An Introduction to Black Start

FEBRUARY 2001

Market Development
National Grid Company plc

SUMMARY

All large power systems require some contingency arrangements to enable a restart in the unlikely event that all or part of the system shuts down. The process of restoring the power system is commonly referred to as ABlack Start@. This entails Aisolated@ power stations being started individually and gradually being reconnected to each other in order to form an interconnected system again.

Not all power stations have, or are required to have, this Black Start capability. With new generating plant continually connecting to the system and with older plant closing, the requirement for additional Black Start capability across England and Wales is constantly under review. The need and requirement to have a Black Start capability is one of the considerations that the National Grid Company (NGC) make for each new large power station. The arrangements between each generator and NGC for this service are dealt with in a Commercial Services Agreement.

The purpose of this document is primarily to provide prospective generators with an initial insight into the technical and commercial considerations associated with the Black Start service.

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1 INTRODUCTION

Black Start is the procedure to recover from a total or partial shutdown of the transmission system which has caused an extensive loss of supplies. In general, all power stations need an electrical supply to start up: under normal operation this supply would come from the transmission or distribution system; under emergency conditions Black Start stations receive this electrical supply from small auxiliary generating plant located on-site.

Normally these auxiliary supplies are provided by a small gas turbine or a diesel plant, the minimum size of which is dependent on the size of the main generating units (typically in the range 3-15MW), which in turn is started from a battery or some other form of energy storage device. Once running, a large generating unit can then be used to energise part of the local network and provide supplies for other stations within its area. By having this capability at a number of sites electrical supplies can be efficiently re-established around the country.

It would not be efficient, either economically or technically, if all power stations were obliged to provide a Black Start service; in an emergency neither NGC nor the local distribution networks could manage restoration from all power stations simultaneously. Rather, NGC looks to contract with generators that are perceived to be particularly effective in strategic areas on the system.

The need to contract for black start at an individual location will largely be driven by current arrangements (or not) at other nearby power stations, the expected longevity of such contracts and the implications involved in improving system restoration. Only large power stations can provide the services that NGC need to buy. As a guide only, about one third of all power stations in England and Wales of a capacity greater than 300MW have a Black Start capability. Although generators directly connected to the transmission system tend to be more effective, large embedded generators, connected to a distribution system, may also be able to provide a useful Black Start service.

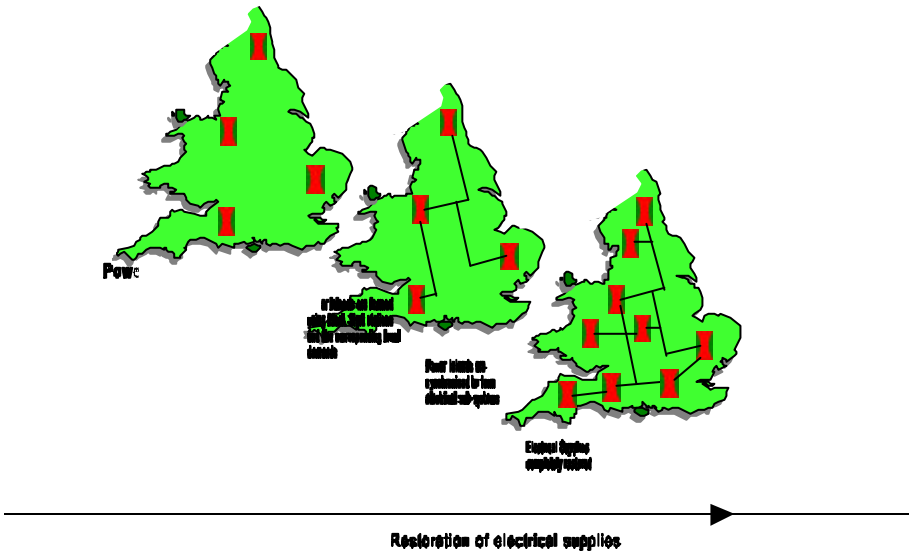
This document is intended to provide a guide to some of the issues and questions that may arise for a new generator in providing such a service. It should be noted that since most large generation projects have used gas-fired technology over the last few years, this document has been written from a CCGT perspective. However, the issues that arise are equally pertinent to other fuel types.

