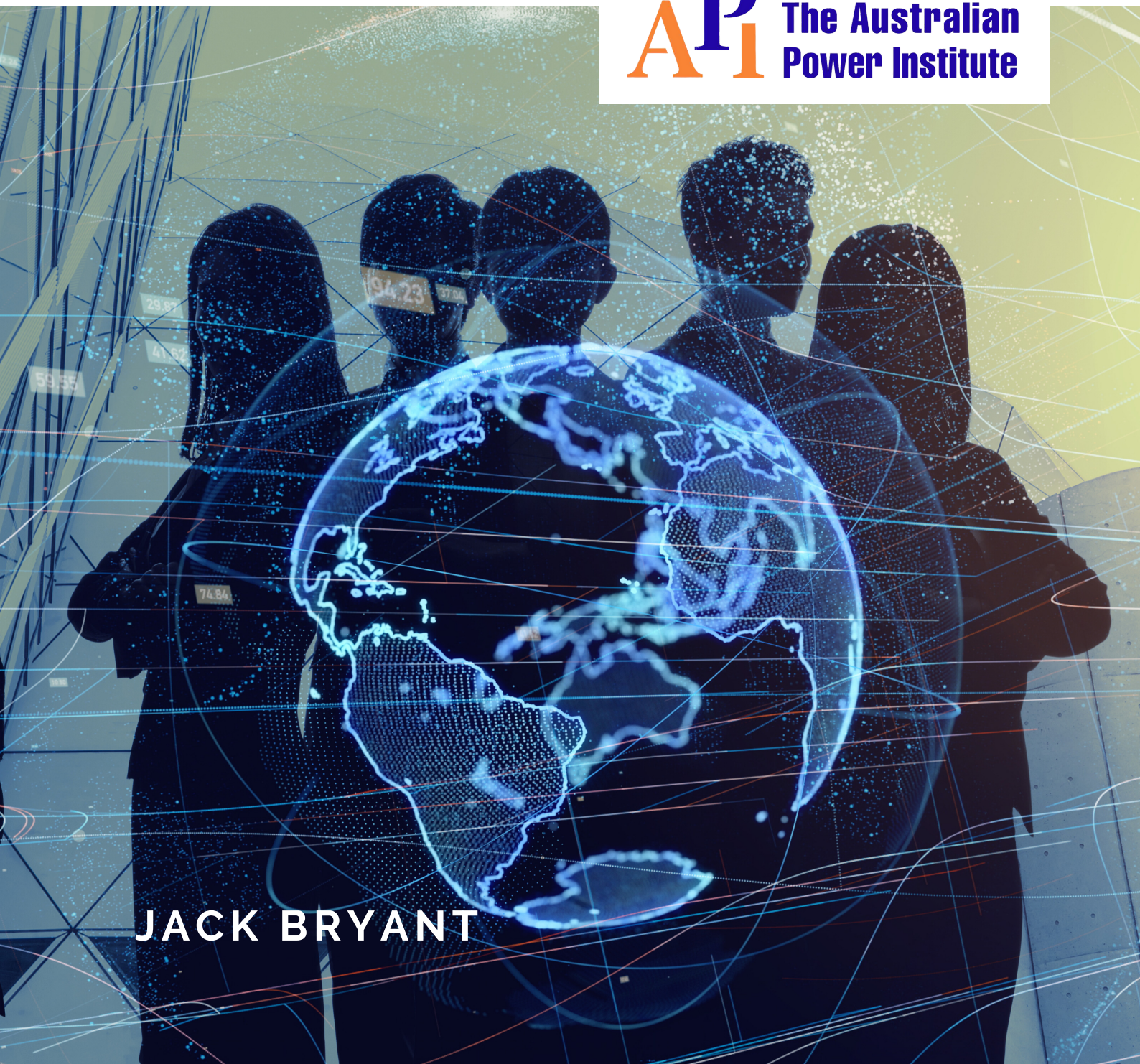
international insights
for the Australian
power sector

TJ Effeney Scholar Report 2019

The Australian Power Institute



JACK BRYANT

About the API's T.J. Effeney Award

In honour of the late Terry Effeney, one of the Australian energy industry's greatest contributors, the API created the T.J Effeney Award in collaboration with the Effeney Family, Ergon Energy & Energex (part of the Energy Queensland Group),

This Award supports the Australian power sector's next generation to undertake a project or program of study (domestic or international) in the energy sector to further their professional career development.

