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# Black Start Strategy

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1<sup>st</sup> April 2018 to 31<sup>st</sup> March 2019**

## DOCUMENT HISTORY

Version 1.0	Aug 3rd 2017	Ofgem approved version
Version 2.0	April 2018	Ofgem approved version

## BACKGROUND

In accordance with National Grid Electricity Transmission plc's (National Grid) Special Condition 4G, this Black Start Strategy sets out the strategy National Grid will use to determine and procure Black Start Capability onto the National Electricity Transmission System (NETS) on an ongoing basis in an economic and efficient manner, ensuring system security.

This document does not provide detail of the current opportunities for Black Start Capability provision nor information regarding the structure and content of Black Start contracts. More information on these areas can be found in the System Needs & Product Strategy (SN&PS) published in June 2017 and the Restoration Product Roadmap shortly to be published on the Balancing Services area of the National Grid external website<sup>1</sup>.

There may be a requirement for this document to be resubmitted following any significant legal or regulatory changes which impact on the procurement of Black Start Capability, the Restoration Approach or provider technologies available.

Unless the context otherwise requires, the words and expressions used in this Black Start Strategy shall have the meanings ascribed to them under the licence condition 4G or the Grid Code.

## INTRODUCTION

National Grid has an obligation under the Grid Code (CC6.3.5) to ensure that the NETS can be re-energised in the event of a Total or Partial Shutdown. Black Start is the procedure to recover from a Total Shutdown or Partial Shutdown of the NETS which has caused an extensive loss of supplies.

This strategy identifies how a Restoration Time expectation is used to derive an appropriate level of Black Start Capability to progress system restoration. A requirement for service provision at this level is identified and then procured, using details laid out in the associated Black Start Procurement Methodology.

A Black Start service is defined as a provider, or combination of providers who can meet the three basic requirements for Black Start; to start up (following a Total Shutdown or Partial Shutdown) independently from external supplies, to be able to energise the transmission network and to be able to provide block loading of local demand. Specific details of these and other requirements for service provision can be found in the technical requirement section of this strategy.

This strategy document will be effective from 1st April 2018. All decisions taken prior to the acceptance of this strategy by Ofgem have been made in line with this strategy document for the year in question.

Implementation of this strategy is intended to increase the transparency for the requirement of Black Start services, both in terms of technical requirements and in terms of the market opportunities for new services.

Historically the Black Start Capability requirement has been met by procuring Black Start services through bilaterally negotiated contracts with a number of strategically located power stations across Great Britain.

In order to continually achieve restoration in an economic and efficient manner the Black Start Restoration Approach, as outlined in this strategy, will be developed, taking into account Black Start providers' capabilities and new technologies and ways of working. Confidence and competition are required in the Black Start market to make this vital service an attractive prospect for providers.

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<sup>1</sup> <http://www2.nationalgrid.com/uk/services/balancing-services/system-security/black-start/>

This strategy is made up of 5 parts which detail:

- Restoration Standard and Restoration Time
- Restoration Approach
- Assessment of capability
- Short term strategy
- Medium term strategy
- Long term strategy
- Summary

## **PART I: BLACK START STRATEGY**

A Total Shutdown leading to a Black Start is a High Impact, Low Probability (HILP) event. Whilst an unlikely event, the consequences will be a significant societal and economic impact. Therefore, it is prudent that the cost of maintaining Black Start Capability should demonstrate value to the end consumer whilst still providing an acceptable level of assurance of capability, and be in line with regulatory expectations of a proven economic and efficient cost.

With the changing generation profile there are an increased number, and type of providers who can assist with restoration during a Black Start event. This Black Start Strategy aims to identify new technologies that can contribute to restoration and potentially become new Black Start providers. However, not all providers will be capable of meeting the technical requirements for Black Start and therefore they may play a part in later stages of the Restoration Approach rather than delivering a Black Start service.