2 BACKGROUND

The NGC Transmission System of England and Wales is designed and operated in accordance with a set of regulated transmission security standards which are intended, inter alia, to ensure sufficient flexibility to maintain supplies under conditions of plant breakdown or weather induced failures for a wide range of demand conditions. For example, extreme weather conditions (e.g. abnormally strong winds), could lead to a partial or full shutdown of the Transmission System. Depending on the particular circumstances, this shutdown could occur without warning and may result in the complete shutdown of all generation connected to the transmission system.

Following such a shutdown, it would be necessary to restart generation, progressively re-energise the transmission system and restore the demand. The complexities and uncertainties associated with the recovery from such a shutdown means it is not possible to state precisely how a recovery will be effected. However, the overall strategy will, in general, include the re-establishment of isolated power stations with corresponding local demands, i.e. separate "Power Islands" are formed. This would then be followed by the step by step integration of these power islands into larger sub-systems and eventually re-establishment of the complete Transmission System (Figure 1 refers).

Figure 1 - step by step restoration of the Transmission System



The likelihood of such an event occurring is considered remote, with the last significant shutdown occurring in 1987 when some 25% of customer demand was disconnected following hurricane force winds in South East England. However, it is the case should a total or partial shutdown occur anywhere on the transmission system that arrangements must be in place to enable a timely and orderly restoration of supplies.

In March 1990 (Vesting) the Black Start portfolio inherited from the CEGB consisted of conventional coal and oil fired power stations together with some hydro plant. As a result of new players entering the electricity market, particularly CCGT stations, some of the older Black Start stations have closed or dropped down the energy merit order such that they may be too cold to restart in the time required. The Grid Code (OC9.4.5.1) requires that ›Black Start Stations‹ are registered › .....*as having an ability for at least one of its Gensets to Start-Up from Shutdown and to energise part of the Total System, or be Synchronised to the System, upon instruction from NGC within two hours, without an external electrical power supply (ABlack Start Capability@)*. Furthermore, plant that is generating less has greater difficulty in recovering its costs in the periods that it does run, leading to a greater likelihood of regiming or closure. Since power stations typically provide 6 months notice of plant closure, and even with new projects taking as little as 18 months to commission, NGC's Black Start contract portfolio needs to be robust against energy market uncertainty.

In view of this, NGC is continually reviewing its contract portfolio to consider not just potential plant closure candidates but also identify which plant may not be able to provide the same level of potential performance due to energy market considerations. NGC is therefore looking to supplement its contract portfolio ideally from new generating plant, but also, in certain circumstances, from existing plant.

To provide this service, power stations require auxiliary plant to enable the main generating plant to start up independently from on-site power supplies. The costs of providing energy from such auxiliary plant is generally not economic for trading in the energy market alone, and therefore such plant will not be installed unless some other income is made available. The costs involved in providing a Black Start capability predominantly arise from the capital outlay on the auxiliaries (and various other associated set up costs). In view of the limited opportunities available elsewhere, it is expected that generators will seek to recover a significant proportion of these costs through an Commercial Services Agreement (CSA) with NGC. Other opportunities that may be available to generators may encompass energy income (via the Balancing Mechanism) and also the provision of Standing Reserve services procured via market mechanisms by NGC.

3 BLACK START CAPABILITY

In order to provide the performance required of a Black Start service, auxiliary generation which is to be installed to provide Black Start capability, together with the main generating plant, need to demonstrate certain technical criteria.

3.1 Technical Requirements

Irrespective of the type of plant installed to provide a Black Start service, the following technical capabilities are required:

(i) the ability to start up the main generating plant (at least one unit / module) of the power station from shutdown in agreed timescales without the use of external power supplies;

(ii) the capability to energise part of the NGC Transmission System or, if appropriate, the host Distribution System within two hours of instruction from NGC;

(iii) the capability to accept instantaneous loading of demand blocks, ideally in the range 30 to 50 MW, and controlling frequency and voltage levels within acceptable limits during the block loading process (under these conditions, frequency will be within the range 47 to 52 Hz);

(iv) the ability to provide at least three sequential Black Starts, within two hours, to allow for possible tripping of the Transmission / Distribution System(s) during the re-instatement period;

(v) ›back-up: fuel supplies (e.g. distillate fuel) to enable the power station to run for a minimum duration, ideally in the range 3 to 7 days, following a Black Start instruction;

(vi) mains independent barring and jacking facilities on all generating units. This facility needs to be independent of the Black Start auxiliary units and must be able to operate for a minimum period of 20 minutes after the loss of external supplies;

(vii) the ability to maintain a high service availability on both the main and auxiliary generating plant (typically 90 - 95%); and

(viii) the reactive capability to charge the immediate Transmission / 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 100Mvar leading (as measured at the commercial interface) should almost invariably meet this requirement.

