ESIG Webinar: System Black Start with DER

22 July 2020

Distributed ReStart

Energy restoration for tomorrow

Your questions answered:

Distributed generation inverters are grid following, not grid forming. How do you overcome this?

Grid forming convertor technologies can provide the same benefit as synchronous generators in that they can generate their own voltage sources, hence act as 'anchor' generators. They can also provide fast-acting frequency response and are more stable in weak networks compared to grid following convertor technologies. However, they are currently not deployed at scale. Grid following convertor plant is currently deployed at scale within GB and can contribute to restoration but only in a supporting role. The Distributed ReStart project has commissioned work looking at how grid forming & grid following convertor technologies can support restoration. The initial results will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the webste at the end of July.
https://www.nationalgrideso.com/future-energy/projects/distributed-restart

Did you consider a potential conflict between DERs providing blackstart services and DER anti-islanding requirements from distribution owners/operators?

It is intended that the protection and control settings will be adjusted at the start of the Black Start process, and may have to be adjusted again, before being returned to normal at the end. This may be one of the functions of a DRZ Controller. This would include generator Loss of Mains protection (Rate of Change of Frequency). This is included in the project's scope for works designing and building the DRZ Controller.

Why was a bottom up approach from small DERs in the Distribution systems selected verses large DERs connected to transmission such as wind farms?

It is envisaged that an integrated top-down and bottom-up approach will be needed to meet the restoration timescales set out in the new GB Black Start Standard. The bottom-up approach will accelerate regional restoration timescales as well as provide competion for large transmission-connected providers. In parallel with this project, the ESO is also running regional tenders for transmission-connected providers to transition the top-down approach towards non fossil-fuelled generation. Wind generation has a part to play here as well as at DER level.

Is your approach to have a network of self sustaining microgrids, that you can call on to restart a conventional plant?

The scope of the project includes establishing self sustaining Distributed ReStart Zones (DRZs) which may be able to energise up to transmission level, to act as either a source of cranking power to restart a transmission-connected generator or competition for such resources. There are many technical challenges to overcome. Detailed case study results will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the website at the end of July.
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Distributed generation trips off in an outage and stays off until the grid is reestablished. How would the DG be "told" to reenergize?

Telecoms resilient to loss of electrical supplies would be needed to allow end-to-end communications from ESO-DNOs-DERs. The initial despatch instruction to the 'anchor' DER & supporting DERs would need to via this resilient telecoms route; e.g. voice. The DRZ Controller system would then act as the despatch tool by applying block loads and balancing DRZ resources. Detailed functional requirements for resilient telecoms will be published in a project report in October.
https://www.nationalgrideso.com/future-energy/projects/distributed-restart

What would be the difference between a DRZ and a microgrid?

They are similar. A Distributed ReStart Zone (DRZ) is a distribution power island that can be restored from blackout whereas a microgrid is a small power island that can be self sustained despite the loss of grid supplies. Both require automation. Block loading capability will be needed for DRZ control. Microgrids tend to be small community-based schemes, such as university campuses or industrial parks, and would need to be scaled up to meet the requirements of a DRZ. The Distributed ReStart project is collaborating with other innovation projects working on microgrids to share learning; e.g. Resilience As A Service, Grid Cell, Imperial College.

Would the DER for blackstart need to be grid forming DER? Moreover, what would be providing the AGC function within the island?

The 'anchor' DER would need to be grid forming; i.e able to generate its own voltage source. Supporting DER within the same Distributed ReStart Zone (DRZ) could be grid following & can be utilised to build the DRZ depending on technical constraints (short circuit levels, phase lock loop limitations, etc.). The DRZ Controller system would despatch demand & generation within the DRZ to balance.

Are you also considering blackstart using Inverter based resources?

Yes. The Distributed ReStart project is investigating using both grid following and grid forming convertor technologies to either support restoration or act as the 'anchor' DER. The initial results will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the webste at the end of July. **https://www.nationalgrideso.com/future-energy/projects/distributed-restart**

Sounds like he is talking about large fossil fuel DER that are on dedicated feeders. Like large Combined Heat and Power. Not renewable energy DER.

The Distributed ReStart project is technology agnostic so all DER technologies are within scope.

Where can we find a copy of the report to be published?

"Assessment of Power Engineering Aspects of Black Start from DER" report will be published on the website at the end of July. 2 other reports will be published in October showing detailed designs for Organisational models, systems and telecoms functional requirements, commercial and procurement & impact on industry codes. **https://www.nationalgrideso.com/future-energy/projects/distributed-restart**

Can you speak on black starting a small grid with genset and ESS? where the ESS will act as black start unit on forming then the genset will come online.