The award's selection criteria are based on the values and strengths displayed by Terry Effeney during his career:
- Knowledge: how the proposal will broaden the students knowledge and skills in the energy sector
- Connections: how the proposal will increase the personal network of contacts for the student
- Supporting others: how the student plans to share the knowledge gained from the award with other students and the broader API Bursary cohort.

empowering the next generation with knowledge, connections and supporting others

The TJ Effeney Award is available on a yearly basis. and only open to Australian university students who have been selected for an API Bursary Scholarship and are in their final 2 years of study of an engineering degree.

Jack Bryant is the inaugural recipient of the T.J. Effeney Award, completing an international study tour to the United States in 2019. Jack's report is featured in the following pages.

Find further information at:

www.API.edu.au

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Abstract

Initially, the proposed program of the inaugural T. J. Effeney Award recipient, Jack Bryant, is detailed. Next, a comprehensive overview of the actual activities and achievements is provided. The three main activities completed as part of the award included attendance at the 2019 IEEE Power and Energy Society General Meeting, research at the University of Michigan, Ann Arbor, and a short-term visit to ITC Transmission in Novi, Michigan. This document subsequently identifies challenges and opportunities for the power sector's future workforce and provides suggestions, recommendations and ideas for senior managers and decision-makers. The award is then discussed in a broader context and opinions are given for possible improvements. Thank you to the API, Energy Queensland, and the Effeney family for their financial support of the award. A special thank you to Professor Ian Hiskens for hosting me at the University of Michigan, Ann Arbor, and for his support during my time in the United States.

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Part I

T.J. EFFENEY AWARD: PERSONAL CONTEXT

1

Proposed objectives

I proposed to conduct work with Ian Hiskens, Vennema Professor of Engineering, at the University of Michigan, Ann Arbor [1]. Additionally, I also planned to undertake short-term placements within local industry to develop my professional and personal skills/qualities further. The overall duration of the programme was approximately sixteen weeks. Before developing my proposal application, I discussed potential opportunities with Professor Hiskens, an international power systems expert. The potential opportunities we identified are detailed below, amongst other opportunities I identified [2].

- Project 1: Development of a research project investigating Australian grid frequency control.
- Project 2: A research project which addresses issues that arise in the implementation of aggregate control of large numbers of residential loads.
- Collaboration with other power system research groups within the US supported by Professor Hiskens.
- Short-term work experience at ITC - the largest independent electricity transmission company in the US, operating across Michigan and parts of Iowa, Minnesota, Illinois, Missouri, Kansas and Oklahoma.
- Short-term work experience at MISO (Mid-continent Independent System Operator) which operates one of the world's largest real-time energy markets, headquartered in Carmel, Indiana.
- Disseminate issues, challenges, learnings/recommendations and open questions.
- Present findings to applicable stakeholders.

2

Overview of completed activities and achievements

2.1 COMPLETED ACTIVITIES

From the 9th of August 2019 to the 6th of December 2019, I was based in the United States as part of the award. During this time, I attended the IEEE Power and Energy Society General Meeting, worked with Professor Hiskens at the University of Michigan, Ann Arbor, and visited ITC Transmission in Novi, Michigan.

2.1.1 *IEEE Power and Energy Society General Meeting - Atlanta, Georgia (4th August - 8th August)*

I spent my first week in the United States at the IEEE Power and Energy Society General Meeting held in Atlanta, Georgia, from 4th August to 8th August. The meeting is the flagship conference of the IEEE Power and Energy Society, attracting approximately 3000 people from both academia and industry. At the conference, emerging issues were presented, and the potential solutions discussed. Some of the key topics included 100% renewable energy scenarios, grid-forming inverters, the definitions for power system stability in inverter-dominated grids, and the value of simulation-based research versus analytic frameworks.