Furthermore, due to the increase in output from the generating unit accepting block loads, it may be the case that this could cause large step changes in the exhaust temperature of the main generating units. This in turn may stress the boiler if there is no facility to vent the exhaust before it reaches the boiler. Generally this necessitates for the provision of bypass stacks. This could be a significant factor in determining whether a CCGT module can provide a Black Start service or not. In any case, the Generator should demonstrate that the boiler characteristics are such that the plant is capable of accepting the size of block loads required.

3.2 Types of Plant

There are principally two types of auxiliary generating plant which are used for ›Black Starting: the main generating plant of a power station, namely:

- Medium speed diesel engines; and
- Small Open Cycle Gas Turbines (OCGT:s).

NGC has liased with a number of manufacturers, consultants and generators in order to ascertain some of the implications associated with these plant and to gain an appreciation of the likely costs ensuing from such auxiliary plant providing a Black Start capability. The choice of auxiliary plant, including other types not highlighted here, will be made by each generator to best meet individual power station considerations.

(i) Diesel Auxiliary Generation

Diesel engines seem to be the preferred choice by parties who are interested in providing Black Start (and Standing Reserve) services, due to their robust nature and general cost considerations. Typically ›all inclusive: purchase prices appear to vary between ,350/kW and ,400/kW installed.

(ii) Open Cycle Gas Turbine (OCGT) Auxiliary Generation

Costs are dependent on whether existing OCGT units are already on site or new generating units need to be installed. The costs relating to existing (i.e. older) plant tend to be limited to annual maintenance and any remedial / necessary overhaul work. For Generators requiring new OCGT auxiliaries, similar typical 'all inclusive' prices are slightly higher than for diesel plant (10% or more depending on the unit size).

In addition to the capital outlay, other operating costs which could arise and should be considered by prospective Black Start providers include the following:

(i) Incremental Business Rates, Use of System (UoS) charges, and any connection charges; and

(ii) Increase in insurance premiums relating to the operation of the main and auxiliary generators.

The level of power needed to supply a station's auxiliary load to allow a main generator to be started is the underlying factor affecting the cost of installing auxiliary generation. Typically this will lie in the range of 3-15MW, depending on the size of the smallest main unit (and the module configuration).

3.3 Commissioning

Auxiliary generators need to be designed into and integrated with the power station configuration. This auxiliary plant will generally be BM Units and will require the relevant consents to be built and operated.

The technical specification for commissioning the service will be set out in an agreed detailed document. The main requirement will be to demonstrate that without external supplies to the power station the auxiliary unit can be independently started, and in turn allow the reliable start-up of the main turbines in the CCGT module.

This assessment will be conducted as soon as is reasonably practicable, generally following completion of the construction project. It is expected that this will be integrated into the general station commissioning programme. The success (or otherwise) of this commissioning assessment will be the trigger for service payments.

3.4 Inspection and Testing

To allow NGC to verify the Black Start capability of a generating station, regular inspection and testing of all the associated station plant on both the main and auxiliary generating units is required. Furthermore, NGC, together with the power station and host distribution company concerned, regularly review any associated Local Joint Restoration Plan (see later) or Black Start procedure. Routine reproving and service level monitoring is also undertaken.

Testing is carried out in accordance with the Grid Code and the specific Commercial Services Agreement:

(i) Grid Code tests

These tests are carried out in accordance with the Grid Code Operating Code OC5.5.4 - ›Black Start Testing‹. This section highlights, inter alia, details of notice given to the generator prior to actual Black Start testing procedures, Black Start failure and re-test procedures (i.e. capability and reproving assessments).

