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Black Start from Distributed Sources

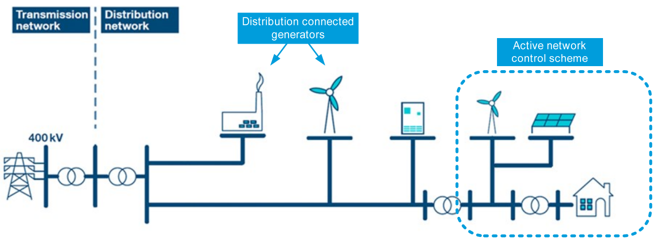
Traditionally Black Start has been provided from large power stations which are predicted to have a declining role in the Future Energy Scenarios. We have explored opportunities for providing Black Start from distribution connected; generators and Power Islands. To realise these benefits we also identify the need for additional investment, code changes and clearer definition of roles.

Executive Summary

Black Start is the ability of a power system to restart itself after a complete or partial system loss of electrical power. National Grid, as system operator (SO), is responsible for maintaining Black Start strategy and managing the process for the system. Traditionally we have achieved this by contracting predominantly with large generators connected to the high voltage transmission network. But trends in the energy market mean that the numbers of these large generators are reducing. In this report we explore alternative methods of Black Start from medium voltage distribution networks. We consider two examples of alternative methods of Black Start as shown in Figure 1:

- using smaller generators connected at distribution level
- establishing small, self-contained, Power Islands.

Figure 1: Distributed connected generation



We show in our analysis that one of the limitations of distribution connected generators, to provide Black Start, is the size of blocks of demand that are added to the system during restoration. By having smaller blocks of demand the pool of potential Black Start providers may increase, however the overall restoration time may also increase as a consequence. Achieving this block load change will require changes to the Distribution Network.

Smaller Black Start generators will need sufficient ability to control voltage as the system is energised. The extent of these challenges is dependent upon the local network setup and may require investment in additional reactive equipment to solve.

Establishing Power Islands will be dependent upon having suitable infrastructure and means of control. However, they are ultimately limited by the energy and power resources available, although this may be helped by connecting storage. We recognise that the increasing uncertainty around generation and demand makes their operation more complex.

In both of the methods described there are additional roles and responsibilities that need to be undertaken compared to the current Black Start process. There will be a role to ensure the Black Start response is coordinated across all of GB. This will enable normal market operations and full customer demand to be resumed as quickly as possible.

We conclude in the report that there are potential benefits to both alternative methods of Black Start in terms of availability, resilience, restoration time and broadening market access. We expect that Black Start from distribution networks would complement rather than fully replace transmission connected providers. To achieve the potential benefits, investment in smart infrastructure would be required. Roles and responsibilities will also need to be clarified as new methods of Black Start are developed to ensure a safe and reliable system restoration capability can be maintained.

This report has been delivered by National Grid, Northern Powergrid and SP Energy Networks in collaboration

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Background

Black Start is the ability of the power system to restart itself after a full or partial system black out. National Grid as the system operator has a duty under the Grid Code to maintain a plan to re-energise the system in the highly unlikely event of a system shut down.

Most power stations are designed to require an electrical supply from the power system to start up. Normally this is provided from the transmission or distribution system however under a Black Start this supply is not available. Therefore to restart the system we require some power stations to have their own auxiliary supplies so they can restart themselves. These power stations can then be used to restart other power stations and then others and thus the whole system can be restarted. The power stations that restart on their own to get the process started are called Black Start Stations.

Traditionally Black Start Stations have been large transmission-connected synchronous generators. Over the coming years the trend of reduction in the number of these plants is expected to continue leading to fewer traditional Black Start providers being available.

As the time that these generators may be running in the energy market reduces there will be periods where black start may be needed and the generators will be starting from cold, leading to less reliability and increased restoration times. As well as the technical aspects to Black Start there is a clear social requirement to provide prompt system restoration in the case of a black out.

At the same time as there is a decrease in transmission-level generation, there is a trend for an increase in distributed generation, and in some locations the introduction of active network control schemes, as illustrated in Figure 1. These changes offer a new potential pool of generation services that are not currently used for Black Start, due to technical, regulatory or commercial reasons. Within the context of the transition to a Distribution System Operator (DSO) model, there is increasing scope and desire to utilise distributed energy resources (DER) for a wide range of services, including Black Start.