The issue of momentary cessation in power electronic inverters was also discussed in the context of the Californian power system. Momentary cessation is an inverter operating state whereby the inverter firing commands are blocked such that active and reactive current goes to zero. 1200 MW and 900 MW solar photovoltaic (PV) disturbances occurred in the US in 2017 and 2018, respectively [3], [4]. Consequently, engineers in the United States have had to examine why this phenomenon occurs and how to model it accurately.

During my time at the conference, I attended many presentations and poster sessions which exposed me to some of the cutting-edge work being conducted within academia and industry. I was also afforded the opportunity to expand my network through interactions with a broad range of people.

The plenary panel session brought together industry heavy-weights to discuss grid transformation issues and technological development. The panel included:

- Jim Robb - CEO of the North American Electric Reliability Corporation.
- Marcelino Madrigal - Inter-American Development Bank.

- Stephen Dihwa - CEO of the South African Power Pool.
- David Sluss - Georgia Institute of Technology.

Interestingly, Stephen Dihwa's presentation examined the interconnection of the South African Power Pool and the evolution of its electricity trading markets. In a similar fashion to Australia, the South African Power Pool has undergone relaxation of its frequency control standards and is now looking at implementing ancillary services markets in the future. It will be interesting to see whether similar issues regarding frequency control appear. Overall, the experience at the IEEE Power and Energy Society General Meeting was fantastic as it allowed me to expand my professional network and gain exposure to cutting-edge research as well as industry trends and issues.

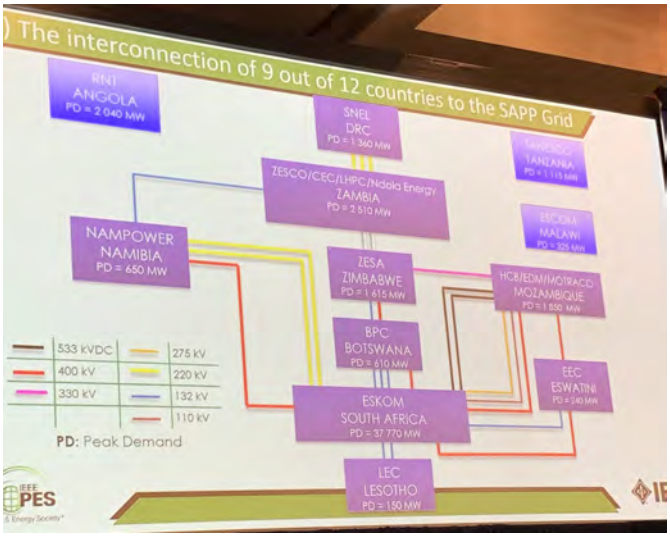


FIGURE 2.1: South African Power Pool interconnection.

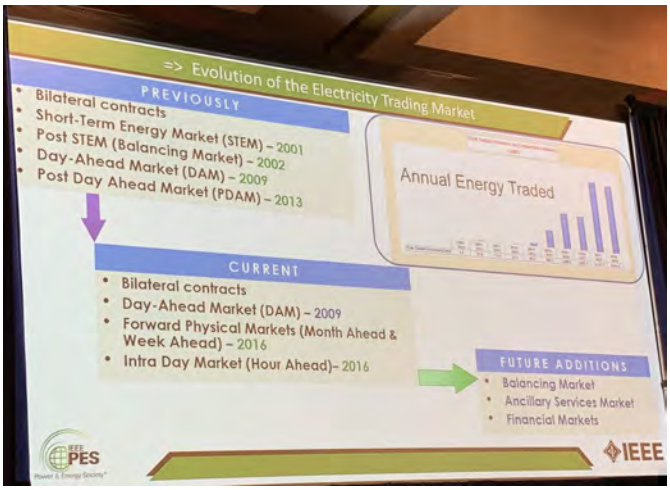


FIGURE 2.2: South African Power Pool electricity market evolution.