If a battery (or other converter-connected resource) has grid forming capability (i.e. can generate its own voltage source) then this is possible. For example, you may have seen reference to Virtual Synchronous Machines (VSM) in recent NGESO research projects (e.g. Dersallach windfarm). If joining a power island already established by an 'anchor' generator, batteries and other forms of energy storage with appropriate control systems could also be used to support with frequency and voltage control.

Voltage Control: Can the DERs handle city neighborhoods with high charging due to underground distribution feeders?

Potentially yes but the 'anchor' DER would probably need to be supported by neighbouring DER. Urban case studies would need studying in detail. Our case study results will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the webste at the end of July. **https://www.nationalgrideso.com/future-energy/projects/distributed-restart**

Analysis of our case studies showed the best strategy for energising a DRZ is to restore supplies to the additional DER so that their auxiliary supplies are restored and can remain on standby to provide active and/or reactive power support as and when required by the 'anchor' DER.

Those are a lot of technical challenges, it sounds like a herculean task! Do you think it is achievable (realistic)? If so, how soon?

The Distributed ReStart project case study results suggest that Black Start from DER is possible. However, there are a multitude of technical challenges to overcome. To extend the reach of the Distributed ReStart Zone (DRZ at 33kV) up to transmission level (275 or 400kV) may require additional support from generation connected at 132kV, to overcome limitations with protection and overvoltages. Also a switchable earthing device will need to be installed at the site of the 'anchor' DER.
See "Assessment of Power Engineering Aspects of Black Start from DER" report published on the webste at the end of July.
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We are also designing the Black Start from DER commercial services to allow a plethora of providers to participate, whether to provide 'anchor' DER services or top-up services (e.g. inertia, short circuit levels, reactive power, demand, fast MWs, energy). The live trials, which start early 2021 and progress through to the autumn 2021, will give us insights whether the service is technically possible.

When energizing from the distribution transmission – to central plants, how is the safety assured specifically with regard to overvoltages due to switching .

The energisation of distribution & transmission circuits produce reactive charging power that needs to be absorbed. Our case study analysis showed that a 33kV network can typically be energised by the 'anchor' DER and that it is acceptable to simultaneously energise multiple 33kV circuits to speed up the restoration process. However, the charging power produced by circuits at 132kV & higher voltages will most likely exceed the 'anchor' DER's reactive power capability. Other DER can provide the additional reactive power required during circuit energisation. This is not necessarily dependent on a prime energy source such as wind being available, as modern windfarms can provide reactive power even under no wind conditions.
Circuit energisation can also result in high switching over-voltages and depending on the network configuration, as seen with our case studies, it could be more than 50% of the nominal voltage rating. This could potentially damage equipment. A solution to this problem is to energise the circuits at a reduced voltage to limit the transient spike within a reasonable boundary of 10%.

How do you choose the anchor generator? What features does it need to have?

The 'anchor' DER needs to be able to generate its own voltage source, regulate frequency and accept block loads.

Regarding fuel reserves: if an anchor generator depends on renewables for BLPU, how do you achieve fuel reserve needed by the supporting renewables? ESS?

Fuel reserves will be required to sustain the end-to-end restoration service and this will form part of the service procurement arrangements. The design of these arrangements is work in progress.

How is the inrush of transformers handled under black start ? (edited)

We have been examining this in power system studies and exploring this issue more generally with DER owners/ operators, manufacturers and others. It is an example of something that will require detailed assessment in each case. Results from transformer energisation studies will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the website at the end of July.
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Are the case studies include both distribution and transmission system?

The 3 case studies include establishing power islands on 33kV networks and extending upwards to 132kV (grid voltage) and 275/400kV (transmission voltage). Results of steady-state, dynamic & transient studies will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the website at the end of July.
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Why not just have your own backup microgrid (with energy storage) at the blackstart resource?

This is an option worth exploring. We are collaborating with other innovation projects investigating whether microgrid technologies can be scaled up to form larger power islands; e.g. Resilience as a Service project, Grid Cell project, Imperial College multi enery microgrids research.

Is what you are referring to as DER large Combined Heat and Power units? And not distributed solar generation, which in the US we usually think of as DER?

All technologies and sizes of DER are within scope. An 'anchor' DER has to be able to generate its own voltage source, which can be done by synchronous or grid forming convertor connected DER. Grid following convertor connected DER can also support restoration depending on short circuit levels and phase lock loop limitations.

Can you elaborate on the earthing technical challenge?

A typical DNO 33kV network in GB is earthed at Grid transformers only – earthing transformer at the low voltage side of 132/33kV Grid transformer. If operating as a 33kV island then there is no 33kV earth. The UK Electricity Safety, Quality & Continuity Regulations state "network connected with earth ... as near as reasonably practical to the source of voltage". So it will be necessary to install a switchable earthing transformer at the 'anchor' DER site.

