Power Grid Research Under International Spotlight

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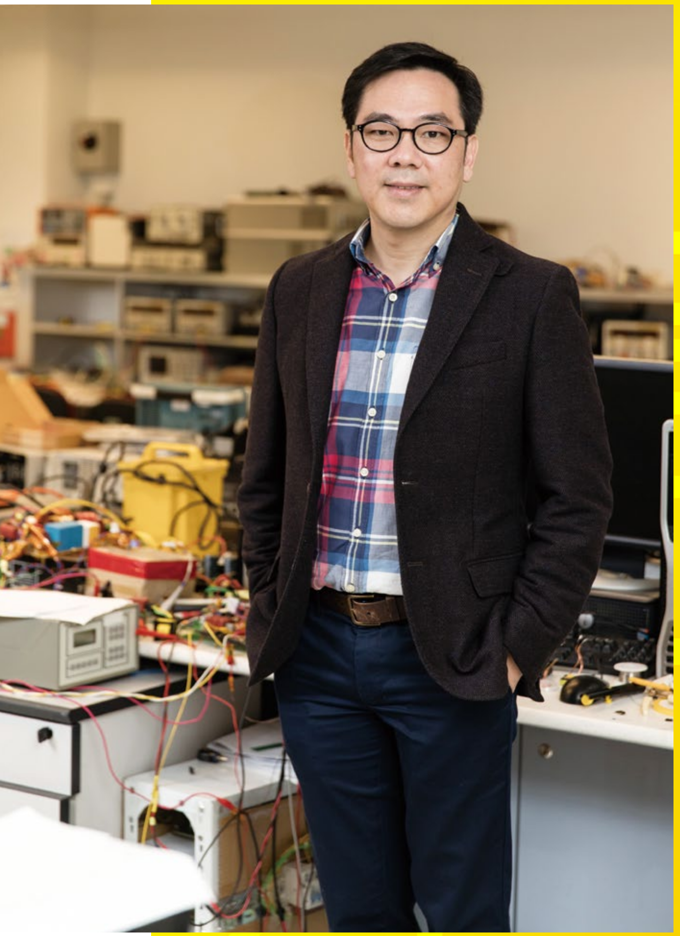
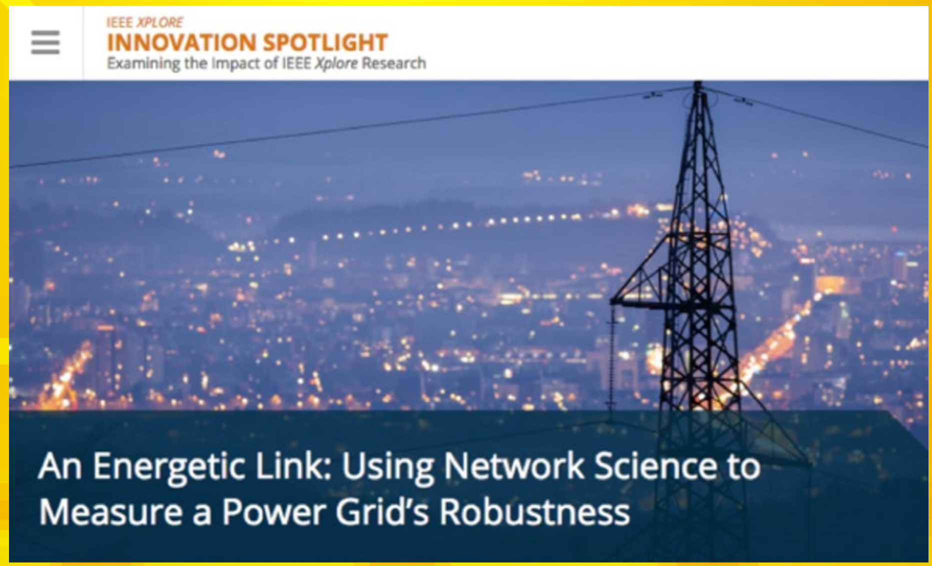


Thinking outside the box plus a decade of hard work have made EIE's research in power grid's robustness a focus of attention, as recently reported in *IEEE Xplore Innovation Spotlight* which features a small number of stories on cutting-edge topics and impactful research handpicked from the IEEE *Xplore* digital library of over 3 million technical documents.