Further information on Black Start and how the SO procures services is available on the National Grid website. The Black Start strategy[1] was recently revised and highlights the need for more flexibility and a wider range of options, recognising that restoration services could be provided by a combination of resources of different types. National Grid commissioned a review of alternative options in an NIA-funded project in 2015 – the reports are available on the ENA Smarter Networks Portal[2]. The preparation of this System Operability Framework report has been supported by the ENA Open Networks initiative and Black Start is regularly discussed in a number of industry and resilience forums.

Method

This report is concerned with the medium to long term development of Black Start services, going beyond the existing strategy and considering the greater use of DER in a system where new DSO capabilities and operating models are emerging. Expanding the number and diversity of options for Black Start should provide quicker and more reliable system restoration at a lower overall cost to customers.

We explore different methods of providing Black Start to the system through a mixture of quantitative analysis and qualitative discussion covering the following:

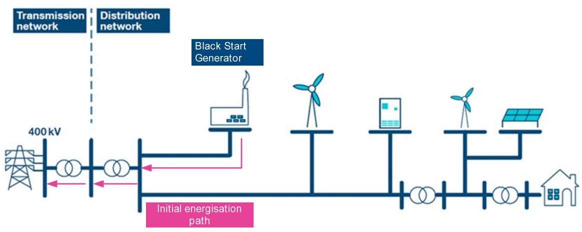
- technical feasibility
- availability of resources in GB
- implications for the roles in the Black Start process
- benefits to customers.

For each of these we aim to highlight the benefits to using these new approaches and the barriers limiting their implementation.

Analysis

We explore two main methods for providing Black Start:

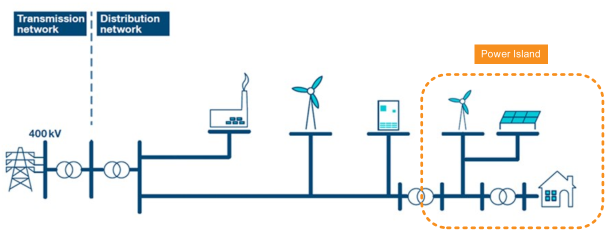
Figure 2: Restoration from large embedded generator



- using large embedded generation, as illustrated in Figure 2. This differs from the current approach by using distribution-connected generators that are smaller than those previously expected to be used for Black Start but still able to self-start and large enough to re-energise parts of the transmission network

- establishing distribution-level Power Islands, as illustrated in Figure 3. This “bottom up” approach using DER is radically different from the conventional “top down” strategy. It requires an area of distribution network to have sufficient energy resources and control to self-start and maintain a Power Island to supply customers until the transmission system is restored. If conditions permit then there may be potential to join small Power Islands together and eventually provide restoration services to the wider system.

Figure 3: Restoration from Power Island



Black Start from Large Embedded Generation

Once a Black Start provider is energised one of its primary aims is to energise the parts of the network necessary to support the start-up of other generation. In this case, embedded generation would be expected to energise from the distribution network to the transmission system and support the restoration of some demand and the start-up of larger transmission connected generation.

Inertia/frequency

In normal system operation frequency is kept within a narrow range of 49.5 to 50.5 Hz. In Black Start it is recognised that frequency will deviate more widely but the objective is to keep within a range of 47.5 to 52 Hz while accepting the addition of blocks of demand in the range 35 to 50 MW.

This block size corresponds to the amount of demand pickup expected when a typical 33 kV grid supply point (GSP) is re-energised. In future, it may be possible to achieve smaller block sizes with the appropriate investment in distribution networks and revision of restoration plans; this is discussed further below.

Assuming that the large embedded generator is a conventional synchronous machine, to maintain frequency within this range a minimum amount of inertia is required. During this stage of restoration the only source of inertia will be the Black Start provider itself and whatever small amounts of load inertia have been added, although this will not be visible to the system operator.

In Figure 4 we show the frequency change expected as block loads (with zero inertia) are connected to machines of different inertia, and from that we can infer the minimum required inertia for each demand block size. Based on the minimum required inertia, and assuming typical generator inertia of 5 per unit, the number of large generators (across all of transmission and distribution in GB) that meet this requirement is as shown in Table 1.