(ii) Ancillary Services Agreement - Remote Synchronisation Tests

The Ancillary Service Agreement may provide for Black Start Remote Synchronisation Tests (RSTs). NGC may carry out a RST to determine whether CCGT units within a module are capable of synchronising to the NGC Transmission System from a remote substation. Typically Black Start stations are required to participate in a RST once every two years. The RST procedure is closely managed by NGC and requires a generating unit at a Black Start station to energise a dead local busbar, a circuit(s), a transformer(s) and a remote busbar. It will then also need to synchronise to the NGC Transmission System by use of a system synchroniser. The Generator may also be asked to operate at synchronous speed, for up to one hour at no load, to enable a full test of the system synchroniser prior to the remote synchronisation. The precise technical requirements for a RST will be set out and agreed in the ›RST procedure‹.

4 PAYMENTS

A power station with a Black Start capability will want a revenue to recover the costs of making a Black Start facility available. A significant proportion of this income will consist of a Black Start availability payment, paid through a Commercial Services Agreement (CSA) with NGC, together with revenue from the Balancing Mechanism.

The Black Start plant may be installed solely to provide a Black Start service. Alternatively, it can also be used for other energy-related services such as peak lopping and standing reserve. Standing reserve is a service that is predominantly used to make up for unexpected energy shortfalls in real time.

In addition to the above Aholding payments@, further payments are made when the service is utilised - both for testing purposes and in the event of a Black Start. The payments will depend on a number of factors including what plant has been instructed, whether all the plant is registered as a BM Unit and what type of fuel was required.

(i) Black Start Exercise Payment - Auxiliary unit

As long as the auxiliary units are centrally despatched separately from the CCGT module, NGC shall pay for the running of the auxiliary units an amount called the ›Black Start Exercise Payment=. This payment typically covers the following components:

- the fuel price specified;
- the amount of active power provided from the auxiliary units upon instruction by NGC (not to exceed the auxiliary contracted MW) during Black Start and testing periods; and
- the periods for which such active power was provided.

(ii) Black Start Exercise Payment - Main Unit / Module

In a Black Start situation, payments for energy provided are dealt with under the BSC.

In a Black Start situation or during periods of testing where NGC has expressly requested the burning of distillate fuel a further payment will be made known as the ›Distillate Exercise Payment=. This payment covers the incremental fuel price for distillate, the amount of active power provided from the CCGT module and the period of the Black Start situation or testing when on distillate fuel.

For the avoidance of doubt, no Distillate Exercise Payment shall be made during any period of training or any period of testing when NGC has not expressly requested the burning of distillate fuel.

5 COMMERCIAL SERVICES AGREEMENTS

In respect of each large power station, there is an CSA between NGC and the Generator. This CSA contains provisions for Agreed Ancillary Services being Part 2 System Ancillary Services (i.e. Black Start) and Commercial Ancillary Services that may be agreed between parties from time to time. Due to the nature of Black Start services, NGC would seek to enter into long term Black Start contracts, typically 12 - 15 years duration or Aevergreen@ i.e. contracts that exist for the lifetime of the power station.

In respect of each application to connect to the Transmission System (either directly or indirectly), NGC will assess the desirability (or otherwise) of such power station providing a Black Start capability. Where this looks to be a useful facility, NGC would seek to discuss this on a site by site basis. The requirement to provide the service may then be formally reflected initially in the ensuing connection offer but in any event be dealt with in the ASA.

The CSA will define the service that is required (and when) and detail the consequential payments that will be made. The form of contract is a generic pro-forma, and as such will require modification to reflect the particular circumstances of each project. A generic pro-forma agreement is available from NGC upon request to prospective service providers.

In addition, the CSA states that during a Black Start situation NGC will instruct a Generator to implement a Local Joint Restoration Plan (LJRP) from the Black Start plant. The LJRP for the particular Generator shall be written, reviewed and updated by NGC, the Generator and one or more of the local Distribution Company. The LJRP shall include details of:

i) the part of the NGC Transmission System and/or Distribution system to be energised by the Generator using the Black Start plant and the methods by which it will be done;

(ii) how the block loading of the Black Start plant is to be achieved (and also how communication between the Generator, the local Distribution Company and NGC will take place); and

(iii) the manner of operation during islanded conditions.

The Generator shall ensure that appropriate personnel are made aware of the LJRP and receive the necessary training.