New Power

REPORT

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When worlds collide

Electricity. telecoms, signal processing and machine learning technologies are all coming together in the initiative to measure and predict system inertia. National Grid ESO has two projects under way

MARC BORRETT, REACTIVE TECHNOLOGIES

Reactive Technologies is about to start providing NGESO with real-time measurements of inertia. Janet Wood heard how it came about

Marc Borrett, chief executive of Reactive Technologies, has a history in semiconductors and says he wanted to bring that skillset into the power industry. Why? "The mobile communications industry and telecoms as a whole have gone on the same kind of journey as the energy industry is going to go on," he says.

> "This is not power engineering, this is signal processing and communications engineering

A major part of the company's business was, and is still, in managing imbalance for half a gigawatt of UK power assets. But in doing that, and gaining detailed knowledge about demand-side response (DSR) in a project with France's Carrefour supermarkets, Borrett says the company found interesting parallels.

He says: "If you think of telecoms it is all about operating lots of different devices at the edge of a network. Making sure that the signal strength stays, you don't drop a call and you can send data backwards and forwards." In moving towards a grid powered by variable renewables, "if we focus on the control side at the edge of the network that will allow us to mitigate some of the impacts".

USING DORMANT ASSETS

The company began by talking to National Grid about DSR, and using assets that are effectively dormant on the system such as immersion water heaters.

At that time, the smart meter rollout had not begun and "there wasn't an easy way to communicate with [the devices]". Borrett says National Grid was reasonably sceptical, "but we could prove that we could cover the whole of the UK with a smallish data message that we could use to change their state". He realised the company had to look at the grid from a communications channel perspective: "We developed our own measurement devices that were very fast and highly accurate," to measure various system characteristics."

He says one that got them very excited was inertia, which up to now has relied on an estimate.

How does it work? The company is building a super capacitor that will send a signal – a tiny disturbance encoded in the central frequency – and installing a network of measurement devices >

around the UK that will measure how the signal transfers through the grid. The system has to pick that tiny disturbance out of other system noise from each measurement point, but Borrett says: "That's exactly what telecoms systems do... This is not power engineering, this is signal processing and communications engineering."

> You have to make sure that autonomous decision-making at the edge is done in a failsafe way

A test project saw Reactive pass on measurement data to National Grid ESO 'blind' and let the ESO measure whether it was close. It was: eventually, Borrett says, the ESO decided that the measurement was close to its estimated figure and at some times closer.

The project is going on to a full commercial service (dubbed GridMetrix). Borrett says: "This is the first time the system operator will be able to take a measurement in the control room rather than basing procurement on historical models. That is genuinely a huge change in thinking."

WHAT NOW?

At this stage NGESO wants a single figure on inertia and to build up a deep understanding of how that figure changes within day, month and season, says Borrett, but he thinks it is a step on the journey to a far more localised view.

The transmission system will have 40 devices but he says: "We might go to having 400 or 4,000, so we can really drill down at depth and understand the power grid in a real sense, instead of an abstract model sense."

Borrett is hoping it will be equally interesting for distribution system operators. What is more, he is contemplating offering the network of devices as a platform to gather data for other purposes when it is not taking inertia measurements.

He says: "Hopefully they will move to a point where they are operationalising the data and getting multiple insights, so they can make better decisions – whether that is by human or a machine. That will play out in the next 10 or 15 years."

I suggest that this type of approach in the power industry will require a different skill set and Borrett agrees that it will "use a lot more data science".

Comparing the power and telecoms industries again,he says: "If you are going to make a resilient system you want it to have the smallest point of failure possible. Coming from the electronics industry and looking at the energy industry, 10 years ago it seemed that it was the other way around – you would have large power stations which were very large points of failure. The system was designed to cope with them … That's just been a function of the economics of producing cheap power but clearly that has changed."

Smaller points of failure means better resilience, he says. But it also means more control is needed if more assets act automatically. For example, he notes that after the August blackout some people called for more battery installations. He imagines an automatic response from batteries seeing system frequency sag: "They could potentially put [frequency] above 50Hz responding to the drop and then they hunt above 50Hz and they pull it down – you are in oscillations and no one is in control. That's the danger: you have to make sure that the autonomous decision-making at the edge is able to be done in a failsafe way."