Figure 4: Frequency change caused by different block loads

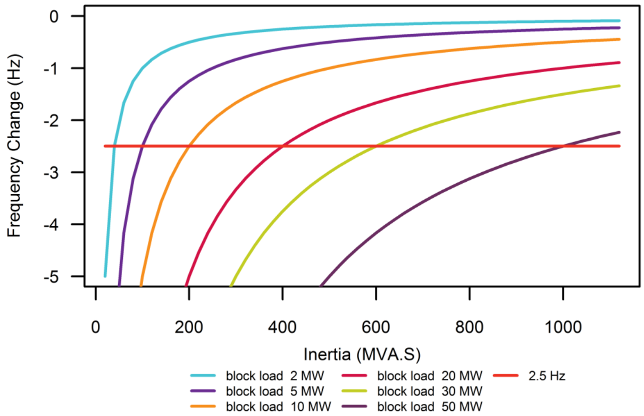


Table 1: No. of generators with inertia to accommodate block loads

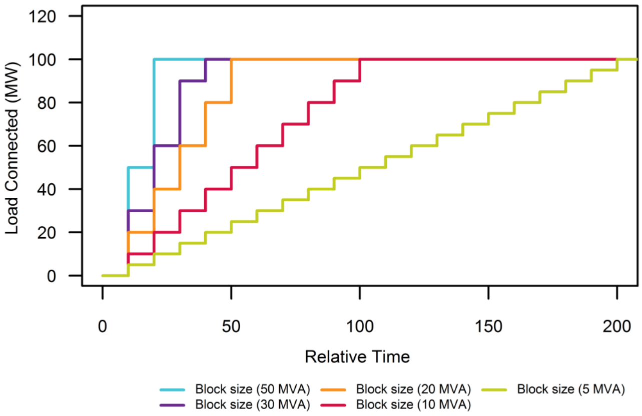
Block load size (MVA)	Minimum inertia to keep frequency within limits (MVA.s)	Required Generator size; assuming unit inertia of 5pu (MVA)	No. of plant on whole GB system; meeting required generation size[3]
5	100	20	294
10	200	40	124
20	400	80	75
30	600	120	63
50	1000	200	53

In order to provide smaller block sizes several factors need to be considered. Firstly the impact on restoration times may be affected. If smaller blocks are used there need to be more of them switched to achieve the same amount of demand re-connected. This is illustrated in Figure 5.

It can be seen how, assuming a constant switching time, the total amount of time to switch 100 MW of load varies depending on the block load size. It should therefore be noted that smaller block sizes allow for more generators to provide Black Start. However, assuming the same resources and methods as currently used, the time to restore demand from these smaller generators will be longer.

More flexible switching on the network requires circuit breakers at lower voltages designed for this function, including the necessary communication channels to be

Figure 5: Time to connect demand for different block load



in place for them to be controlled remotely. This entire infrastructure is required to have resilience such that it can operate in a Black Start scenario. The increase in usage of Active Network Management (ANM) schemes within distribution networks is one example of the greater use of automation and remote control. Similar methods might be used to help reduce the times for load switching and increase controllability of demand.

When switching load blocks, it is important to consider any embedded generation that may also be energised in the same process. This generation may be behind ANM schemes or G59/Loss of Mains protection. As they are re-energised the setting in the above may cause the generation to start, drop off or be constrained. This will have the effect of the total demand seen by the Black Start provider to differ from the expected value. This was assessed in previous SOF reports[4].

As well as infrastructure there is an increase in operational roles in Black Start. Having smaller generators that take up smaller block loads requires more communication and planning between the Black Start parties. This will require additional work to manage.

Voltage control and circuit re-energisation

When re-energising the electricity network from a Black Start there are a wide range of factors to consider and problems that may arise. This includes fast transients that occur during and after switching and the risk of energising on to unidentified short circuit faults. Another important aspect is the charging current from the circuits, also known as reactive power gain.

This gain is normally offset by Mvar losses due to power flow but if a circuit is merely energised without actually carrying any significant power, as in Black Start conditions, then there will be a net Mvar gain. This effect is much more pronounced for underground cables than for overhead lines (OHL) so energising long cables poses particular challenges. Notably, many new generators connect via long underground cables, particularly wind farms. This makes them harder to energise during Black Start.

The changes in reactive power result in changes to the network voltage, which must be kept within limits. Broadly speaking, all the reactive power produced by the energised circuits must be absorbed by the Black Start generators, at least until it is possible to switch on some demand, shunt reactors or other forms of reactive compensation. Thus, it is necessary that Black Start generators have a reasonable reactive power range and can respond quickly in a stable manner to provide more or less reactive power and control voltage. Alternatively the network needs to be designed to be easier to operate within a restoration and adaptations made to have less gain, however there is a cost associated with this.

