E.S. Cornwall Memorial Scholarship
July to September 2019

Siemens AG

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THE UNIVERSITY OF QUEENSLAND

AUSTRALIA

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Contents

1.0 Executive summary

This report provides an overview of my learnings during my time at Siemens AG (Siemens), and impressions made, from July to September 2019. I have been embedded in the HVDC Sales team, learning about current and past HVDC solutions and refurbishments around the world. In addition, I have led a project to develop a process for preparing modeling and connection information required to connect generation systems (including HVDC interconnections) in the National Electricity Market (NEM). This report outlines what I have learnt about Siemens' HVDC technology and how Siemens will prepare modeling information for the NEM connection process.

Through my work I gained the following impressions.

1. Contentions with model preparation for NEM connections

Having worked through the AEMO connection requirements with colleagues at Siemens it is clear there are contentions with some of the requirements, particularly those related to source code and detailed modeling information.

Ongoing connection projects which involve both Siemens and AEMO have provided some an important learning opportunity for me in terms of how these contentions can be overcome. I hope to have more clarity on this in the coming months as these projects progress.

2. HVDC technology is adaptable and capable

HVDC technology is incredibly adaptable and capable of meeting a broad range of technical requirements. Simply put, every HVDC transmission solution operating today is completely unique.

Customers who provide specific technical specifications (such as voltage, converter topology) must be aware that these decisions impact the economic competitiveness. I look forward to expanding on this in the coming months.

Finally, as part of my next quarter I will focus on the following areas.

Next steps

- Develop a model information preparation process for Siemens.
- Continue my contributions to HVDC projects at Siemens.
- A quarterly report, in January 2020, of work completed and impressions gain in my second three months at Siemens.

2.0 Introduction

This report provides an overview of my work at Siemens AG (Siemens) from July to September 2019 and impressions gained. During my time at Siemens I led the development of Siemen's data preparation process for connections in the National Electricity Market (NEM) on the east coast of Australia. In addition, I contributed to Australian and international HVDC projects. My time at Siemens provided me the opportunity to further developed my skills in PSS/E and python. In addition, I developed an understanding of the connection requirements in the NEM and the associated challenges in preparing model information. 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.

In December 2018, the Energy Security Board (ESB) added an Integrated System Plan (ISP) Action Plan which set out twelve recommendations on short, medium- and long-term transmission augmentations. These recommendations are outlined in the ESB's consultation paper[2] staged reform to the transmission frameworks. A major long-term project considered in the 2019-20 Integrated System Plan (ISP) is the Battery of the Nation which includes the development of a new HVDC submarine interconnector ("Marinus Link") between Mainland Australia and Tasmania. This project can be designed to support the ancillary requirements for both systems while assisting to ensure system adequacy, particularly in Victoria where coal retirements are placing pressure on generation reserves.

My time at Siemens has provided me with the opportunity to learn about this technology and understand how it can further contribute to the resilience of the NEM.

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[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

[2] Energy Security Board. Converting the Integrated System Plan into Action. May 2019. Available here: http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/ESB%20-%20Converting%20the%20ISP%20into%20Action%20-%2020190517.pdf

Siemens is a world leading manufacturer of HVDC solutions and has already contributed to Australia's power system through the delivery of Basslink's two converter stations in Victoria and Tasmania. My time at Siemens has provided me with the opportunity to learn about this technology and understand how it can further contribute to the resilience of the NEM.

4.0 Siemens

Siemens is a world leading manufacturer of HVDC solutions and has already contributed to Australia's power system through the delivery of Basslink's two converter stations in Victoria and Tasmania. My time at Siemens has provided me with the opportunity to learn about this technology and understand how it can further contribute to the resilience of the NEM. This section outlines the background behind why Siemens was a good fit for my scholarship theme, the work I completed and the impressions I gained during my time.

4.1 Background

A secure and reliable supply of low-cost electricity is a highly desirable input into a strong, prosperous and robust economy. The changing generation mix has introduced challenges for system operators to maintain power system security and reliability.