2.1.2 *University of Michigan, Ann Arbor (9th August - 6th December)*

Following attendance at the IEEE Power and Energy Society General Meeting, I headed to the University of Michigan, Ann Arbor. It was an honour and pleasure to work within Professor Hiskens' research group for approximately four months. During this time, I was able to interact with members of the Michigan Power and Energy Laboratory (MPEL) and develop broader insights into emerging issues. During my time at the University of Michigan, I finalised an investigation into the influence of governor control on power grids with high renewable energy penetration. As many people will know, governor control is essential for maintaining power system stability. However, governor control has progressively been detuned within Australia's power system over the past few decades. A frequency study demonstrated the significant impact governor parameters have on system frequency, regardless of the amount of renewable energy or location/nature of active power imbalance within the power system. Additionally, high levels of governor inactivity were shown to destabilise the system owing to degradation in the system's dynamic response. The topology of the system highly influences its behaviour. Consequently, there is no 'optimal' universal setting which can or should be applied. In a similar manner, having uniform governor deadbands is not necessarily the best idea - the power system ultimately needs to be tuned. Consequently, there is onus on the network operators, not generators, to determine the necessary parameters for the power system. For hybrid power systems such as Australia's, small governor deadbands and mandatory governor response is recommended to improve system frequency regulation.

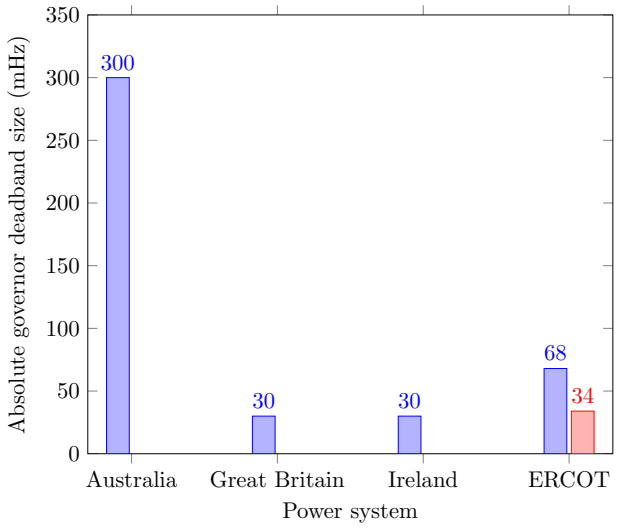


FIGURE 2.3: Governor deadband sizes by power system [5]. N.B. ERCOT uses 68 mHz deadbands for steam/hydro plant with mechanical governors and 34 mHz deadbands for all other generators.

During my time at the University of Michigan, Ann Arbor, I also undertook a significant amount of directed reading (over 150 papers) covering three main areas: inverters/inverter-dominated grids, power system dynamics, and power system modelling. The work allowed me to develop a (global) systems perspective to funnel down into a specific area of research. Weekly discussions with Professor

Hiskens in conjunction with the directed reading was foundational in developing a research proposal for my PhD confirmation (first PhD milestone), which I successfully completed in February 2020. Spending time with Professor Hiskens at the University of Michigan, Ann Arbor, was incredible. Being able to work with a world-renowned power systems researcher has allowed me to come away with a much broader range of knowledge, improved skills, and a new research direction, amongst other things. Furthermore, during my time in Ann Arbor, I was able to develop new personal and professional contacts, which will be beneficial in the future.

FIGURE 2.4: The University of Michigan Quad.

2.1.3 *ITC Transmission, Novi, Michigan (4th November - 6th November)*

Professor Hiskens kindly assisted me in arranging a visit to ITC Transmission, Novi, Michigan. ITC is a fully independent transmission company which operates across three systems: Michigan, Midwest, and Great Plains. Visiting ITC introduced me to a part of the energy industry that I hadn't been exposed to before. I spent time with engineers across a broad range of departments, which provided me with a rounded experience. First, I shadowed an engineer and performed a contingency analysis for the Iowa and Michigan systems. We examined potential issues attributed to taking specific apparatus out of service for maintenance and looked at $N-1$ and $N-1-1$ scenarios. Then, I was taken through the use of PSS/E for the development of system models. We discussed ways to overcome non-convergence issues within the software and I was able to see the Midcontinent Independent System Operator's online file repository for the models. I also spent time with the Dynamic Studies team, which had recently transitioned from using PSS/E to PowerTech DSA Tools. At present, transient dynamic models are required as part of their connection agreements. However, unlike Australia, submission of EMT modelling is not required. In the future, such modelling may be requested.

