ASTP – API Progress Report 2019

Title: Progress report for project "Increasing MV Visibility" (Solar Enablement Initiative)

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» Executive Summary

Distribution Network Service Providers (DNSPs) are increasingly facing the problem of accommodating the connection of intermittent generation assets into networks over which they have historically had only a limited visibility. With huge numbers of Distributed Energy Resources (DER) now connected further down in the networks, more precise knowledge of the operational state of those networks is becoming paramount.

With support from ENA, API and ARENA the Solar Enablement Initiative (SEI) project was established to implement state estimation on distribution networks in both historical and near real-time applications to provide complete visibility of distribution network state (voltages and power flows). The corresponding test were conducted by ENA members Energex, United Energy and TasNetworks and showed that on all the nominated 11/22kV feeders full network visibility can be achieved with data these three DNSPs already possess. While more available measurement data leads to greater accuracy, it has been observed that even in scenarios of very low measurement coverage the achieved precision in terms of voltages and power flows towards the upstream network is remarkable.

Further, the SEI project has developed a scalable and expandable system. Scalable by using parallel computing that allows adjusting the performance of the system to increased analysis load by allocating additional server computers to it, and expandable in the sense that it allows post estimation applications that analyse the state estimation output in more depth. Implemented and demonstrated examples are a PV Connection Assessment Tool, Capacity Constraint Analysis and Capacity Constrained Optimisation, which are all integrated into the SEI system and executed automatically on available network state estimates.

What has been developed and demonstrated in this project can be described as an Energy Data Integration and Analysis platform. It is capable to ingest multiple different types of data from different, including external, sources, extract knowledge about their meaning in terms of the operational state of the monitored network and allow the fast and easy implementation of further complex analysis and assessment functions that can be hosted and executed in the SEI cluster and cloud execution framework.

The SEI system has great potential to improve the understanding of the actual operational conditions of the network much closer to where DER are connected, automate assessment, reporting and planning processes and form the basis of a potential deployment of DER coordination functions in real-time.

With the project concluding on 5 December 2019, after having delivered in full on the project scope and transferring the developed system into the commercial space to ensure ongoing availability of support, maintenance, further development and training, the onus is now on the DNSPs to move forward to an implementation phase.

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» Introduction

The SEI was tasked with refining and applying a novel State Estimation Algorithm (SEA) to operate on medium voltage (MV) distribution networks across three Australian DNSPs (United Energy, Energex and TasNetworks) in a Proof of Concept implementation of true state estimation at the distribution level. The project was given two years (finishing in December 2019) to compete its deliverables.

The SEA calculates the most probable system state (point in time snapshot of voltages, currents, power flows) from available data, overcoming the measurement deficiency common to distribution networks. Detailed network visibility is essential to underpin the evolving role of networks in integrating solar and storage and effectively unlocking the value of energy resources embedded in the distribution network.

The Project Partners were as below:

- Energex
- United Energy
- TasNetworks
- University of Queensland
- Queensland University of Technology
- Springfield City Group
- Aurecon
- Australian Power Institute
- Energy Networks Australia

Furthermore, the SEI has established a software interface and execution framework that allows for the implementation of Post Estimation Applications, being specific, purpose-built assessment functions that can leverage the SEI estimator implementation as well as its execution framework to automate their execution. This makes the SEI a candidate for automating new and existing mainly manual repetitive network-related assessment tasks. With its ability to connect to other IT systems through direct database connections, WebAPIs and web-based user interfaces, the SEI system can not only be integrated to automatically retrieve required data from existing IT systems, offer and deliver result data, but also be controlled by other business processes.

The project has demonstrated that the SEI system works on the selected feeders of all three participating DNSPs and that Distribution System State Estimation on very sparse measurement data is a technically viable option.

» Project Progress / Methodology

– State any changes in project scope

The initial scope of controlling multiple customer level devices manufactured and provided by Redback Technologies had to be revisited due to their voluntary departure from the project. This has been substituted with a medium size PV system owned and operated by Energex, which is now under dynamic export control.

– Methodology

The SEI was established as a collaborative project branching across universities, networks, industry bodies and private companies. Three network partners were targeted as DNSPs all have differing network topologies and variations in the type, source and quantity of network data available. Addressing these challenges as part of the project allowed the development of a robust and adaptable algorithm with significant potential for expansion into other Australian and International DNSPs.

The project commenced with a face-to-face session with representatives from all partners in attendance. A dedicated project team was established at The University of Queensland, the lead organisation in ARENA's funding agreement. The project team was staffed by Dr Olav Krause, lead researcher and developer of the SEA, as well as experts in network modelling and software development. The project has subsequently been driven through strong relationships between technical and strategic leads from each partner organisation working collaboratively with the project team.