## **RESTORATION TIME**

Whilst the Grid Code states there is an essential requirement for the NETS to incorporate a Black Start Capability, there is currently no defined standard to prescribe what this capability should be. A restoration standard is currently being explored by the Black Start Task Group (lead by the Department for Business, Energy and Industrial Strategy (BEIS)) and the results of this may require an update to this strategy to ensure the standard is met. This Black Start Strategy identifies a planning assumption for restoration from a Total Shutdown or Partial Shutdown being achieved for the majority of the Great Britain (GB) network 4G.3a.

The Black Start restoration process is complex and therefore achieving a Restoration Time is reliant on a number of different factors including Transmission Operator (TO) and Distribution Network Operator (DNO) resource availability to physically manage power islands as well as technical and communication elements proceeding as planned.

In the absence of a legal or regulatory restoration standard, identifying an appropriate Restoration Time for GB, with consideration for regional differences and an associated commercial view is required to set a restoration expectation as a baseline against which Black Start Capability is sourced and procured.

National Grid has maintained the planning assumption for Restoration Time, in line with historic expectations; this means planning to achieving an average Restoration Time across the year of 24 hours to restore 60% of national demand, providing that this can be procured economically and efficiently. Determining the likely Restoration Time involves using a probabilistic model with a number of input variables. Restoration Time distributions are generated across a number of scenarios which try to reflect the range of severity of events that could occur.

Whilst there will inevitably be regional variations to this Restoration Time the aim is to create a broadly consistent rate of restoration, reflecting the regional nature of civil contingency planning. During restoration, demand would be gradually restored by establishing a skeleton transmission network and the Restoration Time strikes a balance between a realistically achievable level of network energisation whilst ensuring that an economic level of service provision can be maintained. This timescale currently aligns with industry expectation surrounding a system shutdown and enables further planning by the civil contingency community.

Whilst the planning assumption is set at 24 hours for 60% of the national demand this must be procured at a cost that is deemed both appropriate and practicable in real time operations as detailed in the Procurement Methodology. Therefore the concept of a Minimum Service Level has been established – providing a minimum Restoration Time that is deemed acceptable given potential costs against this strategy, at all times.

Once capability has been procured, it may be necessary for operational actions to be taken (e.g. the issuing of warning instructions to maintain Black Start Capability) due to provider outages or individual provider running patterns. These actions will ensure that the Minimum Service Level is maintained at all times.

The Minimum Service Level has been determined as a Restoration Time which will allow for variations of number of available providers across GB. Should there be a situation where the Minimum Service Level cannot be maintained, either through lack of Black Start Capability or a significant increase in costs to maintain the Minimum Service Level, National Grid will inform both BEIS and Ofgem of this and demonstrate the actions that have been taken to reduce the impact to system restoration and detail the changes being proposed to the level of provision. This situation may arise due to extreme unforeseen circumstances, for example a type fault on an asset class.

## CURRENT RESTORATION APPROACH

The changing nature of the generation mix within GB has led to rising operational costs for current conventional Black Start providers. Alternative approaches to restoration techniques, and Black Start provider technologies are being actively considered and developed, and this has led to an evolution in system restoration and technical requirements.

In order for restoration to be achieved; a number of self-starting generators use local demand to energise a pre-agreed Local Joint Restoration Plan (LJRP) and create a small power island.

Power Islands are developed in line with LJRPs which are agreed alongside a Black Start contract and set out the activities and steps that the Black Start provider, relevant DNO and National Grid will carry out during a Black Start event.

The number of LJRPs that each TO and DNO area can carry out at one time is continually reviewed for changes in Black Start providers and LJRPs. The duration of switching actions and available Control Room resources are likely to limit restoration progress far more than provider availability. During a Black Start event, not all contracted providers may be able to Black Start and a spread of LJRPs across TO and DNO areas is therefore a consideration for resource management during an event.