This requirement applies in distribution networks in the same way it does in the transmission network. However, the Mvar gain of circuits is a function of the

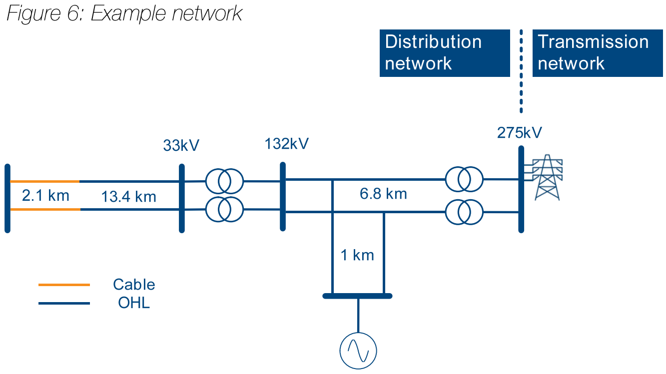
Table 2: Typical gains of conductors

Voltage and Type	Range of Typical Gains (MVAr/km)		Range of Typical Lengths (km)		Range of Typical Gains (MVAr)	
	Low	High	Low	High	Low	High
400 kV Cable	8	24	1	5	8	120
400 kV OHL	0.48	0.8	20	100	9.6	80
275 kV Cable	3.7813	11.3438	1	10	3.7813	113.438
275 kV OHL	0.2269	0.3781	20	100	4.5375	37.8125
132 kV Cable	0.8712	2.6136	1	20	0.8712	52.272
132 kV OHL	0.0523	0.0871	10	50	0.5227	4.356
33 kV Cable	0.0545	0.1634	1	20	0.0545	3.267
33 kV OHL	0.0033	0.0054	2	40	0.0065	0.2178
11 kV Cable	0.0061	0.0182	1	10	0.0061	0.1815
11 kV OHL	0.0004	0.0006	2	20	0.0007	0.0121

voltage level squared.

Thus, the problem is more acute on the 275 and 400 kV circuits of the transmission network, especially if it is necessary to energise underground cables. Table 2 illustrates this with some typical values; these are based on typical values of susceptance between 50 and 150 µS/km (micro-Siemens per km) for cables and between 3 and 5 µS/km for OHL.

Figure 6: Example network



Using the values in Table 2 we can calculate that the reactive ranges needed to Black Start the whole of the network, as shown in Figure 6, would be 1.1-2.2 Mvar.

For a number of reasons, including the Mvar gain, re-energising the high voltage transmission network is more challenging than re-energising lower voltage circuits. Many embedded generators may have sufficient reactive power range to supply charging currents to circuits in their vicinity. Therefore this is one aspect of black start where a "distribution first" strategy has an advantage over the conventional "transmission first" approach. However, if a distribution-connected generator (or combination of generators) is to be used to energise circuits on the 275 and 400 kV transmission network then its reactive range will have to be enough to handle the large gains. Similarly as the size of the energised network grow it becomes increasingly harder to find the capacity to energise the next circuit unless additional generation (or reactive equipment) is energised. This should be considered in the restoration plan.

Using non-synchronous generators

The above analysis is based on synchronous generation. For a non-synchronous machine, such as a wind turbine or Solar PV, the requirement would be the same but the ability of the technology to achieve them is more limited. This is due to factors such as less inertia, less overload capacity to provide inrush current for energisation and the use of phase locked loop (PLL) technology. These technologies work well during normal network operation but during a Black Start would find it more difficult to deal with the extreme network conditions. National Grid is working with industry to explore using non-synchronous generation for Black Start.

Black Start requirements for smaller generators

The existing technical requirements for Black Start generators, as stated in the Black Start strategy, are focused on large generators connected to the 400/275 kV transmission network.

Table 3 presents a summary of the existing requirements and also proposes some indicative values for the requirements that might apply to smaller generators connecting at lower voltage levels. The precise requirements will always depend on the specific circumstances.

Restoration of the system relies not only on the Black Start providers that can restart themselves but also has a critical reliance on the generators that then reconnect to the partially energised system. These "secondary restoration providers" must be able to get started and maintain stable operation on a very weak power system where operating parameters are likely to vary more widely than in normal conditions.

These proposed requirements highlight how smaller generators at lower voltage levels can be expected to have smaller, or more limited, capabilities in some areas, like reactive range and block loading capability, but also that they must be able deliver services to a high quality and with high resilience similar to the large generators conventionally contracted to provide Black Start services.