The NEM faces unprecedented changes in supply and demand which can pose a threat to system security and reliability. Conventional synchronous machines which provide majority of the NEM's power and energy are expected to retire over the coming decades. At the same time residential demand is increasingly being met by intermittent sources which increases the reliance on flexible generation to ensure system reliability.

In 2018, AEMO published updated requirements for connecting generation systems in the NEM. These requirements outlined the necessary information needed to process a generation connection. For connecting parties, it is necessary to understand these updated requirements in order to mitigate risk of projects being delayed. In addition, transmission planning studies are being prepared in Australia to assess the feasibility of additional HVDC transfer capability between Victoria and Tasmania.

For these reasons Siemens is a good fit for my development as a transmission planning engineer at AEMO.

4.2 Work completed

My first three months at Siemens has provided me with the opportunity to lead a project to prepare and assess modeling information required (by Siemens) to successfully connect a generation system in the NEM. Additionally, I have spent time learning about the power electronic technology provided by Siemens for power transmission and reactive power support.

This work has advanced my understanding of power electronic solutions in high voltage networks and has prepared me for modeling this technology in transmission planning studies in Australia.

This section provides an outline of my work completed during my first three months at Siemens.

4.2.1 Model preparation

I am leading a project to develop a procedure for preparing models and modeling information for the Australian generation system connection process. This procedure will be used to prepare converter modeling information for future projects in the NEM.

The Process
The process of preparing models and model information is to be condensed into a six-month period leading up to delivery of this information to AEMO or the network service provider (NSP) for due diligence studies. Key outputs include PSS/E models, PSCAD models, model data sheets, assessment reports and model releasable user guides. A key part of this process is the assessment tool which conducts tests on a small system with the model included and ultimately allows for benchmarking of the PSS/E and PSCAD results.

The Tool
The tool is written in Python 2.7 and works with PSS®E 34. It runs steady state, small disturbance and fault disturbance studies for a range of system conditions (short circuit ratio, X/R ratio, fault severity). Additionally, the post processing tool will be built in MATLAB which assesses the performance of the model to determine whether the model requires further tuning or correction.

Plan
The project spans a six-month period from July to December 2019. General outline of deliverables is below:

- July 2019 [**complete**]
    - Preparation of the plan and outline for deliverables for the coming six months.
    - Collect and consolidate relevant material provided by AEMO.
- August 2019 [**complete**]
    - Preparation of the single machine infinite bus model in PSS/E.
    - Skeleton of the python code.
        - Runs independent of PSS/E.
        - Processes output files into csv's.
- September 2019 [**complete**]
    - Development of the fault disturbance and steady state simulations are completed by the tool.
- October 2019
    - Preparation of the tool documentation for use by other engineers.

    - Completion of the small disturbance simulation code.
        - Frequency, voltage, active power, reactive power and angle step simulations.
- November 2019
    - Completion of the python tool and documentation.
- December 2019
    - Criteria assessment tool in Matlab.

Next steps
The next three months of this project the will focus on completion of the documentation, the dynamic simulation tool and the criteria assessment tool in Matlab.

4.2.2 Siemens HVDC technology

Siemens is a world leading company in the area of large transmission projects, particularly in the design and manufacturing of HVDC solutions. Siemens has played a central role in the development of HVDC technology, having delivered 10 GW of line-commutated current-source converters (LCC) (or HVDC Classic) transmission and is also leading in the area of voltage-source converter (VSC) technology (or HVDC Plus).

As part of my final quarterly report I will provide an overview of the advantages of the various LCC and VSC technologies.