That is a concern for the future. The next step for Reactive Technologies is to begin the inertia measurements. The 40 measurement devices are already installed and the supercapacitor – an asset about the size of two shipping containers – has to be installed at a site in the centre of the UK, to ensure the signal is as a centralised as possible.

That should be at some point next year, and Borrett says: "When the super capacitor is ready to send the signal everything else is ready to go." NP

DOUGLAS WILSON, GE POWER

New Power invited GE to discuss its joint project with National Grid ESO to measure and predict inertia. Douglas Wilson, chief scientist at GE Power, explains how it works

NP: IS THERE DIRECT INERTIA MEASUREMENT IN GE'S SYSTEM, AND HOW IS THAT ACCOMPLISHED?

Inertia is directly identified from measured dynamic changes in the network. We consider the network to consist of a four regions and identify inertia for each of these areas.

This is done using fast, synchronised measurements from phasor measurement units (PMUs). These are standard monitoring devices already >

used to meet various dynamic monitoring requirements in the GB system.

In the project, NGESO will be adding the PMUs to complete the monitoring required for the inertia measurement. These will also add to NGESO's wider dynamics monitoring requirements and align with the system operator's code of practice for transmission monitoring (STC-27-1.

> GE uses ... the natural random movements of the power system

The raw measurements from PMUs are taken at 20ms time intervals and continuously streamed to a central server where they are received, lined up using highly accurate GPS timestamps, and processed. The inertia application is one of a number of applications that use this data.

Each area of the grid is monitored. PMUs measure the sum of power on all of the transmission lines crossing the boundary of the region. A few PMUs inside the area will be measured and used to generate an average frequency for that area.

The power system always has small disturbances and oscillations which looks like noise in measured signals. Measuring total power in and out of the area, and the frequency movements inside the region, will show these small movements. By applying a signal processing approach to these PMU-based power and frequency signals, GE extracts on stability characteristics of the area – in this case the effective inertia. No injection of power is needed.

> Increased confidence in the forecast means you can provide appropriate signals to the market

The inertia values for each of the areas of the grid are useful in their own right, but they can also be summed to create an overall inertia value for the whole system.

NP: WHAT IS THE ROLE OF AI AND MACHINE LEARNING?

There are three main use cases for a machine learning method to be applied to the inertia measurements:

- To predict the expected values of inertia over the coming 24-hour period, so NGESO can plan ahead for any constraints to maintain a "secured loss" level and plan mitigation measures
- To respond rapidly to a large step-change in inertia in an area such as a generator trip. The direct inertia extraction uses a window of data and therefore takes time to respond to major change; the machine learning approach will reflect the change in just a few seconds.
- To determine the influences of various generation, load and storage technologies – it is useful to know the sensitivity of inertia to various operational factors in the grid, such as the levels of load, solar power, wind power etc and any new controlled resources.

The machine learning approach takes a number of slow-update measurable and predictable values in the grid such as large generator infeed, load, wind power, solar power and other variables for each area. These values typically update every few seconds, using information from NGESO's energy management system.

A machine-learning model is created to relate the direct inertia measures to the measurable and predicted values.

Using predicted data, the model can generate future values of inertia. Using real-time data from the energy management system it can provide rapid response for control room users to address conditions when a large generator trips or other large event occurs.

An understanding of what the inertia is now has limited value on its own. Increased confidence in the forecast means you can provide appropriate signals to the market in advance to increase frequency management options and ultimately reduce cost.

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NP: HOW DOES THE GE APPROACH COMPLEMENT NGESO'S OTHER APPROACH?

The GE approach identifies inertia in clearly defined areas of the grid. This is important since rate-of-change-of-frequency (ROCOF) needs to be contained within limits in each area. The GE approach therefore improves the understanding and visibility of how the inertia is distributed throughout the grid, and points out particular "danger zones" where there is an area of particularly low inertia. The area inertia measures can be used in future not only by operators, but also in automated fast-acting control that responds to disturbances in the right regions of the grid to improve its stability, thus enabling connection of more renewable energy without constraining the grid.

The GE approach uses passive monitoring using the natural random movements of the power system and standard PMU devices that can be used in high voltage transmission substations that satisfy the data quality requirements both for inertia and for the wider dynamics monitoring code of practice.

As experience grows, NGESO operators will find out how to use the outcomes of each system in the overall inertia management process. NP

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