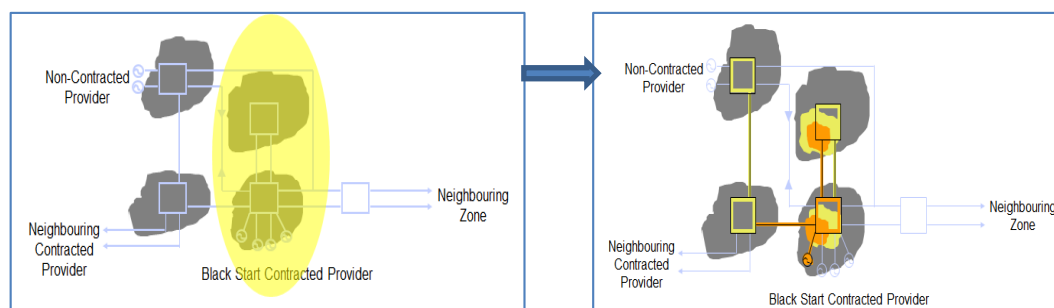


Figure 1: Initial Restoration

Previously the Restoration Approach focused around creating large zonal power islands before joining these together. The current approach means that power islands are extended but the aim is to create a skeletal version of the NETS – called the skeleton network. This has the benefit of extending auxiliary supplies to non Black Start providers sooner. This enhances the restoration as the sooner these providers can start up, the sooner they can contribute to restoring the national demand and the remaining Transmission network.

The skeleton network Restoration Approach adds flexibility to provider diversity and locational considerations. Here the focus shifts from the number of parties within a geographical zone, to the impact that a particular provider (or combination of providers) has on restoration within a region and on GB as a whole.

This Restoration Approach also identifies the importance of providing start up supplies to non Black Start providers in a timely fashion to reduce delay to the overall restoration. In some areas, the Black Start Capability is supplemented with additional restoration services to enable non Black Start providers with significant restoration capabilities to be contracted and committed to the system restoration under certain scenarios.

In 2017, as part of the Black Start Task Group (BSTG) the Restoration Approach was explored and it was concluded that the current skeleton network Restoration Approach is most suitable for the current number and placement of the providers as well as the current network infrastructure. The Restoration Approach will be continually reviewed to align with any significant network infrastructure change or significant change in providers' characteristics.

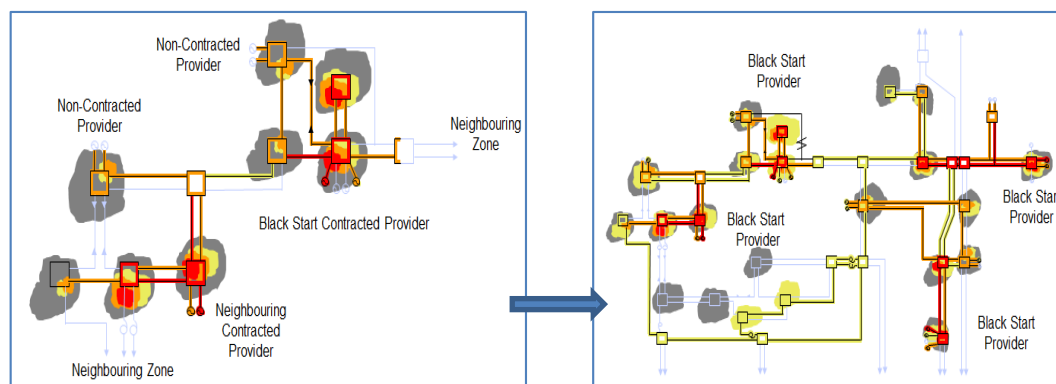


Figure 2: Skeleton Network

To deliver this Restoration Approach procurement of Black Start service provision is carried out across six zones within the GB network.

The use of GB zones for contracting:

- Ensures the split of Black Start providers is spread evenly over DNO licence areas to share the resourcing of enacting LJRP and demand loading
- Ensures that most non Black Start stations are all relatively close to a Black Start provider and therefore auxiliary supplies should be provided as the skeleton network is established
- Creates a relatively uniform restoration of the NETS along the skeleton network

Additional flexibility and resilience for providers is given by the nature of a skeleton network approach as there are no fixed boundaries for contracting zones. These can evolve and flex as the transmission system and Black Start provider locations change and develop over time. Multizone capability immediately promotes competition.