All DNSP participants recognise the immense value of this work and the opportunity it presents to their organisations. Regular in-person updates by the project team at each DNSP have been undertaken throughout the project to more widely engage key personnel and communicate project progress and benefits.

» Results

– Results must align with the project deliverables

The outcome of this project is the successful implementation of a novel SEA on distribution networks overcoming the challenges of measurement scarcity, unbalanced loading conditions and sheer scale which are common on distribution networks and which have prevented the adoption of these network analysis techniques in the past. The SEA has enabled the generation of a complete snapshot of voltages, currents and power flows on an entire feeder from only a limited set of network monitoring inputs. The potential for cost savings due to a reduced need for high penetration of monitoring devices is substantial. The SEA was shown to be able to run on two of United Energy's 22 kV feeders using only existing smart meter data aggregated to each distribution transformer. No additional monitoring devices were required to be installed.

The project has delivered an operational dashboard from which DNSPs can upload feeder models and data, run the state estimation analysis, perform a clustering analysis to identify critical cases where voltages or currents are near limits and run a semi-automated network analysis tool which could be used to inform decisions around network planning and importantly, decision around the connection of future DER systems. The comprehensive information generated by the SEA will lead to improved outcomes for customers as we can better promote network areas compatible with DER connection with the hope of in time migrating to a web-based tool where customers can perform their own high-level automated connection assessments.

The near-real time implementation tested on feeders in Energex's network paves the way for Distribution System Operator functions. Increased oversight of the near real-time state of the network allows the identification of operating envelopes which could be communicated to DER owners, aggregators or other market participants to harness the capability of the existing network to maximise the value of customer DER.

This project has demonstrated that true distribution network state estimation is a reality and can be implemented on networks now. The main challenge will lie in establishing communications, systems and processes to transform this into Business as usual (BAU) which will vary for each DNSP.

Deliverables:

- Demonstration of State Estimation on historical data at TasNetowks on feeders Bruny Island and Bridgewater. Done.
- Demonstration of State Estimation on historical data at United Energy on feeders MTN24 and KBH34. Done.
- Demonstration of State Estimation on historical data at Energex on WMR3, CVL11A, SFC12A, HPK5A. Done. Another 8 feeders added since.
- Demonstration of real-time state estimation at Energex on feeder SFC12A. Done. Feeder CVL11A added since.
- Demonstration of real-time control of mid-sized PV system (initially on SFC12A, but changed to CVL11A). Control signal is being generated. Final checks before sending signal to site.
- Develop and demonstrate semi-automated PV Connection Assessment Tool. Done.
- Various reports to ARENA and participation in Knowledge Sharing Activities. Final report being finalised. Details on reporting and Knowledge Sharing in the SEI progress and final report to ARENA, which project participants, like ENA and API, have access to.

Innovation Leadership: State estimation is a technique which is critical to the operation of the National Electricity Market (NEM) at the transmission level. If new distributed energy resource markets are to be developed oversight of network operations at a more granular level than ever previously considered will be

critical to enable this future as the distribution network is fundamental to facilitate this energy exchange. This project has advanced existing state estimation techniques, which has overcome the added complexities of running on the distribution network. These complexities include lack of measurement data, conflicting measurements, unbalanced loading conditions, four-wire network models and sheer scale, for example, the entire NEM model is 0.03% the size of the model for south-east Queensland. Proof of Concept demonstration of the SEA across eight feeders in three DNSPs has verified the flexibility of the approach which could be scaled to provide the level of network visibility necessary to support efficient orchestration of DER on the distribution network. This work fits within the Intelligent Network & Markets concept of the ENTR and the capability is also cited as critical in the Open Energy Networks exploration of future market models. Knowledge of the network state can feed a multitude of possibilities including the identification of constraint, generation of near real-time safe network operating envelopes for the dispatch of DER, short-term forecasting, network planning and automation of existing process, for example, connections assessments for DER.

Innovation Impact: This project has proven the value of harnessing data from network devices which when synthesised with the network model has immense power to elucidate the operation of an entire network. Scale-up and adoption of this approach to data analysis is part of a wider business transformation roadmap. Success will require the coordination of metering systems, GIS and database platforms, communication pathways, data sharing protocols and cybersecurity considerations. It was a revelation to the university project team how little information is available on some distribution networks yet even with limited data informative results can be achieved. The project has also begun to inform DNSP participants on the most critical locations for future monitoring rollouts. In Energy Queensland Limited (EQL), this project has specifically led to the trial of dynamic PV export limit signalling to medium sized PV systems based on the near real-time network state. Dynamic DER management is considered one option to increase the overall penetration of PV systems as systems can operate based on network conditions rather than being approved/denied network connection based on assumed worst-case conditions, a limitation which has arisen based on the limited network operational data available.