ITC Transmission had recently completed a significant upgrade to its state estimator, and I was fortunate enough to spend time with the supervisor of the Network Applications team. I was taken through the operation of the state estimator, and we discussed some of the steps they take when tackling non-convergence. As part of the upgrade, ITC built a new voltage stability application into

the state estimator's functionality owing to the increase in renewable energy across their systems. Currently, the state estimator is upgraded every 5 to 10 years. However, in the future, ITC plans to perform upgrades more frequently to reduce the amount of work required.

On my last day at ITC transmission, I spent time with an engineer from the Protection team. We discussed the use of the directional comparison blocking (DCB) scheme used across the company's infrastructure and the challenges associated with trying to standardise equipment across the different systems. Last, everything I had been exposed to over the previous few days coalesced when I was given a viewing of the control room. It was the first time I'd been inside a network control room, and it brought home the sheer complexity and magnitude of operating a power system.

During my time at ITC transmission, I was able to shadow engineers from across the organisation, exposing me to day-to-day work and learning about the company and its systems. It was interesting to see the impact of the Federal Energy Regulatory Commission on system operations governance. In the US, the retirement of thermal generation will challenge the system in the future. Furthermore, the integration of new technologies will significantly influence the power grid. In managing this change, I believe being proactive versus reactive is very important. Before my trip to the US, I thought that Australia was more reactive than proactive when it came to power system operation and investment. However, I now believe it is fair to say that Australia, in some aspects, is proactive as it is facing issues which relatively few power systems across the world are facing.

FIGURE 2.5: ITC Transmission.

