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An Introduction to Electricity System Operability

NESO
National Energy System Operator

Introduction

Operability is the technical ability to operate the electricity system safely, securely, economically and efficiently. We at NESO operate one of the most rapidly decarbonising power systems in the world and this transition to a low carbon future will change both the magnitude and location of our operability needs. Furthermore, Clean Power 2030 requires NESO to transition the electricity system away from procuring our operability services from unabated fossil fuels and move to clean power sources.

To ensure that we can achieve this, we consider a wide variety of operability challenges and opportunities across a number of areas. This document is designed to sit alongside the Operability Strategy Report and Electricity Markets Roadmap reports to provide a high level understanding of each operability area. It provides a summary of:

- The impact of the **Whole Energy System**
- How we use the **Balancing Mechanism**
- The role of **Within Day Flexibility** in management of the electricity system
- The management of **Frequency** and **Voltage** within regulatory limits
- The importance of **Stability**
- Meeting demand reliably through **Adequacy**
- Ensuring electricity system **Restoration** in the very unlikely event of a power outage

Whole Energy System

As part of our license requirements, we are required to take an impartial, independent and whole system view in our strategic planning and operational activities.

This means taking a holistic view across the whole energy system both today and in preparing for future net zero operations. Whole System represents an emerging operability workstream which will necessarily develop over time as we learn more about the interactions in a decarbonising energy system.

There are key dependencies between electricity system operability and the wider energy system, therefore we do not consider the electricity networks in isolation. We look at the inter-operability of other critical networks with the electricity network, such as the gas networks.

As the energy system in Great Britain decarbonises, the importance and opportunities of a whole energy system approach will increase significantly. The emergence of new vectors and electrification will increase the level of interaction such as the use of hydrogen and the transition of some demand for domestic heating from the gas to the electricity network. This means we must consider how the operation of each energy network could affect the operability of the electricity system as a whole.

One example of this is the impact of the electrification of transport. As internal combustion engine vehicles are replaced with EVs, this will increasingly shift energy demand that has been met by the petroleum network to the electricity network. This shift will impact the operability of the electricity network by increasing demand and introducing new demand dynamics, both intra-day and seasonal, to accommodate the EV charging behaviour. At the same time, increased EV uptake offers several opportunities which would be beneficial to operability as part of an efficiently designed market. EV demand is flexible, which presents opportunities for some charging to respond to price signals such as cheaper overnight charging, flexing demand away from peak hours. EVs also represent flexible, distributed battery storage which could play an important role in future.

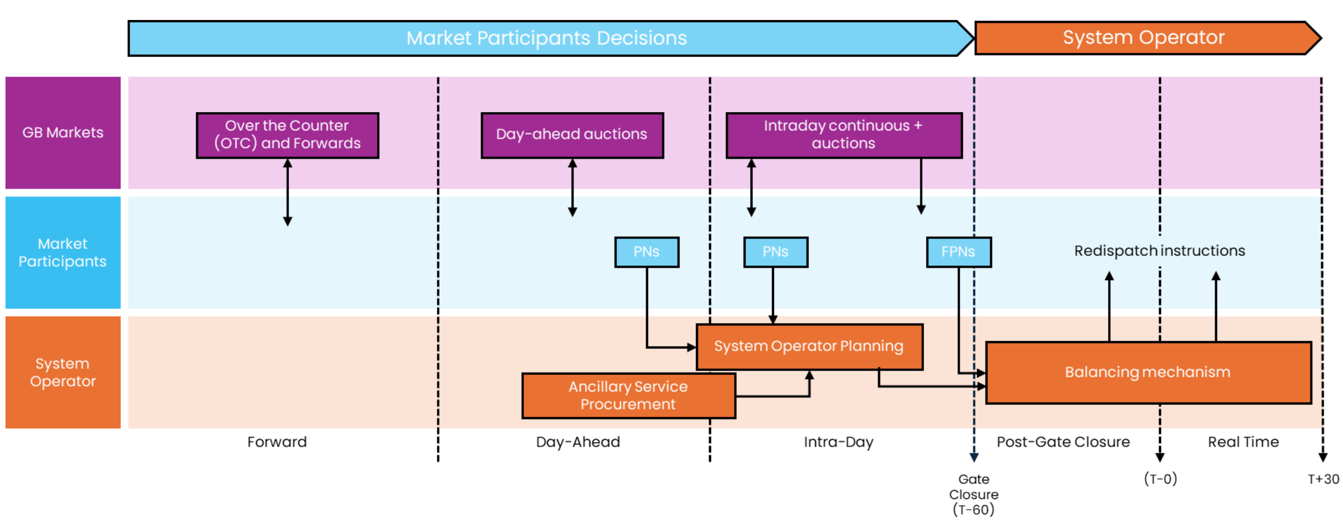
Balancing Mechanism

We are responsible for ensuring that electricity supply and demand are continually matched. The [Balancing Mechanism] is our primary tool, and we use this to procure the right amount of electricity required to balance the system. We do this minute by minute, second by second, to balance supply and demand in real time.

At gate closure (one hour before electricity is delivered), physical notifications, which reflect the expected level of generation or consumption, become final. The Balancing Mechanism is where we 'take over' from the wholesale market to fine-tune energy balance, whilst also managing system constraints, such as stability, voltage control and thermal limits.