Conventional study of power grid follows a simplified circuit model on which analytical results are developed, simulated and experimentally tested. Recently the research group led by Prof. Michael Tse at EIE has come up with a radically different approach to studying emerging topics in power grid. Refrained from the use of conventional analytical models which have limited capability for dealing with large scale power grids, Prof. Tse introduced a complex network approach and developed key robustness parameters with a network model which has its theoretical basis from both network science and physics of electrical circuits. This on-going research project has produced results that have been found promising thus far to quantitatively measure power grid system's robustness. A recent article in *IEEE Xplore Innovation Spotlight* reported that "what makes this project particularly impressive is that power grids are nearly impossible to analyze at-large due to their scale and constantly fluctuating nature to meet energy load demands. There are nearly 20,000 individual generators in the U.S. alone operating in complex networks – and using different types of fuel – to serve millions of residential and commercial consumers. On top of that, they are equipped to dynamically redistribute power flow when a component breaks down, sometimes succeeding and other times leading to cascading failures and black-outs depending on load capacities. All these factors make it very difficult to establish a uniform measurement system to assess a grid's robustness, or its ability to tolerate faults."

The main advantage of taking the combined complex-network and electrical circuit approach is the ability to provide realistic assessment of the percentage of unserved nodes in the event of a fault cascade and the percentage of non-critical links in a given power network, both of which offer quantitative measure of how well a power network withstands attacks and the likely extent to which a fault will cascade to a wide-area black-out. The study has highlighted the importance of connectivity, i.e., network structure, on the robustness of the system which has not been thoroughly understood. The *IEEE Xplore Innovation Spotlight* further reported that "the model provides a platform on which engineers can simulate the impact of change, and compare structures before they're even developed to favor the most robust one. Additionally, the model can be extended to other types of electrical components, such as solar panels in renewable energy systems."



(http://ieeexplore-spotlight.ieee.org/article/an-energetic-link-using-network-science-to-measure-a-power-grids-robustness/)

Research in applications of network science became active in EIE in 2003 when SARS hit our Hong Kong city claiming 300 lives and infecting over 2000 individuals. Prof. Michael Tse's research group applied a complex network model to generate realistic disease propagation patterns that were consistent with the infection data in Hong Kong. The key was the special form of connectivity, called scalefree and small-world distribution, that was crucial to accurately reproducing the realistic super-spreader phenomenon. Research continued to extend to avian flu spreading, leading to publications in the world's top journals and attracting global attention. The recent effort in power grid research has actually been built on the success of the group's network research conducted in the past decade on financial data and communication systems. Having seen tremendous opportunity in exploring network connectivity in practical complex engineering systems, the group has made serious efforts in the study of a few practical systems in which they already have considerable strength and experience, including traffic and information flows in cellular networks and the data packet flow in the Internet. Frequent invitations to deliver plenary talks at conferences and workshops have made this line of research well known to the research community.

Apart from successes in network applications research, Prof. Tse's group has an international reputation in power electronics and distribution, especially in lighting systems and the coupled power converter systems. Having received several major research awards, including the top IEEE Paper Prize, Prof. Tse's work has set the direction for stability analysis of networked converter systems and his proposed analysis method, commonly referred to as design-oriented method, is now a popular approach adopted by many power electronics researchers for analysis of complex behavior and stability of grid-connected converter systems. Recent awards received by the power electronics group of EIE which Prof. Tse leads are two Gold Medals from the International Exhibition of Inventions Geneva in 2009 and 2013. The award-winning technologies have been patented by the University and one key technology has also been licensed to a Hong Kong company. Key inventors include Dr Y.M. Lai and Dr. K.H. Loo, and ex-colleague Dr S.C Tan. The high level of recognition of EIE's research in networks and power electronics is also evident from the appointments of our colleagues to prominent positions in editorial boards of top-notch journals. Serving as Editor-in-Chief of IEEE Transactions and Magazines, Associate Editor of IEEE journals and Editor of major international journals, our colleagues are contributing their expertise to the research community, at the same time raising the visibility of PolyU in the international academic community.

In the coming decade, we expect to see new opportunities in power electronics and network research driven by the rapid development of the use of renewable sources, high-performance conversion systems (presenting as constant power loads), solid-state loads, and wireless power transfer systems. Power distribution will move toward DC distribution at the load-side while integration of a variety of sources to existing grids will pose tremendous challenges to stable and safe power distribution. At present, Prof. Michael Tse and Dr S.C. Wong are already developing practical design methods for wireless power transfer and DC distribution, and their works have attracted worldwide attention. The main challenge for the future is the need for cross-disciplinary expertise as the most important research problems identified so far are all at the boundaries of conventional electrical engineering and other disciplines including material science, physics, chemistry and mathematics. Tremendous amount of global research efforts are expected to be devoted to power distribution research, as evidenced by the many recent discussions in key international research forums. And for the research group at EIE, the coming decade will see another exciting and adventurous journey in this important area of power distribution research, the outcome of which will have a high level of relevance and impact to society and the way we live.

Research Breakthrough