Although service availability is a requirement for a Black Start provider there may be instances when an operational decision is taken by National Grid to make a provider available, when it is not currently – i.e. to take actions to warm (if appropriate) and run a provider to put them into an Black Start available state in order to maintain the Minimum Service Level.

## PART II: ASSESSMENT OF CAPABILITY

A mathematical probabilistic model has been developed using @risk software. This model takes our jointly agreed and electrically validated LJRP restoration routes, with a number of input parameters to create a distribution of Restoration Times for the national and zonal picture. Network parameters (for example reactive power) are therefore not modelled, however the impact of Control Room resource, network failure and the time of day are considered.

The model outputs are therefore used as a baseline indicator of the impact of a combination of Black Start providers to deliver the Black Start Capability within the range of Restoration Time and Minimum Service Level. Input variables to the model have been validated within the Black Start Task Group.

It should be noted that the model may undergo further developments and therefore the results may change as the model is improved. Once this baseline and current Restoration Time has been established, decisions made on Black Start provision and procurement will refer back to this baseline, to demonstrate improvements and to show that value is being delivered.

In this probabilistic model, situations (cases) are developed based on a range of scenarios that may be in place during a Black Start.

The Central case is deemed as a credible balanced scenario, representing a more typical, and perhaps more likely, set of circumstances. It reflects a general belief that restoration is unlikely to go precisely to plan - as suggested by the various options and in-built flexibility within LJRP, as there will be mild difficulties and obstacles throughout the restoration process. This is the case which will be used for Restoration Time consideration against a statistical confidence level that 50% of events meet the Restoration Time expectation (a P50 expectation).

Input variables to the model include:

- Availability and characteristics of Black Start and non-Black Start providers.
- Basic network configurations
- Control room procedures
- Telecommunications resilience
- Staffing levels
- National demand characteristics
- Contract details
- Substation resilience
- Other major external influences such as weather and potential network damage.

The changing generation mix over the past year and in the future means that various scenarios (based on Future Energy Scenarios<sup>2</sup>) need to be assessed. National Grid already uses these scenarios to assess possible options for new Black Start providers and requirements and will continue to do so. Each provider assessed against the technical requirements detailed here, undergoes a strategic assessment. There is the opportunity for the model to include potential providers in order to further understand the resultant impact to potential system Restoration Time.

## PART III: BLACK START SERVICE TECHNICAL REQUIREMENTS

There are a number of areas for consideration when identifying the potential benefit that a provider can bring when developing a Black Start service. These include, but are not limited to:

- Location – proximity to other stations and Black Start providers
- Connectivity – location on the network and number of circuits
- High block loading and charging capabilities

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<sup>2</sup> <http://fes.nationalgrid.com/>

- Expected station reliability and availability
- Number and size of main units
- Provider longevity
- Start up time from cold
- Station configuration

The key technical capabilities required for current providers:

