Topic 8 – Distributed Energy Resources (DERs)

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Prepared by: Arthur Gonçalves Givisiez
Prof Luis(Nando) Ochoa
Department of Electrical and Electronic Engineering
The University of Melbourne

Contact: Prof Luis(Nando) Ochoa
+61 3 9035 4570
luis.ochoa@unimelb.edu.au

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1. Introduction

This brief report presents an overview of the project "Accelerating the Implementation of Operating Envelopes Across Australia" carried out by The University of Melbourne and funded by CSIRO as part of stage 3 of the "Australian Research for Global Power Systems Transformation (G-PST)". It also highlights the importance of this project to Australia's energy transition and the benefits for the global community. Lastly, it outlines recommendations for future activities and focus areas for research within Topic 8 – DER.

Australia is leading the world in the adoption of rooftop solar PV with almost one in three houses having the technology. Rooftop solar PV has already achieved the mark of generating 14% of the total Australia's electricity demand. This and other distributed energy resources (DERs) such as batteries and electric vehicles are creating opportunities to homes and businesses to save or even make extra money. Savings are achieved by reducing energy bills while extra money can be made through aggregators, who bundle DERs to participate in the electricity market run by the Australian Energy Market Operator (AEMO). The challenge, however, is to enable homes and business to make the most of their DERs while ensuring the integrity of the existing electricity distribution infrastructure (the 'poles and wires').

To tackle this challenge, Distribution Network Service Providers (DNSPs[1]) across Australia are gearing up to offer their customers flexible connection agreements known as operating envelopes (or dynamic operating envelopes). These operating envelopes (OEs) can be used to orchestrate the bidirectional flows from DERs whilst ensuring the integrity of the poles and wires. However, DNSPs in different States and Territories are likely to calculate and allocate OEs differently, given that they have different monitoring infrastructures at the distribution level, particularly in terms of smart meters and availability of network models. Therefore, it is important for DNSPs and, ultimately, to AEMO, to understand the spectrum of potential benefits and drawbacks of using the different OEs.

In this context, the previous project "Assessing the Benefits of Using Operating Envelopes to Orchestrate DERs Across Australia" [1] carried out by The University of Melbourne as part of Stage 2 in implementing CSIRO G-PST Topic 8 Research Plan, demonstrated that full electrical network models and full monitoring of customers (i.e., 100% smart meter penetration) are not necessarily needed to calculate adequate OEs. Simpler OE implementations that require very limited knowledge of the low voltage (LV) electrical network (to which residential customers are connected to) and very limited monitoring have great potential to be good enough to solve excessive voltage rise/drop and asset congestion within the LV network. Whilst this is great news for DNSPs and AEMO, as it shows it is possible to start the roll-out of OEs with simple approaches and unlock potential opportunities from DERs, **further research is still needed to make sure OEs can work in a future where they are widely adopted by customers in multiple neighbourhoods in a given high voltage (HV) feeder**.

Building on the four OE implementations – which are the Ideal OE, Asset Capacity OE, Asset Capacity & Critical Voltage OE, and Asset Capacity & Delta Voltage OE – developed in the previous project, this project is:

- **Assessing the implications of large-scale OE calculations in terms of accuracy, necessary algorithmic adaptations, and computational requirements**. The Stage 2 project, as well as the recently finished Project EDGE trial, consider the calculation of OEs for a single neighbourhood (a single distribution transformer) at a time. Although this is a first step, in the future, multiple neighbourhoods (multiple distribution transformers) will need OE simultaneously which can further exacerbate voltage and thermal issues. This makes it necessary to consider the interactions among LV networks and the HV feeder which, in turn, require adaptations to how OEs are calculated.
- **Providing guidance on data-driven techniques that can enhance their electrical modelling processes**. The data provided by smart meters, even if limited amount is available, can help DNSPs to improve their processes in the validation and/or creation of phase grouping, topology, and impedance estimation as they will be foundational in progressing with more advanced OE implementations. The outcomes of this part of the project will offer guidance to DNSPs in terms of the techniques that could be adopted in the short term.
- **Providing guidance on forecasting techniques for OEs**. Even with simple OE implementations, OEs might need to be calculated in advance, i.e., hours ahead, as this is needed by aggregators. This means

[1] DNSP is how distribution companies are known in Australia.

that forecasts of critical inputs are needed. However, to date, there is no effective forecasting solution for key parameters such as the active and reactive power demand of smaller groups of residential customers (let alone individual ones) that capture the peaks, lows, and shapes right, which is critical for OEs. Similarly for voltages at distribution transformers (or other critical points) there is limited work in the literature. Wrong forecasts can lead to wrong settings for DERs hours ahead, affecting networks and markets. The outcomes of this part of the project will offer guidance to DNSPs in terms of the techniques that could be adopted in the short term.

The findings from this project will directly and indirectly answer many of the research questions prioritised by the Australian Research Plan for Topic 8 “Distributed Energy Resources” [2], specifically: RQ0.1, related to DERs data flows; RQ1.3, related to DER standards; RQ4.1, related to equivalent models; and RQ5.1, related to organisational changes.