Knowledge Sharing: The potential application of this project extends to anyone charged with managing or operating a distribution network, most critically DNSPs in Australia and internationally. Knowledge sharing has been extensive including presentations at the API Summer School, ENA Conference, IEEE Power & Energy Society and IEEE Distribution State Estimation Working Group. Also, participation in CIGRE sessions and ARENA's Insights Forum on Distributed Technologies as well as articles in Transmission & Distribution magazines. The project was central to the API Innovation Summit in August 2019 with a presentation at the Clean Energy Council sponsored All Energy 2019 Conference to be delivered in October 2019. A commercialisation framework has also been established to bring this capability to market.

Efficiency and productivity: This project has immense potential to improve affordability, reliability and sustainability of the energy system and network services. The energy sector is undergoing a process of adaptation to accommodate renewable sources of generation. These connections must be supported by the existing network, or the network must be upgraded to ensure safe and reliable operation. Improved visibility over the actual operational state of the network allows the targeted identification for connection opportunities and further, can support the proposed future energy market operations that seek to dispatch and manage DER to maximise the value to the customer. The application of state estimation techniques allows 100% visibility without 100% monitoring coverage resulting in cost savings. A sustainable and equitable approach to connecting DER cannot remain as "first-in best dressed' indefinitely. The network knowledge provided through the SEI will support a more equitable adoption of DER through improved orchestration.

» Next Steps

The project concludes on 5 December 2019 and the project team will dissolve on this day.

The commercial offering, further development and maintenance of the SEI system will be conducted by GridQube Pty Ltd.

» Conclusions

The project has achieved all Milestones and Deliverables, on time and under budget. Apart from this managerial success, it has successfully demonstrated the technical viability of Distribution State Estimation and that all three participating DNSPs, despite their wide range of measurement types and densities, had enough data to achieve useful results, with the achieved precision far higher than initially expected.

Furthermore, it has delivered a prototype implementation of a system that can integrate with DNSPs' IT systems, automatically perform state estimation and further specialised data analysis both on historical and near real-time data reliably in its intended environment.

All technical requirements for making the SEI system a crucial component of Business as Usual and to use it to automate both repetitive and complex assessment tasks are fulfilled. The SEI system is scalable, integrate able, customisable and extendable. With this level of maturity it has outgrown the context of a university and has to be continued in a commercial setting to ensure continued required support, maintenance, further development and training. For this purpose the new company GridQube has been formed together with UniQuest, Springfield City Group and Olav Krause, to provide these services and continue the development.

The onus is now on the DNSPs to move towards implementation in their businesses.

» Recommendations

The project team would recommend for ENA to coordinate with their members to start scoping the implementation phase. In order to achieve this, increased Knowledge Sharing, especially with the DNSPs who participated directly in the project and its trials, is a good first step.

On a high level the project team would recommend the following course of action:

- Circulate a high-level project outcome report, together with a possible vision statement amongst ENA members. The vision statement can cover the SEI state estimation capabilities and application as a data integration platform ingesting multiple different types of data from different sources, as well as the SEI system's architecture which supportsthe creation and execution of Post-Estimation Applications (potentially automated), which are a way to extract more value out of the estimator produced knowledge and to support and relive burden on current staff.
- Organise a Forum with interested ENA members in which:
  - » DNSPs that participated in the ARENA funded trial (Energex, United Energy, TasNetworks), as well as DNSPs who have committed to extending the trial (Energex, Ergon Energy) provide their perspective on the SEI system's capabilities, development potential and possible place in the business.
  - » GridQube Pty Ltd, as the company continuing the SEI system development in the commercial space, providing more technical details on the existing functionality (State Estimation, Constraint Analysis, Capacity Constraint Optimisation, PV Connection Assessment) and how the SEI system can support and facilitate the implementation of further specialised and customised power system analysis functions.
  - » Form cross-DNSP focus groups that target specific identified areas of interest. Possible candidates are:
    - General network performance assessment and reporting
    - Connection application assessments
    - Dynamic import and export limits
    - Required interfaces to the DMS and Control Room.
- Interested DNSPs to come forward and scope a technology demonstration with GridQube and other appropriate partners.

» References

n/a

» **Appendix**

– **Progress report endorsement by all industry members (compulsory)**

Endorsements

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Energex (Part of Energy Queensland)

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United Energy

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TasNetworks