Distribution-Level Power Islands

Traditional approaches to Black Start focus on large generators starting up and energising the transmission system, what is sometimes called a "top-down" process. Loads are connected to help stabilise the generators and let more generation connect until the full system can be restored. In this section we explore how distributed energy resources (DER) might be used to start up and maintain distribution-level Power Islands, as illustrated in Figure 3, what might be called a "bottom-up" process. This could be done in parallel with the transmission-level Black Start process, potentially meaning supplies could be restored to more customers more quickly, subject to the DER available in each area.

This approach recognises the development in recent years in the "microgrid" concept. It seeks to harness the increasing volume and range of DER, including equipment like standby diesel generators. Rather than have individual customers operate "off-grid" during an extended black out, a Power Island operating across

Table 3: Proposed technical requirements for Black Start providers

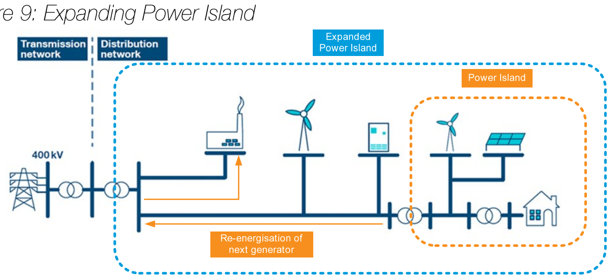
Technical Capability for Black Start Providers	Requirement at 400/275 kV	Suggested requirement at 132 kV	Suggested requirement at 33 kV	Suggested requirement at 11 kV
Availability of BS capability on main and auxiliary plant	>90%	>90%	>90%	>90%
Number of times able to start (at least one unit/module) without external power supplies	Three	Three	Three	Three
Facilities to ensure all plant can be shut-down safely without external supplies	Yes	Yes	Yes	Yes
Time to be ready for network energisation following instruction (from the SO or the party delegated authority by the relevant LJRP)	2 hours	2 hours	2 hours	2 hours
Reactive range to energise the immediate network	Typically 100 Mvar absorbing	Approx. 50 Mvar absorbing*	Approx. 5 Mvar absorbing	Approx. 0.5 Mvar absorbing
Ability to withstand inrush currents and transient voltages associated with network energisation	Yes	Yes	Yes	Yes
Demand block loading capability while controlling frequency and voltage within limits (47.5 – 52 Hz for frequency and 0.95 to 1.05 pu for voltage)	35—50 MW	35—50 MW (Energise 132/33 kV GSP)	10—20 MW (Energise 33/11 kV Primary)	0.5—1 MW (Energise 11/0.4 kV Secondary)
Time expect to run off auxiliaries following a BS instruction, and therefore back-up fuel supplies to be available	Ideally 3—7 days	Ideally 3—7 days	Ideally 3—7 days	Ideally 3—7 days

part of a distribution network could potentially provide greater security and resilience to a larger number of customers, including those who are vulnerable and do not have access to a backup supply. This type of approach would require DNOs to expand on their existing capabilities and experience in operating temporary Power Islands, beyond that which is sometimes currently done in emergency conditions. Some of the technology, tools and skills needed to operate in this way will require similar investment and development as for other aspects of the transition to DSO; this approach is consistent with these wider changes in the industry.

Once the Power Island has been established there are three possible next steps. Firstly, it could remain as a self-contained system as in Figure 3 and wait until the top-down restoration reaches the area. If suitable infrastructure is available, such as power system synchronising circuit breakers, then it may be possible to reconnect the island to the main system without interrupting supplies. Otherwise, the island could be de-energised before reconnecting to the main system.

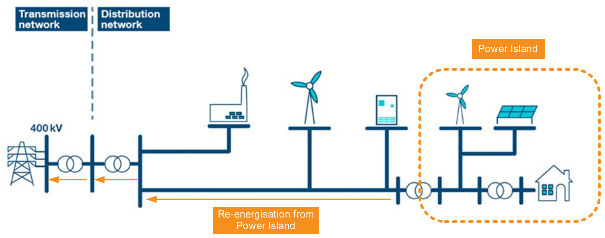
Secondly, if the local network and DER allow it, the island could be expanded to energise a greater area of network, support the restart of non-Black Start generators and the restoration of more load, as illustrated in Figure 9. However, as a Power Island grows the uncertainty in demand variations and generation output becomes more onerous and requires more sophisticated control.

