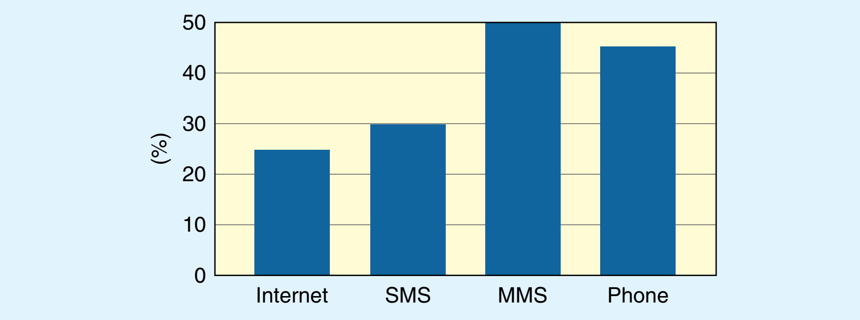

Figure 1: Network traffic increase due to COVID-19.

our extended families, communities, organizations, companies, and institutions.

Physical distancing measures have been attainable because of the networks that we depend upon. Would our collective resolve and resulting success in flattening the curve have been so strong if our networks were failing to perform at the scale they have needed to? One wonders.

Working From Home

I have had the fortune of working at a company that rolled out a work-from-home program beginning more than a decade ago. I have worked from home for most of that period for varying portions of my work week—first one day per week, then two, and then three days each week. I am classified as a "mobile" worker.

Since the COVID-19 physical distancing measures were implemented, I began working from home full time. My company had to dramatically increase the capacity of our corporate virtual private network so that tens of thousands of employees could work from home. The growth was roughly a doubling of capacity.

Many companies did not have the benefit of existing work-from-home programs, including infrastructure, policies, and procedures. There is no doubt that the pandemic has catalyzed the introduction of remote work to a very broad range of organizations that will likely retain this model once our communities no longer require us to observe physical distancing.

Health Care From Home

As COVID-19 became a global crisis, the health-care sector began bracing for the worst. Fears of hospital overcrowding were realized in the areas hardest hit. The Canadian response, like many other countries, included measures to limit hospital usage to avoid overcrowding as well as to limit the spread of COVID-19.

As Canadians have had limited access to hospitals and clinics, citizens of British Columbia, Alberta, and Ontario have been able to speak with physicians by way of video chat. A mobile app called *Babylon* by TELUS Health has facilitated the continuity of health care for those who have needed access to a general practitioner over the past several months.

Networks: Bridging the New Physical Distances

There is no doubt that networks have played an increasingly crucial role in 21st-century life. Not one person could have anticipated just how much we would have been relying on them in 2020. During one of modern history's most isolating times, networks have proven that their capacity to connect us not only to the information we need but to the people we care about is indispensable. ■

About the Author

Matthew Wilder is an engineer whose passion is to see Internet technology improve lives. He works at TELUS as a network engineer, having held responsibilities including network standards, planning, architecture, security, and systems architecture. He received his M.B.A. degree from the University of Victoria and his B.ASc. degree in electrical engineering from the University of British Columbia. He currently serves as the treasurer of the IEEE Vancouver Section.

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