Technical Capability Required	Why is this required?
High availability of Black Start Capability on both the main and auxiliary generating plant (typically 90%);	Whilst a system shut down is low likelihood, it could happen at any time.
Ability to start up the main generating plant (at least one unit/module) of the station from shutdown without the use of external power supplies.	In the event of a Black Start the transmission system will not be energised so a provider will need to be able to start up independently and start to energise the system.
Ready to energise part of the NETS or, if appropriate, the Electricity Distribution System within two hours of instruction from National Grid.	The sooner stations can start energising the network the sooner total restoration can be achieved. Establishing the initial status, preparation and switching will need to also take place between the System Operator (SO), TO and DNO) so two hours is considered a realistic timescale for all parties to be coordinated.
The reactive capability to energise the immediate Transmission/Network Distribution System(s). This capability will depend on the local system configuration, but generating plant connected at 400kV or 275kV with a capability of at least 100MVA <sub>r</sub> leading (as measured at the commercial interface) should almost invariably meet this requirement. The generator must also be capable of withstanding the magnetic inrush and transient voltages associated with this energisation.	Energising the local system is one of the first steps in restoring the network. The reactive capability must be sufficient to energise a nearby substation.
The capability to accept instantaneous loading of demand blocks, preferably in the range 35 to 50 MW, and controlling frequency and voltage levels within acceptable limits during the block loading process (under these conditions, frequency can be within the range 47.5 to 52 Hz);	The MW size of demand blocks being restored will be determined by the ability to separate the DNO system into areas. The size of these demand blocks will have some uncertainty.
The ability to provide at least three sequential Black Starts, to allow for possible tripping of the Transmission/Network Distribution System(s) during the re-instatement period or trips during the station's starting sequence itself;	During system restoration the system will be less stable than under normal operation so the likelihood of faults/ trips is increased.
Facilities to ensure that all generating units can be safely shutdown without the need for external supplies, and can be maintained in a state of readiness for subsequent start ups;	It may be that multiple attempts are required to deliver restoration.
Back-up fuel supplies (e.g. distillate fuel), if appropriate, to enable the provider to run for a minimum duration, ideally in the range three to seven days, following a Black Start instruction;	Alternative fuel sources will provide increased resilience in the restoration.

The technical requirements are fundamentally describing three significant activities undertaken during restoration:

- the ability to start up independent of external supplies
- the ability to energise part of the transmission network
- the ability to block load local demand

Historically one large provider has delivered all aspects detailed above; however in certain situations these requirements can be met using a combination of providers to deliver the equivalent Black Start service, therefore opening up options to other provider types than have previously been compatible with technical requirements.

One example of this arrangement could be an interconnector which is able to provide active and reactive power and energise part of the transmission network. If it can then provide start up auxiliary supplies to a mainland provider, and if the mainland provider is proved capable to block load demand, then the requirements of a Black Start service would be met. Further examples are shown in Figure 3.

This arrangement must be considered on a case by case basis as not all provider combinations may be capable, or may not wish to enter into such an arrangement. The negotiated commercial terms for this agreement will be in line with the procurement approach detailed in the Procurement Methodology.

