The Future of Operational Forecasting has Landed in Australia

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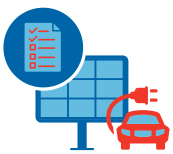


THE FUTURE OF OPERATIONAL FORECASTING

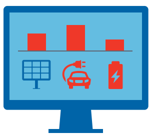
Recently, the Itron Forecasting Team was provided with the opportunity to develop a forecasting framework to support a new market mechanism that Australia is evaluating for growing and managing distribution energy resources (DER), particularly solar PV generation and battery storage. The market establishes a process where DER owners are financially incented to supply local energy and support services. The twist is that this market must act within the technical limits of the low voltage network to ensure that the backflow of embedded generation, which has led to failures in the past, will be avoided in the future.

Wholesale power markets dispatch grid-connected generation to meet aggregated power demand subject to the technical limits of the high voltage network. This is done by solving a constrained optimization problem where the objective function is to minimize the cost of serving demand, subject to the operating characteristics of the high voltage grid. The key inputs to the mathematical model are the wholesale supply bids sorted from cheapest to most expensive (supply curve), a real-time forecast of power demand (aggregate demand curve), and the high voltage network topology.

Australia is evaluating the plausibility of pushing this concept down to the level of the low voltage network. This creates significant challenges and opportunities. Unlike grid-connected generation units that are monitored in real-time, system operators have limited to no real-time measurement of consumer-level generation and storage. Further, the high voltage system has been designed with dispatchable controls on the delivery of grid-connected generation. The low voltage system has limited to no dispatchable control over the excess generation flowing from consumers into the low voltage network. And, to add another layer of complexity, there are potentially millions of distributed generation units that are subject to the vagaries of cloud movement which also is non-dispatchable.

Despite what appears to be a rather daunting challenge of encouraging significant investment in distributed generation while at the same time not having the low voltage grid burn to the ground, Australia is testing a rather clever market solution. This solution encourages consumers to invest in distributed generation and battery storage, while simultaneously eliminating the need for centralized control of all those generation and battery storage units. At the heart of this solution is the concept of Dynamic Operating Envelopes (DOE)s.

Historically, when consumers want to install a solar photovoltaic (PV) system, they apply for an operating permit from their local utility. The permit imposes a static operating threshold that limits the amount of electricity that can be pushed into the low voltage grid. The static limits apply all the time, regardless of whether the low voltage network could import more or less power at any given point in time. Unfortunately, even with static limits, parts of the Australian low voltage network have experienced times when technical limits of the grid are exceeded, leading to failures. The concept that is being tested is setting the operating limits dynamically to avoid failures. For example, on days with the potential for low demand and high solar PV output, consumers would be assigned stringent limits on the quantity of power they could push into the low voltage network. In contrast, on days with the potential for high demand and low solar PV output, consumers would be assigned less restrictive limits to help offset some of the demand for power.



For example, consider a consumer wanting to install a solar PV system. Under static limits, the consumer is restricted to a 4KW system. With dynamic limits, the consumer could install a 10KW system knowing that there will be many days that they could be paid by the market for the extra 6KW of energy they push into the grid. At the same time, the consumer accepts there will be days their solar system will be restricted in its production to 4kW or less. The goal is to provide consumers with the financial incentive to oversize their systems so they can be net exporters of power, while at the same time staying within the physical limits of the low voltage system.

The dynamic operating limits are computed by solving a constrained optimization problem configured to reflect the operating characteristics of the low voltage network. Unlike the wholesale problem where the objective function is to find the least cost mix of generation to meet demand for power, here two separate problems are solved simultaneously. The first problem is to maximize the capacity for delivery of power subject to the technical limits of the low voltage network. The second problem is to maximize the capacity for receipts of power from consumers to the low voltage network subject to the technical limits of the low voltage network.

In the wholesale problem, the demand forecast represents the amount of power that is to be consumed. To develop the dynamic operating limits, two forecasts are required: (1) the quantity of power to be delivered to consumers and (2) the quantity of power to be pushed by consumers to the low voltage network. In other words, the forecasts are for capacity to operate and not forecasts of energy flows. The solution to the two dynamic operating envelopes establishes technically feasible operating parameters within which there will be no problems with the low voltage network, as long as consumers conform to the restrictions. The key is for the market to provide the right level of financial incentives for consumers to work within the limits. In this way, potentially millions of distributed resources can come online without violating the physical limits of the low voltage network.

Dynamic Operating Envelope Example.

Consider the case where there are two classes of consumers. Prosumers are consumers with one or more controllable devices (e.g., solar inverter, battery storage, smart thermostat, smart EV charger) that have elected to participate in the market. In this example, the prosumer controls their solar inverter to change the mix of delivered and received capacity. Non-prosumers are consumers that elected not to participate in the market. The following three figures illustrate the DOE concept. In these figures there are two DOE trains: (1) a DOE delivered train that has the capacity to deliver 20 seats of power to the two customers and (2) a DOE received train that has the capacity to receive 20 seats of power from the two customers. The 20 seats of delivered and received power represent the technical limits of the low voltage system.