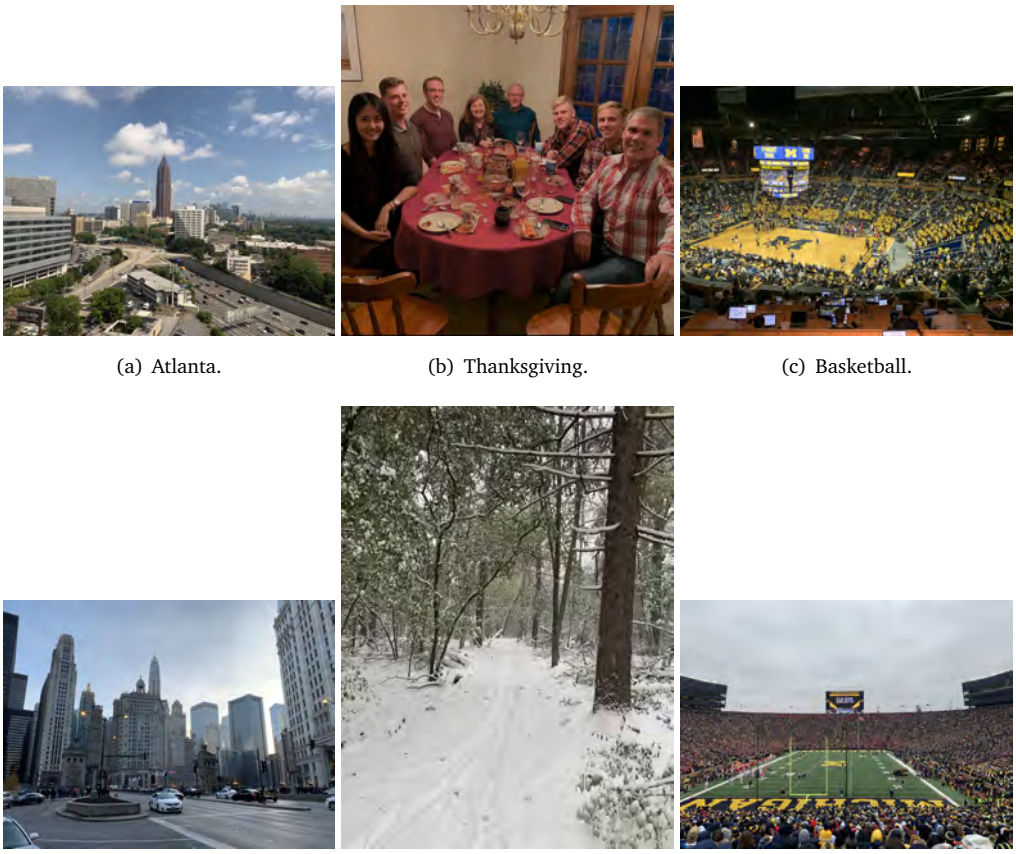
2.1.4 *Other activities*

- Professor Hiskens and his wife, Judy, were kind enough to invite me to their home for Thanksgiving dinner.
- Attended "The Game" - The University of Michigan vs. Ohio State football game on Saturday, 30th November 2019. Over 110,000 people packed into The Big House - University of Michigan's football stadium - to see them take on their arch-rivals.
- Attended a pre-season basketball game between the University of Michigan and Houston Baptist.
- Assisted MPEL member with their PhD proposal.
- Attended a PhD defence for one of Professor Hiskens students.
- Presented to the research group about Australian frequency control practices.
- Took part in Midwestern Fall traditions - apple picking and Fall festivals etc.

2.2 KNOWLEDGE SHARING ACTIVITIES

Numerous knowledge sharing activities have been undertaken which include:

- Progress report submitted to API at the halfway stage of the programme (October 2019)
- 45 minute presentation to the delegates of the API's Summer School in February 2020.
- Presentation to the API Board.
- Presentation and Q&A session to API bursary holders via Zoom.
- Promotion of the award while overseas.



(a) Atlanta. (b) Thanksgiving. (c) Basketball.

(d) Chicago. (e) Snow. (f) Football.

FIGURE 2.6: A snapshot of some of my other experiences in the United States.

2.3 ACHIEVEMENTS

- Finalised frequency control research direction.
- Identified a new research direction at the intersection of inverters, power system dynamics, and power system modelling.
- Finalised a white paper on frequency control. A workshop bringing industry and academia together was held in Melbourne on 25th October 2019 centred around the document.
- Presented to MPEL research group.
- Expanded professional network.
- Developed new skills and attained greater insights into power system challenges and issues.

Part II

POLICY AND DECISION-MAKING

3

Challenges and opportunities for the power sector's future workforce

The power sector is currently undergoing a rapid transition, driven by climate change concerns and technological innovation. In the future, inverter-based renewable energy generation will be ubiquitous within power systems across the world. However, this cleaner power generation augments traditional power system dynamics owing to its reduced inertia and stochastic generation profile, amongst other things. The future workforce will undoubtedly need to be familiar with these different characteristics.

An excellent understanding of the dynamics, modelling and operation of power electronic inverters will be vital, specifically grid-following and grid-forming control schemes. These devices will be the cornerstone of power generation in the future owing to their use as an interface between renewable energy sources and the grid. Overall, the future workforce will require complex problem-solving skills and creativity to overcome issues associated with rapid technological development.

Data is becoming increasingly valuable owing to the digitisation of the world around us. Within the energy sector, a shift is ensuing, which is leading to the widespread use of digital controls and communication protocols. For example, smart meters have been rolled out across parts of Australia, resulting in a large amount of usable data being collected. The question becomes how to organise and analyse such vast amounts of information. Skills in data analytics, or at the very least, digital literacy will be required from the sector's future workforce.

While the digitisation of our electricity network has many benefits, cybersecurity is a potential vulnerability. From an IT perspective, we will require professionals who have the skills to manage this potential threat to ensure system resilience.

Based on the above points, I would suggest newcomers to the industry seek to develop software-related skills, such as familiarity with the use of Python. Additionally, a good understanding of the operation of power electronic inverters would also be favourable owing to the fact that these devices will likely underpin the bulk of electricity generation in the future. Specific to Australia, familiarity with PSS/E and PSCAD software is advised as models for the NEM are required to be performed using the software.

