

# Frequency response

## White paper

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Demand response. Delivered.

“Frequency response” means automatic, rapid adjustments to generation or demand in response to a change in measured mains frequency.

The job of frequency response is to keep mains frequency within safe limits. If frequency falls, this indicates a power shortfall, so sites will either increase generation or decrease demand in order to make up the shortfall. If frequency rises, the reverse happens.

Frequency response is a routine part of balancing the electricity system. It is always required, and always active. When large power stations fail, frequency can fall very quickly, putting the stability of the electricity system immediately at risk. Therefore, National Grid takes frequency response services very seriously.

Only National Grid has a need to pay for frequency response. Distribution network operators (DNOs) and electricity suppliers have no need to control mains frequency.

The best way to understand frequency response is to separate out the various characteristics that define it. These are:

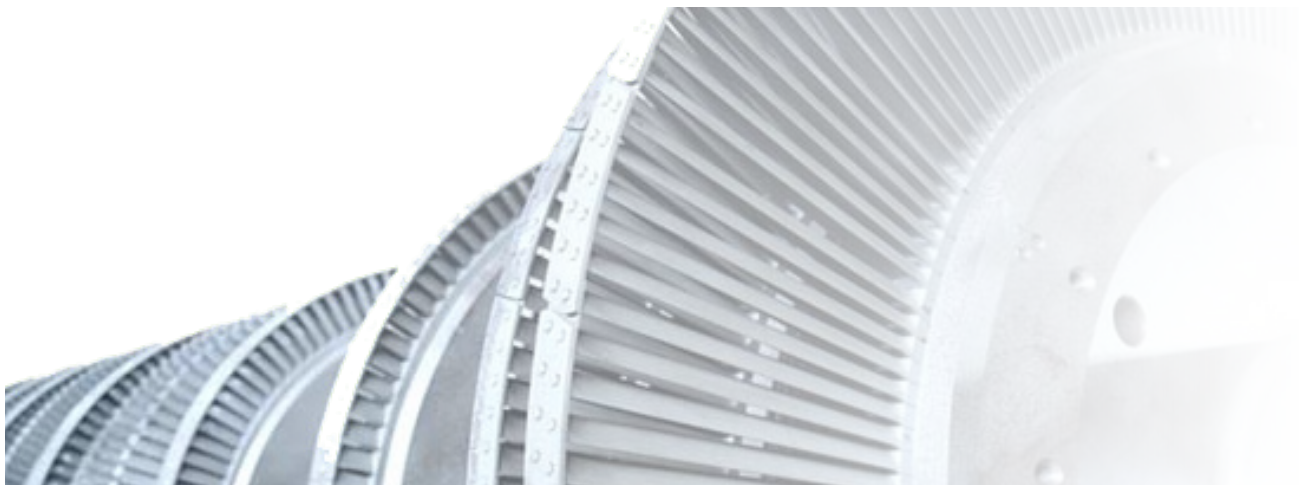
- **Static or dynamic**

A site which provides static (or non-dynamic) frequency response will have a relay which detects mains frequency locally on the site. If frequency falls (or rises) to a pre-set level, the relay will trigger an action, like switching off a load or turning on generation. This only happens when the relay is armed.

Most static response sites spend most of their time doing nothing, or carrying on with the “day job”. Frequency deviations that trigger a response tend to be related to large events, like power station failures.

In contrast, dynamic frequency response requires continuously, adjusting generation or consumption as mains frequency falls or rises in normal operation. If a steam turbine provides dynamic response, the turbine inlet valve will be continuously making minor adjustments to the steam flow.

One important difference between static and dynamic response is the amount of response relative to the size of the site. A typical static response site will drop load across most of the site when frequency reaches the trigger level. In contrast, dynamic response involves making small adjustments around some mid-point of consumption or generation. It's seldom possible to use the whole capacity of the site in dynamic response. This affects the commercial gains that the site can make.



- **Low or high**

Low frequency response means reducing demand or increasing generation when frequency falls. High frequency response means reducing generation or increasing demand when frequency rises.

With some caveats, power stations can always be turned down. Turning them up is not always possible. Therefore, low frequency response is a more critical purchase for National Grid than high frequency response.

- **Speed and sustain time**

The slowest class of frequency response is termed secondary response. This class must also deliver for longest. A secondary response provider must be able to reach full delivery within 30 seconds of a frequency deviation, and it must be able to hold this delivery for 30 minutes.

Primary response is faster. For dynamic resources, primary response means reaching full power in ten seconds and holding it for 30 seconds. Clearly, a capable resource can provide primary and secondary response from the same asset, and many do.

Static resources are normally treated like a combination of primary and secondary. A typical requirement is for full power within two seconds of an event followed by 30 minutes of delivery. Some sites cannot act this quickly, and are instead allowed to act in secondary timescales. Payments tend to be lower as a result.

More recently, National Grid has experimented with new categories. The first of these is rapid frequency response, which is similar to primary response but with a five-second target instead of ten. This service did not take off commercially and does not appear to be a priority for National Grid.

