E.S. Cornwall Memorial Scholarship
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Electranix Corporation
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THE UNIVERSITY OF QUEENSLAND
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Contents

1.0 Executive summary

This report provides an overview of my learnings during my time at Electranix, and impressions made, from January to March 2019. During this time, I worked on dynamic performance testing of large inverter connected generation in weak systems in North America. These included solar farms, wind farms and battery energy storage systems (BESS's) with the addition of nearby High Voltage Direct Current (HVDC) converters, synchronous machines and other inverter connected generation. I developed new skills in PSCAD and E-TRAN while further developing my skills in PSS/E, Python and technical communication. Through my work I gained the following impressions.

1. **AEMO is better positioned to plan and operate a power system with higher penetrations of inverter connected generation.**

For power systems with increasing amounts inverter connected devices, it is necessary for system operators to conduct more detailed studies in order to maintain power system security. This ensures system security now and in the future.

It is important for AEMO's engineers to be informed, and more understanding of the issues and nuances surrounding tools like PSCAD, and understand the limitations of the tools and the industry capability. This is necessary for effective application of the new connection standards.

2. **Increased risk in the connection process.**

The introduction of EMT modeling in the connection process has increased the risk of projects failing to progress through to full operation. Vendors must prioritise model support to reduce the risk of project failure.

Publications such as the Integrated System Plan (National Transmission Network Development Plan) or regional annual transmission planning reports can assist in outlining the current and future network limitations. These publications can reduce the risk of project failure through stakeholder education.

As part of my next quarter I will focus on the following areas.

Next steps

- **Run dynamic performance testing of queued generation projects in North America.**
- **Document concepts which enhance the understanding of EMT and RMS study tools.**
- **Explore automation approaches for use in AEMO studies.**

2.0 Introduction

This report provides an overview of my work at Electranix Corporation (Electranix) from January to March 2019 and impressions gained. During this time at Electranix I was fortunate to work on dynamic performance testing of North American generation connections. I learnt to use PSCAD and E-TRAN while improving my skills in PSS/E. These studies provided me an opportunity to become familiar with the individual and interdependent behaviour of grid connected devices in weak systems. These models included:

- Inverter connected generation;
- HVDC converters;
- FACTs devices; and
- Synchronous machines.

This report meets the requirements of a quarterly report as part of the 2018 – 2019 ES Cornwall Memorial Scholarship.

3.0 Scholarship theme

In June, 2017 Dr. Alan Finkel, Australia's Chief Scientist, and an Expert Panel published the Independent Review into the Future Security of the National Electricity Market. The report recommends a way forward to ensure a secure and reliable energy future as the energy industry experiences significant change[1]. Four key outcomes were identified for the National Electricity Market (NEM): increased security, future reliability, rewarding consumers and lower emissions. These outcomes are enabled by three key pillars: Orderly Transition, System Planning and Stronger Governance.

Chapter 5 delivered five key recommendations focused on improving System Planning. The first two recommendations focus on the delivery of an Integrated Grid Plan, conducted by the Australian Energy Market Operator (AEMO), which have since been addressed or are underway. The third recommendation (recommendation 5.3) is now coming into focus and states:

> *The COAG Energy Council, in consultation with the Energy Security Board, should review ways in which the Australian Energy Market Operator's role in national transmission planning can be enhanced.*

AEMO's national transmission planner functions include review and advice on the development of the transmission grid across the NEM; provide a national strategic perspective for transmission planning and coordination; and have regard to the National Electricity Objective. The underlying theme of my Scholarship proposal is to identify ways the national transmission planning role can be enhanced.

Transmission planning, in Australia and around the world, is becoming increasingly challenging due to the rapid increase in inverter connected devices and the decommitment of synchronous generation. As a result, fault levels have declined and are now being monitored by AEMO to ensure reliable operation of the grid. AEMO's national planner role requires enhanced skills associated with studying weak systems to ensure security and reliability, while ensuring minimum cost to consumers. My time at Electranix has, and will continue to, enhanced my skills and experience as a transmission planning engineer.

[1]Dr Alan Finkel, Ms Karen Moses, Ms Chloe Munro, Mr Terry Effeney, Professor Mary O'Kane. Independent Review into the Future Security of the National Electricity Market. 2017. Available here: https://www.energy.gov.au/sites/g/files/net3411/f/independent-review-future-nem-blueprint-for-the-future-2017.pdf

4.0 Background

A secure and reliable supply of cheap electricity is a highly desirable input into a strong, prosperous and resilient economy. The changing generation mix has introduced challenges for system operators to maintain power system security and reliability. AEMO monitors the impact of these changes such as declining fault levels.

These changes are seen elsewhere in the world, in regions like North America, Hawaii and Europe. Some system operators in these regions apply detailed power system analysis to ensure the secure operation of the power system. ISO New England (ISONE) in northeast US (Massachusetts, Connecticut, Maine and Vermont) and Electric Reliability Coordinator of Texas (ERCOT) in Texas are examples of system operators who conduct these types of detailed studies.