What is block load pickup?

The Block Load Pickup capability of a DER is the maximum demand which can be instantaneously supplied while ensuring frequency remains within an acceptable range. It is typically 10–25% of the DER's MW rating and depends on factors such as turbine technology, governor type, machine inertia & spinning reserve.

What are the types of DER that can provide DER Restart or act as anchor generator? If they are wind power plants can they commit to this service?

Currently installed at scale on the GB electricity system only synchronous generation can act as 'anchor' DERs, although asynchronous DER can support restoration. However, the Distributed ReStart project has commissioned work looking at how grid forming & grid following convertor technologies (including wind) can support restoration. The initial results will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the webste at the end of July.
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How can the dynamic response of an anchor generator to block load pickup be technology agnostic. Are anchor generators modeled as synchronous?

The Block Load Pickup capability of a DER is the maximum demand which can be instantaneously supplied while ensuring frequency remains within an acceptable range. It is typically 10–25% of the DER's MW rating and depends on factors such as turbine technology, governor type, machine inertia & spinning reserve. Our 3 case studies are based on synchronous DER due to network-connected availability. We have commissioned studies to investigate whether grid forming convertor connected DER (e.g. windfarms, batteries, etc.) can act as 'anchor' DER. The results of these studies will be published in December on our website.
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How will the distribution protection work within the DRZ if fault magnitudes are drastically lower? Will you lose the entire island for a fault?

Modern protection relays have the facility to be programmed with a 2nd group of settings which can be changed remotely (via Scada). Our case study results show that a minimum short circuit level will be required at each system voltage for satisfactory protection operation (assuming revised setting are applied as required) –
50MVA for 33kV
50MVA for 132kV
100MVA for 275kV
250MVA for 400kV
Based on our case study results it is unlikely that a 33kV DRZ will be able to provide enough short circuit levels for existing 400kV protections to operate correctly, so additional supporting short circuit levels will be required at higher voltages (e.g. DER at 132kV).

Was adding more demand side management a consideration?

Yes, demand side management is being considered. We are proposing utilising a flexible demand source to initially load the 'anchor' DER, then utilising consumer demand to grow the Distributed ReStart Zone (DRZ). This could be procured as a 'top up' service. Other 'top up' services could include fast MW, energy, short circuit levels, inertia & reactive.

Very interesting work...is the black start process susceptible to single point failure if the anchor generator trips due to some reason?

Yes, hence protecting the 'anchor' DER is seen as a priority. The approach here is for automation to play an important role in minimising risk to the 'anchor' DER through smooth despatch of resources. Cold Load Pickup of consumer demand is a big problem here so it is proposed that a flexible demand resource is utilised in the initial stage of loading the 'anchor' DER. The DRZ controller (being designed & built by the project) will perform this function.

What do you use for the anchor generator? A synchronous generator? Or inverter-based? Grid forming?

The 'anchor' DER would need to be grid forming; i.e able to generate its own voltage source. It would also need to regulate frequency & be able to block load. The Distributed ReStart project will be utilising synchronous DER to carry out the live trails on the 3 case studies because of availability. However, we are also investigating whether grid forming convertor technologies can also perform this function. The initial findings will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the webste at the end of July.
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Have this project crossed the discussion of critical load restoration (example: nuclear off-site power) and any other traditional priority loads?

This is outside of project scope.

In terms of the stability analysis problem using DER for BlackStrart is the current formalism enough to analyse stability?

We have carried out steady-state, dynamic & transient study analysis on 3 case studies. The results of these will be published in the "Assessment of Power Engineering Aspects of Black Start from DER" report on the webste at the end of July.
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The case studies include analysis on Block Load Pickup stability, DER reactive power stability, transformer energisation, circuit energisation, wider network energisation, protection stability, grid following & grid forming convertor connected DER stability.

Is coordinated/parallel DRZ-traditional restoration approach a consideration within the scope of this project?

This is outside of project scope. However, the project insights & outputs will feed in to a larger piece of work investigating compliance with the new GB Black Start Standard (x% demand to be restored within y timescales). Once UK Government has approved this, National Grid ESO will be responsible for enforcing industry compliance. It is envisaged that both top-down & bottom-up approaches will be needed for an integrated Black Start restoration strategy in order to meet the Black Start Standard.

Also, what kind of Control System design are involved, Optimal Control, Artificial Intelligence?

The Distributed ReStart project has commissioned work (through market tender) to design an automated control system to despatch DER to stabilise & grow Distributed ReStart Zones (DRZs). We are currently working with 4 suppliers on this, each with a different technical approach. The outputs of the design stage will be published in a project report in December. A Stage 2 build stage tender has been initiated to deliver a working DRZ Controller by spring 2021. The intention is then to test it on a simulator & in the live environment.