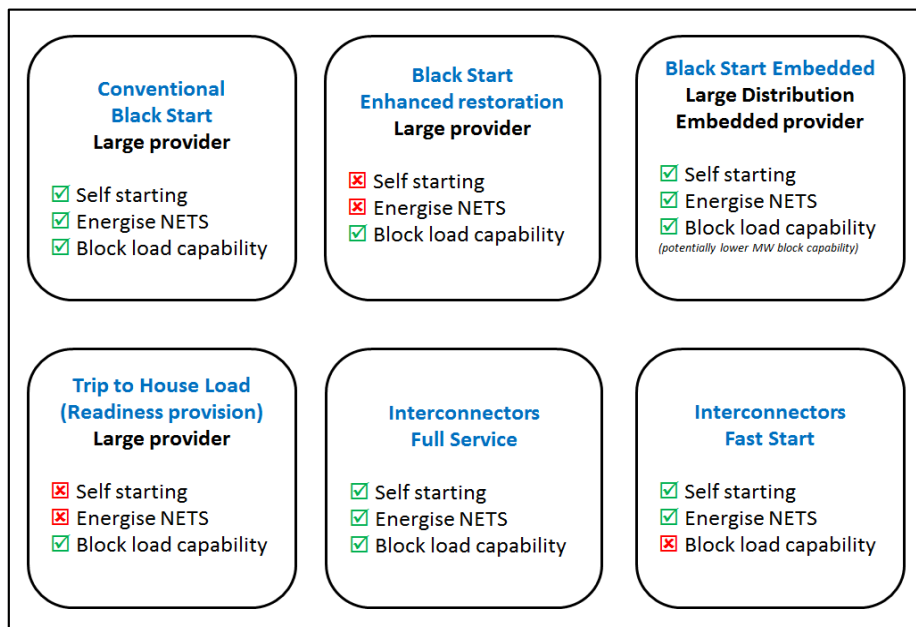


Figure 3: Examples of Black Start services

Whilst there is additional resilience in one provider delivering all activities; in that there is no reliance on specific transmission routes for all activities to be carried out (needing to energise part of the transmission network before block loading can commence), the benefits of diversification of provider type will bolster resilience against events which may render one type of technology unable to start up (e.g. a gas shortage for CCGT plant).

National Grid believes it is important to procure new Black Start providers that can fulfil these requirements and demonstrate a positive impact to the restoration process. Furthermore, providers that do not have Black Start Capability still have a critical role to play within restoration and National Grid will continue to engage with these non-Black Start providers to ensure that their requirements are understood for further modelling and that the providers are clear on their Black Start understanding and expected actions.



## **PART IV: SHORT, MEDIUM AND LONG TERM STRATEGIES**

The ability to maintain Black Start Capability is an ongoing requirement and as such the competition and transparency of Black Start provision needs to evolve. Below are the proposed activities over short (1 year), medium (1-3years) and long term (3-5years) timeframes to build confidence in the Black Start market and to evolve and develop Restoration Approaches and new provider technology options.

The evolution of the system restoration strategy and the development of new technology options to provide Black Start Capability are interlinked and a development in one may trigger both a need and an opportunity in the other.

### **Short Term Strategy**

The Restoration Approach as detailed in this document has been adopted to allow for flexibility of provider technologies to be further explored. This approach will enable the Restoration Time expectation of restoring 60% of GB demand within 24 hours to be met with wider types of providers and with more consideration for the entire network, rather than particular areas.

In the short term the aim is to develop the baseline for the restoration expectation and increase the transparency of a Black Start service. Developing a baseline will include the use of probabilistic modelling to determine current Black Start Capability opportunities. More specifically, this provides transparency around technical requirements and guidance for service opportunities for providers of all technology types in a clear and consistent manner. This will increase both the market awareness of the service and open the service to a wider range of providers, enabling competition.

Periodic reviews of Black Start requirements, that may arise due to contracts expiring or new requirements being established, will be carried out to ensure that actions within this strategy year are building market competition and enabling new technologies to participate within the Black Start market. This will be achieved through a robust forward procurement plan which will identify potential opportunities as they become available, and proactively procuring to meet this need.

To maintain a flexible, fit for purpose restoration plan National Grid has sought to enable varied technology restoration solutions. This will reduce the reliance on any individual solution for restoration and will increase competition in this area. Alternative solutions are detailed below and are at various stages of being integrated into restoration plans, which will include the procurement of Black Start services.

- **Service Splitting:** This approach delivers a full Black Start service from two separate providers, as illustrated in Figure 3 above. The concept of service splitting is to 'split' the full Black Start service into the "self-start" and "energise" elements being delivered by one provider and the "demand loading" element being delivered by another, dependent on the electrical proximity of both providers
- **Islanding or Trip to House Load as a restoration service:** This approach allows some providers to offer economical and faster restoration option, where the provider trips to its house load and then contribute to restoration.
- **Interconnectors:** Interconnectors with suitable technology are considered for Black Start, as a Black Start provider or integrated into restoration plans, which drives increased competition within each zone against other providers. Interconnection provides greater resilience to a restoration; however this service does rely on an agreement being in place with the remote System Operator around the energy provided.
- **Wind generation:** Significant levels of wind generation on the system are now able to integrate into restoration plans and NG is liaising with developers as to how restoration could be facilitated in this way

Over the Strategy duration, the Black Start service providers will undergo a programme of tests and exercises to assure their competence and provide assurance against their contracted position. New provider technologies identified to be Black Start capable will be progressed, as required.