Figure 9: Expanding Power Island



Finally, once the Power Island is established, in some instances it may have additional power available that is not being utilised within the local load group. If this is the case and it is technically possible, this Power Island might be used to act as a “virtual power plant” (VPP) to provide Black Start services to energise the transmission system, as illustrated in Figure 10. To achieve this, the VPP must be able to achieve capabilities and performance levels equivalent to a conventional Black Start provider with a control system and aggregated resources flexible enough to deliver all required services.

Figure 10: reenergising the network from a Power Island



As the amount of distributed generation has increased in recent years, new forms of control have been introduced – often described as active network management (ANM) – giving DNOs more scope to control the impact generators and demand have on power flows and voltages on the network. The transition to fully-fledged DSOs may see more advanced and more extensive forms of communication and control added. A number of manufacturers already offer microgrid controller products, typically aimed at industrial or campus-style locations that want to optimise a range of energy resources and improve resilience in case of grid outages.

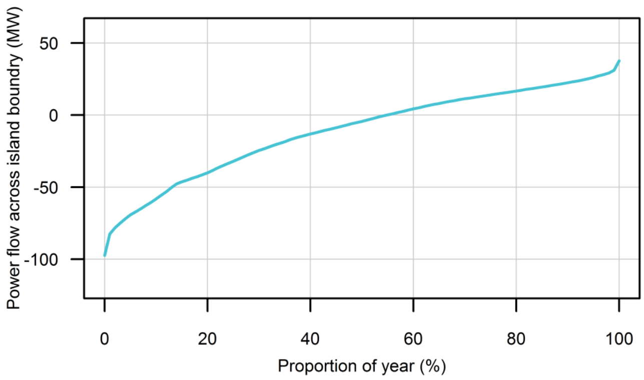
Establishing small Power Islands and sustaining operation within acceptable limits is known to be technically possible within small specifically designed networks if the required resources and infrastructure are available. This is often seen in small island systems around the world or in emergency situations. Commercially available microgrid controllers rely upon having a pre-defined network with known generation and demand. Operating the island relies on having sufficient visibility to monitor the state of the system, flexible resources that can adapt to the conditions, and control systems and infrastructure to implement all necessary actions. The challenge lies in making Power Islands larger and incorporating more diverse resources involving multiple different parties, including distribution network infrastructure that are outside the direct control of the Power Island.

Availability of power

In order for an area of the network to become a Power Island the minimum requirement is for it to have sufficient resources to energise the network and supply power to at least some of the demand. If there is sufficient power available from generation and energy storage to meet all demand the group might operate as an island without having to ration or control demand. However, it is more likely that some form of demand control would be required, to increase or decrease demand as necessary, to operate the island within limits. This is particularly required if the generation resources are intermittent in nature.

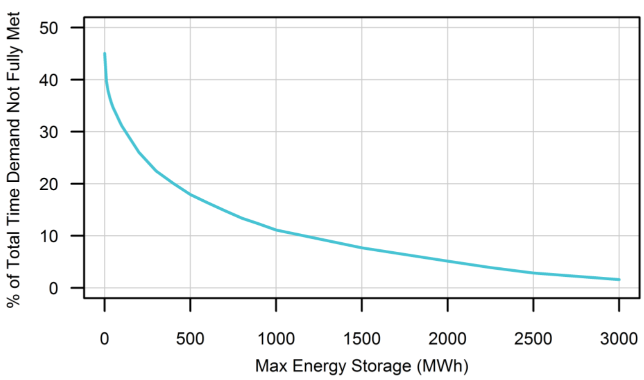
In order to illustrate this we have considered historic data from an example network in an area with a high concentration of embedded generation, primarily wind. For this network the power flows at the boundary were measured over the course of a year. Figure 11 shows the duration curve for power flow across the GSP transformers. This type of profile, where the GSP actually exports more energy than it imports, is becoming more common as more embedded generation is connected. In this example the areas was exporting for 54% of the time and had net energy export from the area over the year of 95.7 GWh.

Figure 11: Power flow into areas of the network for different proportions of the year.



If energy storage was introduced to this area then it would be possible to capture some of the excess energy and use it to supply demand when generation is insufficient. Figure 12 shows how the amount of storage affects the amount of time that demand can be supplied based on analysing one year of data. We can see that having a small amount of storage has a large impact on the ability to run as a Power Island however there are diminishing returns. This means that using storage to get to 0% unmet demand would be unlikely to be economic. If there is a temporary shortfall it is possible to meet this by reducing demand if there is enough controllability within the island.