2. Research Completed

This section summarises the tasks completed to date and the insights that have been gained from them.

T1. Assessment of the performance of the four OE implementations of stage 2 when used for integrated HV-LV networks (i.e., multiple neighbourhoods).

- ✓ The OE implementations of stage 2, which consider the calculation of OEs per LV network (i.e., per neighbourhood), were tested for an integrated HV-LV network (i.e., multiple neighbourhoods).
- ✓ Results show that the per neighbourhood OE calculation leads, as anticipated, to technical issues when multiple neighbourhoods use the OEs. Voltage issues occur in all four OE implementations. This includes the ideal OE, where it is assumed that perfect electrical models of the network and 100% smart meter penetration are available.
- ✓ These voltage issues happen because the interactions of multiple LV networks (i.e., multiple neighbourhoods) connected to a same HV feeder are not captured during the per neighbourhood OE calculation. OE calculations must consider, simultaneously, both HV and LV networks to be effective.

T2. Design of improved OE calculations/implementations considering both HV and LV networks.

- ✓ The four OE implementations of stage 2, initially designed per neighbourhood, were redesigned for widespread use of OEs by considering both HV and LV networks (i.e., multiple neighbourhoods).
- ✓ The ideal OE was improved to use perfect electrical models for the integrated HV-LV network to calculate OEs, instead of only considering separated LV networks models.
- ✓ The Asset Capacity OE was improved to consider thermal limits of both HV and LV networks. In the HV, thermal limits were considered for the head of HV feeder and the zone substation transformer. In the LV, thermal limits were considered for distribution transformers as well as for head of LV feeders.
- ✓ The Asset Capacity & Critical Voltage OE was also improved to consider thermal limits of both HV and LV networks, as in the Asset Capacity OE. The sensitivity curve to calculate the critical voltage did not change.
- ✓ The Asset Capacity & Delta Voltage OE was improved to consider thermal limits of both HV and LV networks, as in the Asset Capacity OE. In addition, the voltage changes caused by the interaction of LV networks are also considered using a new sensitivity curve.

T3. Implementation and assessment of the redesigned OE calculations for integrated HV-LV networks.

- ✓ The redesigned Ideal OE calculations performed well to solve network issues, with specific limitation for LV networks without flexible customers (where voltage problems cannot be solved via OEs since no flexible customer is available).
- ✓ The redesigned Asset Capacity OE calculations perform well to solve thermal problems in distribution transformers, but voltage problems are not solved even for low penetration of flexible customers. This was expected since this OE implementation does not consider voltages in its calculation.

- ✓ The redesigned Asset Capacity & Critical Voltage OE calculations do solve thermal problems in distribution transformers, but voltage issues still occur. This was, to some extent, expected since this OE implementation only considers the relationship between the active power and voltage at the critical customer, not directly considering the voltage interactions of multiple LV networks/neighbourhoods.
- ✓ The redesigned Asset Capacity & Delta Voltage OE calculations do solve thermal problems in distribution transformers, showing a slightly better performance than the previous simplified OE implementations. However, voltage problems are still not solved since it does not directly consider the voltage interactions of multiple LV networks/neighbourhoods.

3. Outstanding Activities

This section outlines main Tasks to be completed by the end of June 2024.

T4. Recommendations to DNSPs and AEMO on the use of the improved calculation of OEs for integrated HV-LV networks.

T5. Qualitative assessment of data-driven techniques that can enhance DNSPs electrical modelling processes.

T6. Qualitative assessment of forecasting techniques for operating envelopes.

T7. Prepare final report and presentation.

T8. Share algorithms and data with CSIRO and AEMO.

4. Progress Against the Roadmap

This section outlines how stage 3 is tracking some of the research questions of the Australian Research Plan for Topic 8 “Distributed Energy Resources”, which makes part of the Australia’s G-PST Research Roadmap.

RQ0.1 What data flows (DER specs, measurements, forecasts, etc.) are needed to ensure AEMO has enough DER/net demand visibility do adequately operate a DER-rich system in different time scales (mins to hours)?

This project is partially addressing this question as it is demonstrating that OEs can be quantified across a large area (e.g., an HV feeder), hence informing AEMO on the extent to which DERs could be utilised by aggregators. AEMO could use this information to estimate the minimum demand on a given area, which would help them with the planning of the power system operation. Moreover, the forecasting necessary for OEs can significantly help with forecasts at higher voltage levels, thus also helping AEMO to have a more accurate forecasts to plan ahead.

RQ1.3 What is the role of DER standards in concert with the future orchestration of DERs?

The most up-to-date Australian Standard for inverters is being used in the project. Specifically, the use of Volt-Watt and Volt-var functions with priority to Volt-var. This allows assessing the role of standards when used in combination with other DER orchestration techniques.

RQ4.1 What are the minimum requirements for a DER-rich distribution network equivalent model to be adequate for its use in system planning studies?