Figure 1. Business-as-Usual Case

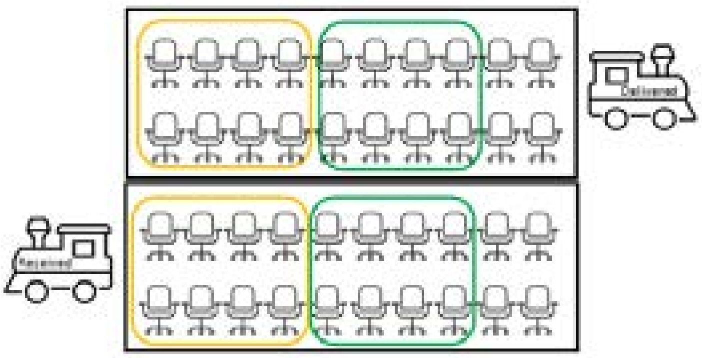


Figure 1. Business-as-Usual Case. In the Business-as-Usual Case, the non-prosumer is expected to use eight (8) seats of delivered power and eight (8) seats of received power. This means the prosumer must work within the Dynamic Operating Envelope of the remaining 12 seats of available delivered power and 12 seats of available received power. On this day it is expected the prosumer will only use eight seats of delivered and eight seats of received power. The remaining delivered and received power seats are unused. As long as both the non-prosumer and prosumer act according to expectations the operating limits of the low voltage network constraints will not be violated.

Figure 2. High Demand for Power Case

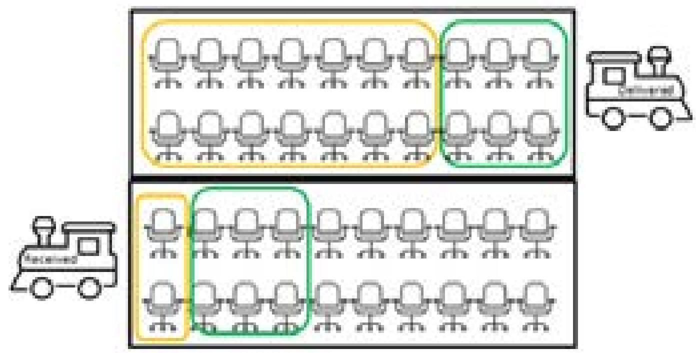


Figure 2. High Demand for Power Case. In this figure, the non-prosumer is expected to lean on the low voltage network for 14 seats of delivered power due to unusually high temperatures. Further, most of the non-prosumer solar PV generation is expected to be consumed leaving a requirement for only two seats of received power. As a result, the prosumer's Dynamic Operating Envelope for delivered seats is squeezed to no more than six seats. In contrast, the prosumer's Dynamic Operating Envelope for received seats is expanded to no more than 18 seats. In this case, the prosumer will be incented by market prices to either reduce their demand for power by implementing some form of load control and/or changing their solar inverter control to allow for more solar PV generation. Again, as long as both the non-prosumer and prosumer act according to expectations, the operating limits of the low voltage network will not be violated.

Figure 3. Low Demand, High Solar PV Generation

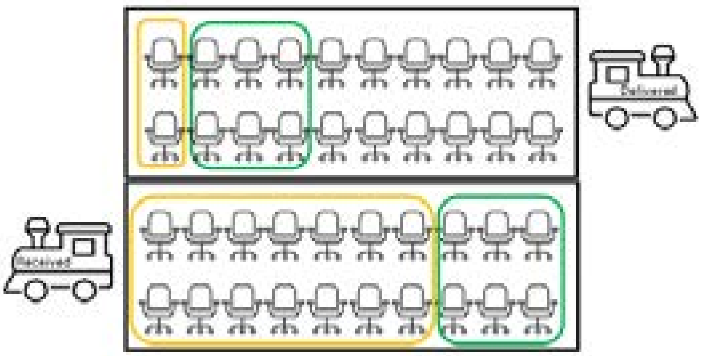


Figure 3. **Low Demand, High Solar PV Generation Case**. In this figure, the non-prosumer demand for power is expected to be unusually low, which would be typical for a clear, mild temperature Spring day. At the same time, it is expected that the solar PV production for the non-prosumer will be high. As a result, it is expected the non-prosumer will only need two seats of delivered power but 14 seats of received power. The Dynamic Operating Envelope for the prosumer is then 18 seats of delivered power and six seats of received power. Because the prosumer's demand for power is also expected to be low so as to stay within the received operating envelope, they will be incented by the market to adjust the solar inverter to reduce solar PV generation.

Implications for Operational Forecasting. In the initial Australian trials, the goal is to develop a rolling 48 hours of five-minute level Dynamic Operating Envelopes at the circuit, transformer, and/or possibly premise levels. If we take transformers as the lowest level of specificity, then a new forecast by transformer is required every five minutes. Let's say there are 100,000 transformers. Then, the requirement is for 100,000, 48-hours ahead forecasts generated every five minutes. Further, the transformer level forecasts need to be segmented into delivered and received power. This translates into 200,000, 48-hours ahead forecasts generated every five minutes. If Active and Reactive power forecasts are needed, then the problem expands to 400,000, 48-hours ahead forecasts generated every five minutes. To complete the picture, the forecasts would need to be segmented at the minimum into non-prosumer and prosumer buckets. This results in a requirement for 800,000, 48-hours ahead forecasts computed every five minutes. If premise level forecasts are required, the size of the forecast problem quickly runs into millions of forecasts generated every five minutes. All these forecasts need to be completed in less than one minute to provide sufficient time to solve for the Dynamic Operating Envelope and distribute the results to all third parties. To put some perspective on the scale of this problem, the Australian Energy Market Operator relies on five-minute level load forecasts for no more than 100 load zones. Conservatively, the new forecast problem is 10,000 times bigger.

With the right market incentives, the beauty of the Dynamic Operating Envelope approach is that it will be technically feasible to ingest significantly more distributed generation without overwhelming the low voltage network. The market incentives and non-centralized control will ensure the low voltage network operates within technical limits. To make this vision a reality requires a forecasting framework that supports production of millions of forecasts in real-time. The future of operational forecasting is in Australia, where Itron has jumped on the DOE train.

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