4

Suggestions, recommendations, and ideas for senior managers and decision-makers

Below are some suggestions, recommendations, and ideas for senior managers and decision-makers:

- From a frequency control/power systems perspective, it is recommended that the traditional underlying physics of the system is not overlooked. Market mechanisms for system control certainly have their place in specific contexts; however, such mechanisms should not override the system's physics and operational design.
- One thing I was impressed by in the United States was the connectedness between industry and academia. In the future, as we navigate the issue of rapid technological change, we will face increasingly complex problems. Having increased connectedness between academia and industry would improve how we traverse future problems.
- Being proactive as opposed to reactive is vital, which again goes back to the rapid pace at which the industry is currently changing. We need to be proactive in identifying and tackling problems before they become insurmountable. Using data in unique ways to inform decisions is key to this.
- Retaining knowledge and know-how is extremely important from generation to generation (of the workforce). Systems should be in place to ensure knowledge is passed on from very experienced employees to those less experienced. The transfer of knowledge is essential from both an industry perspective, as well as from that of a business.

Part III

T.J. EFFENEY AWARD: BROADER CONTEXT

5

Suggestions and feedback on the T.J. Effeney Award and how the API could help recipients to generate more value from the experience

A few suggestions are as follows:

- The development of the proposal for the T.J. Effeney Award is relatively self-driven and dependent on the applicant being able to leverage their network. Consequently, it may be difficult for applicants to develop a robust proposal. Likewise, if an applicant wishes to go to a country in which they do not have a personal network, then the process of applying for the award may seem to be insurmountable. It could be beneficial for the API to leverage its connection with CIGRE to assist applicants in developing relevant connections. By connecting applicants with CIGRE members, then applicants may be able to utilise this broader network of people to develop a strong proposal.
- Regular updates or connection with the award recipient throughout their programme would be beneficial to both the API and the individual.
- It might be beneficial for the API to develop a key set of knowledge sharing activities for all recipients in the future. Award recipients can then propose bespoke activities in addition to the key set of API activities. Having a key (or base) set of activities will provide continuity throughout each year of the award and ensure a constant knowledge stream. Bespoke activities will cater for outcomes to be highlighted to specific audiences.

6

Ideas for what the API could be doing with, or asking from, award recipients during and after the placement to maximise the value

A few suggestions for maximising value during and after the placement:

- Regular updates or connection with award recipients throughout their programme would be beneficial to both the API and the individual.
- If the API is concerned about the acknowledgement of its support of the individual through the award, then the API should explicitly detail how it would like to be acknowledged by future recipients. For example, a clause in the award's contract between the API and future recipients specifically detailing acknowledgements. By having this facility built into the contract, it would align the award's terms with other awards/scholarships across Australia. Furthermore, it would eliminate any ambiguity and provide a clear path forward for the individual when undertaking work.
- A workshop could be held once per year which gathers the most recent award recipient and potential applicants to hold a workshop-style event regarding developing the proposal. A Q&A session could follow to answer any questions. This could encourage more people to apply for the award by making this task seem less daunting.

7

Acknowledgements

I want to give special thanks to:

- The API and Mike Griffin for their continued support of my professional development.
- The API, Energy Queensland, and Effeney family for their support of the T.J. Effeney Award.
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- The MPEL for their support.
- Jillian Henderson for her dedication in organising my visit to ITC Transmission.
- Peter Sokolowski, Lasantha Meegahapola, and Brendan McGrath from RMIT University for their ongoing support.

Bibliography

[1] I. Hiskens. (Mar. 2018). Ian A Hiskens - Venemma Professor of Engineering, [Online]. Available: http://web.eecs.umich.edu/~hiskens/.

[2] J. Bryant. (Nov. 2019). Proposal: Application for the T. J. Effeney Award, [Online]. Available: https://api.edu.au/_pdf/Jack%20Bryant.pdf.

[3] NERC, "900 MW fault induced solar photovoltaic resource interruption disturbance report," NERC, Tech. Rep., 2018.

[4] ——, "1200 MW fault induced solar photovoltaic resource interruption disturbance report," NERC, Tech. Rep., 2017.

[5] J. Bryant, R. Ghanbari, M. Jalili, P. Sokolowski, and L. Meegahapola, "https://www.researchgate.net/publication/337135611_Frequency_Control_Challenges_in_Power_Systems_with_High_Renewable_Power_Generation_An_Australian_Perspective," RMIT University, Tech. Rep., 2019.