The second, enhanced frequency response (EFR), requires full power within one second, and so far only exists as a dynamic service.

- **Contract forms**

Combinations of static/dynamic, low/high, and primary/secondary can be sold to National Grid using different contract forms:

- o Frequency Control by Demand Management (FCDM) – this is only for demand-side resources providing static frequency response. The normal combination is two-second response (like primary) but sustained over 30 minutes (like secondary). Providers have a lot of freedom to make themselves available as suits them.
- o Firm Frequency Response (FFR) – this contract form allows every type of response except for enhanced, and is therefore a very common route for many types of capacity. Static and dynamic resources with a variety of speeds and other capabilities compete through monthly tenders. If an offer is accepted, the resource must make itself available in accordance with the offer, although from September 2016 it will be possible to make weekly adjustments to this. FFR offers typically include:
  - Thermal power stations offering primary and secondary dynamic response, low and high
  - Pumped-storage hydro offering low frequency dynamic response
  - Merchant peaking power stations (such as diesel farms) offering static secondary low frequency response
- o FFR Bridging – this is an introductory version of FFR for resources which cannot provide the minimum capacity requirement of 10MW. It is time-limited and has recently been partially closed due to oversubscription.
- o Enhanced Frequency Response (EFR) – this is a fledgling contract form designed to source new capacity able to meet the higher speed requirements of enhanced response.
- o Mandatory Frequency Response – this is National Grid's fall-back method: licensed generators (large power stations) are obliged to offer mandatory frequency response according to their technical capabilities (although the price is not mandated). If National Grid doesn't get enough frequency response through other routes, it can buy it this way close to real time.

## The market for frequency response

Only National Grid buys frequency response, and it only buys it to the extent that it needs it.

The need for frequency response varies by season, time of day and characteristics of the market on the day. Very roughly, National Grid will buy enough response that if a large power station like Sizewell B were to trip (potentially taking out 1,320MW of gross generation) then mains frequency would fall from 50Hz to 49.5Hz. At night or in summer, when demand is low, Sizewell B is a larger component of total demand than in during the day or in winter, so more response is needed to meet this target. On the other hand, if Sizewell B is not generating on the day, less response may be required.

Some categories of frequency response are theoretically useful but seldom purchased. Static high response, such as by tripping CHP generators, would help balance the system if, for example, one of the interconnectors to Ireland were to suddenly disconnect while exporting. However, many power stations offer bundled low and high services, so in procuring the low response that it needs, National Grid can often end up with all of the high response it needs as part of the package. Consequently, static high response currently has no market value.

Secondary low response, on the other hand, is a regular purchase. Recently, a number of generators at diesel farms were placed into static secondary low service, requiring the operators to simultaneously synchronise a large number of generators at each site and then ramp all of them to full power, all within 30 seconds of a frequency event.

This is an onerous duty for most reciprocating engines, which is only partially eased by the relatively low number of starts which the engines will experience (eight to ten events each year). Because of the thermal stresses involved in such rapid power increase, we do not normally recommend it for generators with a standby role, as it will increase their risk of failure in an emergency situation.

The large number of sites presently capable of providing secondary static response, and the lack of any other capabilities for this group of assets (primary timescales or dynamic operation are both out of the question for diesels) has led to a price drop in this particular strand of the market. Conventional standby diesels are therefore better off in other services.

When launched in 2015, enhanced frequency response (EFR) was described as being suitable for batteries (among other resource types). This led to an unprecedented surge in connection and planning applications for battery projects. The first EFR contracts are expected to be awarded in July 2016. Prequalified capacity is around five times the indicative procurement volume, and the prequalified capacity itself may be only one tenth of the volume of speculative battery projects currently under consideration.

National Grid's requirement for frequency response can be met by a mixture of static and dynamic, but there is a minimum amount which must be met from dynamic. Once that is met, then any dynamic resources not contracted then compete with static ones for the remaining opportunity.

### Prequalification and testing

All frequency response resources must be physically credible. For example, National Grid will not buy firm low frequency response from wind farms, though it may do so from a battery located at a wind farm. Although variable-speed wind turbines have some capability to release stored energy by allowing the rotor to slow down, no wind farm operator can commit to being able to do this several days ahead. Without this ability to make a firm offer, a resource cannot participate in FFR tenders.

All frequency response sites must include high accuracy, local frequency detection. It is not acceptable for sites to be triggered remotely. Both the frequency detection and the response of the site must be tested and demonstrated before the site is qualified to participate in tenders or offer the service. This must be in accordance with a recently-revised but strictly enforced programme of testing.

The testing programme requires injection of a variety of mains frequencies and frequency profiles from calibrated equipment. National Grid has the right to witness such tests and may require to see calibration certificates. It is also necessary to demonstrate that the frequency detection equipment has a design accuracy of  $\pm 0.01\text{Hz}$ . This is relatively rare among commercial frequency measuring devices.