Figure 12: Storage required to meet demand during Black Start



Inertia/frequency

The Power Island would be required to maintain frequency and voltage within reasonable bounds so as to not damage equipment within it. It is reasonable to assume that the limits applicable to the transmission system in Black Start should also be used in any distribution-level Power Islands. As shown in the previous section, the ability of the Power Island to maintain frequency and voltage within these ranges is dependent upon the inertia of the island, the block load sizes, and the reactive power range available.

Control

In order to control the network within limits there are three requirements. Firstly there is a requirement for monitoring such that the state of the network can be seen. This means measurement of frequency, power flows and voltages. Secondly the Power Island needs to be able to control the generation and demand such that based on the measurement of the network they can be varied and controlled to maintain a stable network. The final thing is a controller that can respond fast enough to process the input signals and control the outputs to the generation and demand.

The largest challenge for the control of the Power Islands come when they are expanded from a small, specifically designed network to a larger island. At this point, along with more generation and demand to control, there is increased uncertainty as to their outputs.

Communications

Establishing a Power Island will require communications between the resource being controlled and the DSO or TSO. This will allow for coordination such that the island and the wider network can be operated safely and efficiently. If the Power Island is to act as a virtual power plant there must communication channels with the TSO to enact its energisation plan.

During a Black Start communication channels may be affected by the lack of power. Therefore any channels that are required for Black Start must be able to operate even under a whole system black out.

Ownership

Setting up a Power Island of this type would require co-ordination between multiple different controllers and communication channels that are likely to be owned by several parties. This could be the network owner who is likely to have installed the assets for network management but can use them for setting up a Power Island during a Black Start. They could also be owned by a network user who has installed the controller for additional security such that they can run “off grid” during a system fault.

Networks owned by the DNO would have a requirement under Black Start to be run in such a way as to set up and expand their Power Island to provide power to as many customers as possible. However if the controller and network was owned by a network user there is currently no mechanism for requiring them to use their assets to expand their Power Island to other users.

Regulation

In a Power Island situation the network will be controlled in a local area and there must be some requirement to act to ensure safety for the system, the assets connected and the people using them. It is unclear who this party will be and may depend upon the owner of the network.

When the island is seeking to expand there will come a point where control of the island switches from the owner to the DSO or TSO. When this change happens there will need to be a clear definition of hand over of responsibilities to ensure safety is maintained. There also needs to be clear responsibilities placed on all parties to ensure the high level requirement to participate in the restoration process.

Protection and earthing

Two potential technical constraints when considering back energising distribution networks are, earthing and protection schemes. Most DNO networks were built assuming downstream power flow at the lower voltage levels with delta secondary windings and protection schemes designed to activate for downstream faults. Back energising is usually only undertaken at specific points on the distribution network where the equipment has been chosen to permit power flow in both directions. Whilst this is less likely to be a problem at 132 kV, legacy voltages and equipment may mean that certain areas of a distribution network restrict the extent of a localised Power Island or require additional investment to achieve a wider restoration. However, a sufficient size of embedded generation will normally have been connected with these constraints considered or overcome such that it is worth a more detailed investigation to determine whether these issues are substantive.

The protection arrangements need to ensure that they align with existing standards and requirements such as G59. G59 defines the operation of protection of generators on the distribution system; however the requirements during Black Start will be different than during normal operation. During the Black Start process there is expected to be greater than normal movement in frequency, however G59's requirements to operate based on frequency do not align with the Grid Code requirement for Black Start. This needs to be taken into account when considering new Black Start approaches and changes to standards may be required.

Additional Roles and Responsibilities

Under both Black Start methods discussed above there will be additional roles and responsibilities beyond those that are currently defined for Black Start. The industry is transitioning into a TSO and DSO model[5]. There are many options to align with this transition and thought should be given into where each of the roles identified best sits. Some roles may require coordination nationally and some may require more knowledge of local networks. Below we consider possible roles for the considered methods however an industry agreed approach is needed.