Similar to RQ0.1, being able to estimate OEs across a large area (e.g., an HV feeder), will help AEMO determine the effects of DERs depending on how aggregators use the OEs (fully or partially). This in turn, could help AEMO to develop equivalent models to represent the DER-rich distribution networks.

RQ5.1 What are the necessary organisational and regulatory changes to enable the provisioning of ancillary services from DERs?

OEs are meant to be calculated by DNSPs and are largely focused on the poles and wires of the distribution networks. However, AEMO might need to impose limits at the Transmission-Distribution interface. If that happens, those limits will need to be used by DNSPs to calculate OEs.

5. Research Relevance

The adequate orchestration of DERs can ensure a future in which every house in Australia can have solar photovoltaics and electric vehicles and, ultimately, help Australia meet our 2030 renewable targets in the most cost-effective way. The concept of Operating Envelopes is one that is already being adopted in Australia as it can help orchestrating DERs whilst ensuring network integrity (the 'poles and wires') by providing time-varying export and import limits at the connection point of customers (or DERs). In fact, the export part of operating envelopes has already been approved by the AER [3] to be offered by DNSPs to customers that would like to have a variable flexible export limit instead of the fixed one (which is default today). Some DNSPs are already offering this new type of connection to their customers [4, 5] while others are preparing accordingly.

As DNSPs move to use OEs to orchestrate DERs, each of them will adopt approaches to calculate and allocate the OEs considering their own data availability. This data availability (electrical models, monitoring, etc.) is, in Australia and around the world, very diverse particularly when it comes to residential low voltage (LV) networks. Therefore, this project is important to Australia as it will provide an objective comparison on the widespread use of different OE implementations (i.e., calculation and allocation) likely to be seen across the country. The assessments and recommendations made by this project will help DNSPs, AEMO and other decision-makers to make informed decisions with respect to the development and adoption of the most suitable OEs considering network integrity, DER utilisation, and effects on customers.

The knowledge being developed by this project is not only important to Australia, but to many other countries since the increase in the DER adoption is happening worldwide. Therefore, Australia is in a strong position to share its knowledge and lead collaborations with research institutions from other countries and thus help in the world's energy transition.

6. Recommendations

This project so far is demonstrating that the OEs developed for individual neighbourhoods – as considered in stage 2 – are not effective to solve issues, particularly voltages, when OEs are used across multiple neighbourhoods. It is also demonstrating that OEs developed when considering integrated HV-LV networks (multiple neighbourhoods simultaneously) work better. However, further research is needed with respect to other aspects. This includes two main streams of work:

- **Implications of Australian PV inverter Volt-Watt and Volt-var requirements on the effectiveness of OEs**. The mandatory use of Volt-Watt and Volt-var functions on PV inverters can impact the extent to which calculated OEs can be fully utilised by flexible customers. These PV inverter requirements can curtail PV generation due to voltages despite a generous OE being calculated for flexible customers. This, in turn, would also reduce any service that aggregators would try to provide to AEMO. Therefore, it is important to demonstrate in what cases the PV inverter requirements will work well with OEs, and in what cases they will create a conflict with the calculated OEs. This is relevant to multiple stakeholders, including DNSPs, AEMO and end users (i.e., flexible customers). This stream of work relates to RQ 1.3 of the Australia's G-PST Research Roadmap.
- **HV-level quantification of aggregated OEs considering rural and urban HV feeders as well as forecast.** Further analyses are needed to capture the effectiveness of different OE approaches when applied to different types of distribution networks (different topologies, impedances, types of customers, etc.). For instance, rural areas have low customer density and many use Single-Wire Earth Return (SWER) networks which also means different phase shift among customers. Therefore, the effects and robustness of different OE approaches need to be assessed considering different network types as well as

operational aspects. This assessment would allow to extract recommendations on what AEMO could expect from different types of distribution networks, forecasts, and OE implementations. This is relevant to DNSPs but mainly to AEMO. This stream of work relates to RQ 4.1 of the Australia's G-PST Research Roadmap.

7. References

[1] Prof. Luis(Nando) Ochoa, Arthur Gonçalves Givisiez, Dr. Michael Z. Liu, and Vincenzo Bassi, "Assessing the Benefits of Using Operating Envelopes to Orchestrate DERs Across Australia," in "CSIRO GPST Stage 2: Topic 8 – Distributed Energy Resources," The University of Melbourne,, 2023.

[2] L. N. Ochoa, A. G. Givisiez, D. Jaglal, M. Z. Liu, and W. Nacmanson, "CSIRO Australian Research Planning forGlobal Power Systems Transformation: Topic 8 "Distributed Energy Resources"," The University of Melbourne, 2021.

[3] Australian Energy Regulator (AER), "Flexible Export Limits: Final Response and Proposed Actions," 2023.

[4] *TS129: Small EG Connections Technical Requirements - Capacity Not Exceeding 30kVA*, SA Power Networks, 2021.

[5] *STNW3510: Dynamic Standard for Small IES Connections*, Ergon Energy and Energex, 2023.