4.2.3 CIGRE SC B4 International Colloquium

As part of my time at Siemens, and with the support of AEMO, I was able to attend the B4 International Colloquium in Johannesburg, South Africa in October. This was a valuable networking and learning opportunity. I broadened my perspective on HVDC technology and the current challenges which are being faced around the world. Area of discussions included:

- Network stability
- Renewable energy
- LVDC and MVDC distribution and microgrids, Distributed FACTS devices, synthetic inertia, HVDC insulation
- HVDC reliability, refurbishment and upgrades of HVDC and FACTS installations
- HVDC and FACTS Equipment and technology
- Regional Interconnections

A key area of relevant learning for me, and for my return to AEMO, is ongoing reliability monitoring of operating HVDC systems around the world. It is difficult to come to conclusions on what causes unplanned outages due to limitations in the data being collected. However, ongoing monitoring and adequate data collection is invaluable in the correct and efficient operation of HVDC technology in any power system. This monitoring can be extrapolated into power system planning models to improve supply adequacy projections.

4.2.4 Site visits

During my first three months at Siemens I was fortunate to visit two operating converter station, the transformer factory in Nuremberg and the power module assembly factory in Nuremberg.

The first visit was to the power module assembly factory in Nuremberg following by the transformer factory not far away. Here I witnessed the assembly line which produces the power modules (housing of IGBTs, capacitors and necessary electronics) for FACTS and converter station applications. Following this visit I attended the transformer factory where I witnessed the assembly of various sized power transformers – conductor coiling, assembly and testing.

The second was the BorWin III converter station owned and operated by TenneT in Northern Germany. This converter station receives power from offshore wind systems and injects up to 900 MW into the Northern German power grid at the Emden connection point. I visited the switchyard, switchgear, control room and protection housing.

The third was the +-533 kV Apollo HVDC LCC converter station close to Pretoria, South Africa, which was refurbished from 1977 to 79. This converter station is the southern receiving end of the Cahora Bassa HVDC transmission system and receives power from Songo generation in Mozambique. This station is owned and operated by Eskom, the South African system operator. This source of power is the Cahora Bassa Hydroelectric generation station at the Cahora Bassa Dam on the Zambezi River. The HVDC link is in parallel with relatively lower voltage HVAC and has bus splitting schemes to manage the loss of the HVDC line which is currently operated at 1065 MW.

Eskom has done some interesting pollution monitoring work at the Apollo end of the system. HVDC infrastructure (particularly insulators and switch yard equipment) are much more prone to leakage current than HVAC infrastructure due to the charged nature of the electrical equipment. Eskom’s work provides strong recommendations for composite insulators over glass insulators due to reduced flash over incidence after wet weather.

4.3 Impressions gained

This section outlines the impressions gained during my time at Siemens from July to September 2019.

1. **Contentions with model preparation for NEM connections**

   Having worked through the AEMO connection requirements with colleagues at Siemens it is clear there are contentions with some of the requirements, particularly those related to source code and detailed modeling information.

   Ongoing connection projects which involve both Siemens and AEMO have provided some an important learning opportunity for me in terms of how these contentions can be overcome. I hope to have more clarity on this in the coming months as these projects progress.

2. **HVDC technology is adaptable and capable**

   HVDC technology is incredibly adaptable and capable of meeting a broad range of technical requirements. Simply put, every HVDC transmission solution operating today is completely unique.

   Customers who provide specific technical specifications (such as voltage, converter topology) must be aware that these decisions impact the economic competitiveness. I look forward to expanding on this in the coming months.

5.0 Next steps

This section outlines the planned next steps from October to December 2019 at Siemens.

I will be continuing my work to develop a model information preparation process for Siemens and following HVDC solutions Siemens is involved in. I will produce a quarterly report, in January 2020, of work completed and impressions gain in my second three months at Siemens.

6.0 Conclusion

This report provides an overview of my work at Siemens from July to September 2019 and impressions gained. It outlined the modeling information preparation process I am developing for Siemens, site visits I have attended and broad information on what I have learnt about Siemens' HVDC technology. I have continued to develop my skills in PSS/E and Python. I have also developed a strong understanding of the NEM connection process, and the challenges associated with meeting these requirements. This report meets the requirements of a quarterly report as part of the 2018 – 2019 ES Cornwall Memorial Scholarship.