Large embedded generation

For a Black Start using large embedded generators the enhanced requirements of roles may be:

- embedded Black Start provider has a contract and is part of the Black Start restoration plan. It is responsible for maintaining its availability for Black Start and running its equipment to enact its local restoration plan during a Black Start
- for the network owners and operators:
  - there is a requirement to instruct generators to start, take load and energise as per their local plan
  - there is a requirement to maintain responsibility for the process and coordination between all parties.
- there is a requirement to co-ordinate load blocks and switching of the distribution network to facilitate Black Start. If smaller block loads are required this may be an increase in volume of work when compared to current Black Start processes.

If lots of distributed generators provide Black Start there may be more generators to coordinate than under current Black Start plans. This will have an increase in the amount of resource required to manage the process.

Power Islands

For a black start using Power Islands the enhanced roles of the parties may be:

- there is a requirement to be responsible for establishing the Power Island and controlling generation and demand within it to maintain a stable and safe system
- if the island is to expand or operate as a VPP then there is a requirement to be responsible for controlling the island as instructed, or to hand over control of their island to another party
- there is a requirement to co-ordinate and manage all Power Islands within an area and be responsible for network switching to facilitate their operation
- if a island is to expand or operate as a VPP then there is a requirement to switch the network to enable this
- there is a requirement for a role to be responsible for the Power Island expansions and balancing
- there is a requirement to work to re-energise the system down to the Power Island such that they can be re-synchronised with the system. This need to be done in coordination with the parties responsible for the operation of the Power Island
- if the Power Island is to operate as a VPP they will be instruct to provide Black Start services as would any other Black Start provider.

Engineering resource

The traditional, centralised approach to Black Start recovery recognises the real time complexity of balancing load to generator capacity by assuming that each Black Start Local Joint Restoration Plan requires a dedicated power station, transmission and distribution control engineer in constant communication. This therefore presents a constraint on the number of Power Islands that can be activated based on the available number of control engineers. Therefore Power Islands requiring central coordination to back energise the transmission network will most likely need to be considered as an additional transmission Black Start service provision rather than a stand-alone facility.

DNOs currently prioritise the available number of control engineers to match the workload on the network such that there will be periods when more distribution control engineers will be available than transmission and power station control engineers. It should be noted that at this stage the future requirement for numbers and skill sets of distribution control engineers under a DSO model is unclear but may well increase.

When deciding on new roles for parties in Black Start from distributed generation this constrain on engineering resource need to be consider and addressed in terms of number and skill requirement.

Conclusions

From the above analysis we can conclude that with the decline in number of providers of traditional transmission connected Black Start there are opportunities for an increasing role of distribution connected Black Start providers.

For large embedded generators there is potential to provide Black Start services to the transmission system operator. For smaller generators they may be limited by the size of the block loads and the reactive range required to energise the network.

To help overcome these limitations the DNO could look at offering smaller block loads. This will allow smaller generators to potentially provide Black Start but may require an increase in infrastructure to do so and may result in longer restoration times.

As a new approach to Black Start we explored the concept of self-starting Power Islands. The ability for a part of the network to establish as a Power Island is limited by both the energy and power resource within it. This can be helped but not fully solved by connecting storage within the group or by rationing demand. With the correct infrastructure and control, Power Islands could be established and maintained. When these islands are expanded, the uncertainty around generation and demand grows making their operation more difficult.

Both of the studied approaches may help in providing Black Start. To fully develop these approaches more specific design and research is required. This is recommended to focus on solutions to some of the challenges identified in this report around roles and responsibilities and the need for additional infrastructure. It is also important to note that both approaches rely on the traditional Black Start being available so would not fully replace this but instead support it.

With the transition to a DSO model there needs to be consideration as to where the new roles best fit and the amount of resources required. They should be chosen to allow the safest and most efficient Black Start. We therefore recommend that National Grid, DSOs and other industry stake holders collectively consider the best whole-system approach.

References

1. Black Start Strategy - http://www2.nationalgrid.com/uk/services/balancing-services/system-security/black-start/
2. Black Start report - http://www.smarternetworks.org/Project.aspx?ProjectID=1653#downloads
3. Data taken from National Grids TEC register and the long term development statements for each of the DNOs:
   TEC : http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589943020
   LTDS: (available from DNO's website)
4. System Operability Framework 2015 - https://www.nationalgrid.com/sites/default/files/documents/44046-SOF%202015%20Full%20Document.pdf
5. ENA report: "Open Networks Project, Commercial Principles for Contracted Flexibility: Promoting Access to Markets for Distributed Energy Resources" - http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/ON-WS1-P4%20Commercial%20Paper%20(Final%20Draft)-170816-final.pdf

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