4.1 Work completed

My first three months at Electranix has provided me with the opportunity to conduct power system analysis on prospective inverter connected generation projects in North America. These studies assessed the adequacy of generation models as part of the grid connection process. In addition, I studied the interaction of existing grid connected devices in the world's largest interconnected transmission network – the eastern interconnection. These studies included PSS/E and PSCAD models of synchronous machines, wind farms, photovoltaic (PV) farms, HVDC converter stations, STATCOMs, and Battery Energy Storage Systems (BESS) models. I also translated PSS/E cases to PSCAD with Electranix's E-TRAN package. This section provides an outline of the major areas of learning.

1. Power system modeling

Electranix specialises in power system studies in PSS/E and PSCAD. A key component of my learning at Electranix is associated with PSCAD, understanding how PSS/E and PSCAD studies are different and how they complement each other. Outlined below are the key areas of learning related to power system modeling in PSCAD:

- The fundamental differences between RMS and EMT studies
- Translating PSS/E cases into PSCAD using the E-TRAN package
- Simplifying a system for more targeted analysis
- When and how to use weak system metrics
- Characteristics of weak systems
- Working with inverter and power plant controller models from various vendors
- Model interactions
- Protection settings
- Network modeling and frequency dependence
- Developing and managing model libraries
- Fault automation in PSCAD
- PSCAD-PSS/E result reporting and comparisons

2. Scope of works

Connection requirements define the scope of work for many of my projects. The scope of work generally includes the following:

- Model development and testing: Translate PSS/E system case into PSCAD system case with system equivalence.
    - Detailed models are stored in PSCAD library and included in the PSCAD case.
    - PSS/E load flow solution is used to initialise generators and controls, transformer tap settings, switched shunt elements, STATCOM set-points, machine (P, Q, V and angle) power order, direction of power and to represent loads.
    - Portions of the network which are not translated are replaced with network equivalence calculated by E-TRAN. Generally, the translated network extends from the project to the bulk power system (typically 345 kV) and includes local generation points of connection.
    - PSS/E transient stability data obtained from .dyr file is used to create generator control and machine models.
- PSCAD fault analysis: Several worst-case dynamics events are studied, with a particular view to reducing the SCR as much as possible in the post-fault state and maximising potential for interactions between devices.
    - Develop a library of automated network faults.
    - Report observed instabilities (and potential solutions) to client and vendor.
- PSSE model validation: Plot and compare the results from PSCAD and PSS/E analysis. This sometimes requires discussion with the manufacturer and updates to the models.
- Prepare report.

3. Communication and technical writing

I regularly reported progress to the client and drafted technical reports outlining the key findings of the studies. For projects which are unable to meet connection requirements, Electranix recommends solutions which assist to progress the application.

4.2 Impressions gained

This section outlines the impressions gained during my time at Electranix from January to March 2019.

1. AEMO and the TNSP's are better positioned to plan and operate a power system with higher penetrations of inverter connected generation.

Detailed EMT models are now required for system planning. This is necessary in order to plan and operate the system with high penetration of inverter connected generation and more so for future penetrations.

It is important to acknowledge the importance of AEMO's engineers to be informed, and more understanding of the issues and nuances surrounding tools like PSCAD, and understand the limitations of the tools and the industry capability. Lack of understanding

can introduce unnecessary delays in the connection process or the transmission planning process. This is necessary for effective application of the new standards.

The requirements in the NEM ensure system security *now* and in the *future*. This is because models obtained, validated and approved now will be required for future assessments of both generation connections and transmission augmentations.

2. Increased risk in the connection process.

The introduction of EMT modeling in the connection process increases the risk of projects not progressing through to full operation. The new requirements have introduced financial and time pressures on project developers and vendors. The overall cost of ensuring the accuracy of system models has increased, however this cost will gradually reduce as connection applicant are better prepared to manage this risk.

Another source of risk is due to lack of support from some vendors to review and refine models. This introduces delays in the connection process which ultimately results in project cancellation.

Developing, implementing and understanding EMT models is challenging and the industry is quickly upskilling to adjust to new requirements. The provision of network information, from system operators, has never been more important. This information can drastically improve the preparedness of connection applications.

Publications such as the Integrated System Plan (National Transmission Network Development Plan) or annual transmission planning reports outline the changing system fault level to assist in generation planning. Information in these reports can assist in reducing the risk of project failure due to emerging challenges such as system strength.

5.0 Next steps

This section outlines the planned next steps for my time at Electranix from April to June 2019. These topics may be outlined in the next quarterly report and the Final Report: Part Two. The next steps include:

- Running dynamic performance testing of queued generation projects in North America;
- Documenting concepts which enhance the understanding of EMT and RMS study tools; and
- Exploring automation approaches for use in AEMO studies.

6.0 Conclusion

This report provided an overview of the work completed from January to March 2019 as part of the 2018 – 2019 ES Cornwall Memorial Scholarship. During this time, I worked on generation connection studies in North America and developed skills in PSCAD and E-Tran. I had the opportunity to conduct PSS/E-PSCAD dynamic performance testing and PSCAD model adequacy tests. This report meets the requirements of a quarterly report as part of the 2018 – 2019 ES Cornwall Memorial Scholarship.