### **Medium Term Strategy**

In the 1-3 year time frame, the focus for the Black Start strategy will turn to whether a tendered approach to procurement can be established. The increased market competition driven in year 1 should allow more parties to participate and drive down the overall cost of this service to the consumer.

National Grid will continue to explore new provider technologies and innovative Restoration Approaches to improve the efficiency of the service. National Grid will continue its active engagement with both the Black Start Task Group and wider industry.

This will include, but is not limited to:

- Continual development on Interconnectors with voltage source converter (VSC) technology as a Black Start service
- Continual development on Islanding or Trip to House Load as a restoration service
- Understanding how renewable generation can contribute to restoration: National Grid have an ongoing dialogue with the wind industry in terms of Black Start provision and the technical requirements.
- Distributed Energy Resources: Generation embedded within the DNO networks has the potential to provide a restoration service, depending on the level at which it is embedded into the network and the ability to control restoration at this point. National Grid SOF had undertaken a piece of work to explore alternative methods of “Black Start from distribution networks<sup>3</sup>”. This report also detailed the current challenges in place and National Grid is looking to further explore technical solutions to these and the commercial viability.
- Whole System Approach: Any future restoration approach needs to consider future trends in generation, and the ability to adapt to new technologies whilst maintaining reliance of restoration. In some areas further network investment may be required to enable alternative restoration methods
- Black Start service developed with more than one provider
- Spinal Restoration model – energising a single energy corridor during restoration, rather than creating power islands

If a Restoration Standard has been imposed then this will be implemented and a suitable Restoration Approach derived. If no Restoration Standard is in place during the medium term then the short term expectation will be reviewed and amended if required.

### **Long Term Strategy [4G3. b/c]**

The longer term strategy (3-5years) builds on the work of the previous years in building a Black Start market, and identifying which provider technologies can contribute to restoration. The Black Start requirement will continue to be procured to meet the strategic requirement.

If there is enough liquidity and it can be demonstrated that a tendered approach for Black Start provision provides value for the end consumer and encourages competition then a tender round will be carried out for identified areas.

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<sup>3</sup> <https://www.nationalgrid.com/sites/default/files/documents/SOF%20Report%20Black%20Start%202017.pdf>

There will be continued exploration into Restoration Approaches with the intention of moving towards a more suitable Restoration Approach for GB. . New emerging technology types, such as storage will also be continually explored to understand how these can contribute to restoration and whether a commercial service is appropriate.

The Restoration Approach will be reviewed at least once every two years, to ensure that Black Start Capability procured keeps pace with all relevant technologies. Any significant network infrastructure change or providers' geographical dispersion will also trigger review of Restoration Approach.

If a Restoration Standard has been imposed then this will be implemented and a suitable Restoration Approach derived. If no Restoration Standard is in place during the long term then the medium term expectation will be reviewed and amended if required.

## **PART V SUMMARY**

Whilst there is a low likelihood of a Total Shutdown leading to a Black Start event the major impact on society and the economy means National Grid are obligated to provide Black Start Capability for system restoration. This strategy document, along with Procurement Methodology, aims at standardising the process of procuring Black Start services and establishing a Restoration Time expectation. National Grid's planning assumption for Restoration Time for 60% of the national demand is 24 hours with a Minimum Service Level for the same level of demand restoration to provide flexibility on the availability of Black Start providers.

With the ongoing change in generation types and mix, it is even more prudent to consider opportunities from new Black Start providers to open the market to new providers and to increase competition. All potential providers are assessed against standard technical requirements and with the change in technology types, these requirements may evolve. New restoration approaches will be also explored when there is a significant change in network infrastructure and providers' geographical dispersion in order to improve Restoration Time. With the current skeletal approach for restoration, emphasis is already on improving Restoration Times.

Therefore, over the medium and longer term, the requirement will shift towards technology diversity, competitive procurement for consumer benefit and efficient restoration, in order to maintain economic Black Start Capability.

## **Disclaimer**

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