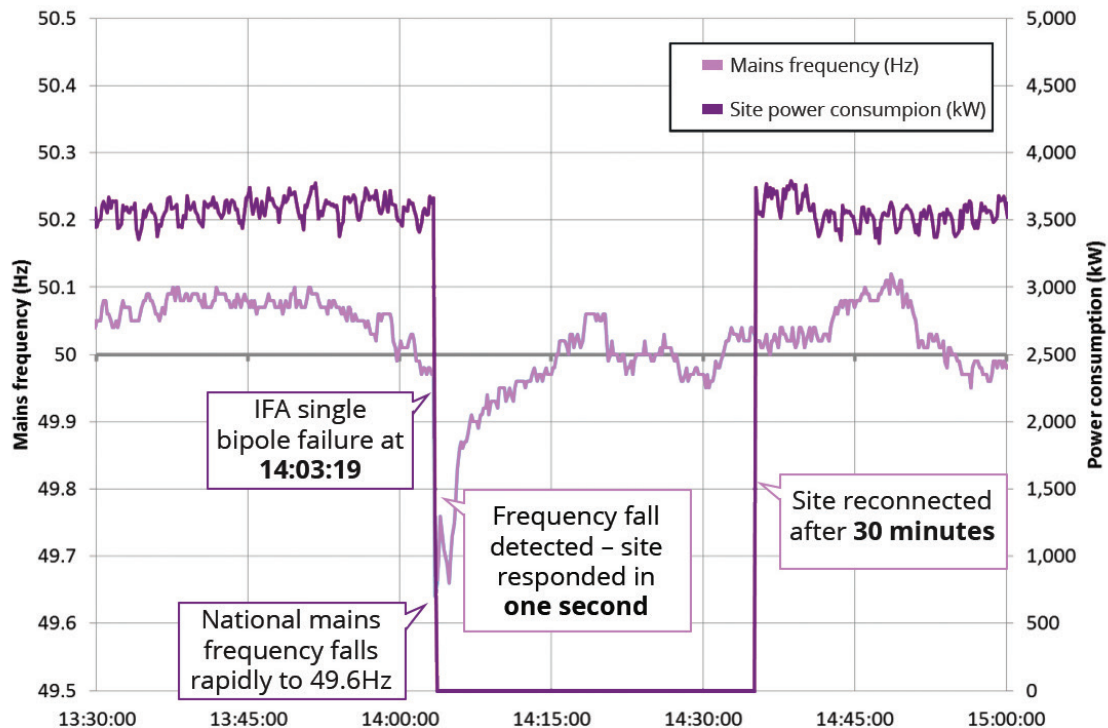


## Frequency and inertia

The reason for National Grid's growing interest in faster and faster response services is the falling inertia of the national electricity system. In large power stations, heavy turbines and alternators are directly coupled to the AC transmission networks, and their very weight (or to be precise, their rotational inertia) slows down frequency changes. Wind and solar power stations do not contribute inertia because of the way that they connect. So when renewable output is high, the system is less able to cope with sudden events like major power station failures.

National Grid is working with Flexitricity to develop a way for demand response to address the inertia problem directly. This is the Smarter Frequency Control (SFC) project. In SFC, resources respond not to frequency itself but to its rate of change. This can also be used to stop the oscillations that can happen when disturbances happen around the edges of the network – such as when the interconnectors to France or Belgium fail.

SFC will run as a trial service during 2017.



## Smart frequency control

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Mains frequency is directly related to the rotation rate of turbines and engines at power stations across Great Britain. Its nominal value is 50Hz, which is equivalent to 3,000 cycles per minute. For this reason, the rotation rate of most power generators is a factor of 3,000 revolutions per minute (rpm). Micro generators might run at 3,000rpm; small hydro, CHP and diesel engines usually run at 1,500rpm; and larger power station turbines spin at 1,000rpm, 750rpm or less.

Wind turbines don't follow this rule, because their alternators are connected to mains in different ways. This is to allow them to spin at rotation rates which better suit wind conditions. Other types of generator, like photovoltaics and batteries, don't have rotating alternators, so they have to create a version of mains frequency from scratch using inverters. These differences mean that wind and solar power do not contribute rotational inertia to the system.

The alternating current (AC) transmission network acts like a system of mechanical drive-shafts and gears, keeping all parts moving in locked step. This means that frequency is notionally the same across GB at all times. But a real mechanical transmission system would have some "give", allowing parts to flex and twist relative to one another depending on the forces applied. In the same way, the electrical transmission system allows frequency to deviate over long distances, for short periods when power flows change suddenly. But frequency at the various locations is always pulled back into line. If this does not happen, then a "pole slip" will occur, almost certainly resulting in power cuts.

The flexibility inherent in the transmission network means that in a major fault, the system can oscillate, with power flows rapidly changing and potentially making a bad situation worse. Inertia, smart frequency control (SFC) and enhanced frequency response (EFR) are needed to counteract this danger.

Flexitricity operates the largest and most advanced demand-response portfolio in Britain. Join us today. Call **0131 221 8100**.

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