Balancing Mechanism participants (e.g. generators) must submit prices and volumes to the Balancing Mechanism that indicate their willingness to pay or be paid for adjusting their self-dispatched positions. This takes the form of "Bids" (to reduce generation or increase demand) and "Offers" (to increase generation or reduce demand). Balancing Mechanism actions are categorised as follows:

- Energy actions are taken to resolve the overall energy imbalance after system actions have been taken. This includes the provision of services for frequency response and reserve. The cost of these actions is reflected in System Imbalance Price calculations.
- System actions are taken for system management reasons, such as thermal constraints, network stability, or voltage. The cost of these actions is removed from the System Imbalance Price calculations.



Within-day flexibility

Within-day flexibility is the ability to shift energy in time across the day. It can be delivered by changes in both demand and generation. It is used to balance supply and demand, as well as managing constraints such as those from thermal capacity.

We are responsible for identifying our within-day flexibility requirements to meet the needs of the system, but we are not explicitly required to hold a specific amount of within-day flexibility.

At present, within-day flexibility is mainly delivered through the wholesale market, using flexible assets such as batteries, gas-fired power stations, pumped storage and demand response. To achieve a clean power electricity system, within-day flexibility will increasingly transition from unabated fossil fuel to clean energy sources such as electric vehicles (EVs), long duration energy storage, and distribution connected demand flexibility.

We are working to enable greater participation from flexibility sources across our markets, helping increase flexible capacity in the Capacity Market and Distribution System Operator markets. As detailed in Clean Power 2030 Annex 1 and the Clean Flexibility Roadmap, there is forecast to be up to 10-12GW of consumer led flexibility by 2030. This includes flexibility resulting from wholesale market derived tariffs and trading. The smart meter roll-out, market-wide half hourly settlement, tariff innovation and Balancing and Settlement Code modification P415, are critical to unlocking access to this flexibility.

To ensure there are routes for flexible assets to access our markets, projects such as the Demand-Side Flexibility Routes to Market Review highlight ways in which barriers to existing markets can be removed. The Demand Flexibility Service and Local Constraints Market offer routes for flexibility assets to take part in energy balancing markets. In addition, the Enabling Demand-Side Flexibility programme summarises the projects that are necessary to meet the goals set out in the Clean Flexibility Roadmap.

Frequency

Changes in system frequency reflect the instantaneous balance between electricity supply and demand.

We have developed an innovative range of response and reserve services to support effective frequency management as the electricity system decarbonises. We use response and reserve services to correct imbalances and maintain system frequency around 50Hz and within the Security and Quality of Supply Standard. Both frequency response and reserve deliver a change in active/real power, provided by a source of generation or demand, (including storage) to manage system frequency. Response services are automatically activated, while reserve services are dispatched manually by a control room operator when needed.

We continually evaluate the requirements for each service, using operational insight and the Frequency Risk and Control Report to secure the system against risks and operability challenges. Depending on the service, response and reserve can be procured at different timeframes through different pricing structures – with the latest information published on the NESO website.

We continually review our services and markets. We are currently assessing the potential merits of locational response and reserve procurement, as well as reevaluating our legacy services to ensure they are fit for purpose in a changing power system.

Voltage

Voltages on the system must be maintained within statutory limits to ensure power quality, system stability, asset security and safety.

Voltage on the transmission system is managed in operational timescales through the adjustment of reactive power. Reactive power can be provided from conventional synchronous machines (generators, synchronous condensers), capacitors and inductors, and inverter-based assets offering dynamic reactive capability.

Voltage control in the system is becoming increasingly complex as the system decarbonises. We anticipate that more dedicated voltage control devices including, but not limited to, shunt reactors and capacitors, operated by transmission owners and other commercial providers, will need to be installed across the grid. These devices will complement voltage support provided by generation, storage, and connected demand.

We collaborate with Transmission Owners, Distribution Network Operators and commercial providers to identify, forecast and secure the requisite reactive power and voltage control services. To do this, we utilise a range of mechanisms, including:

1. **Network Assets:** Transmission Owners and commercial providers supply reactive power support using dedicated voltage control network devices.
2. **Self-dispatching generation:** The Grid Code requires that all transmission-connected generators maintain a minimum capability to both absorb and inject reactive power. When reactive power services are required and suitable network assets are unavailable, reactive power can be procured by utilising self-dispatching generation units.
3. **Balancing Mechanism and Trades:** We may synchronise units out of merit through bids and offers, or via pre-gate closure trading to ensure voltage compliance.
4. **Long-term markets**: The Long-term Reactive Power Market allows us to competitively procure long-term needs for locational reactive power requirements. The first long-term market tender was launched in March 2025.
5. **Mid-Term markets:** These markets will provide a competitive route to secure services closer to real time through existing assets based on their additional capability over and above the requirements of the Grid Code. This will complement the Long-term market.
6. **Short-Term Tenders:** From time to time, we use short-term tenders when an interim reactive power need is identified, for example to cover an asset outage. In the future, we endeavour to meet these requirements through new markets.

Stability

A stable electricity system can securely withstand and recover from unplanned events such as faults on overhead lines, the sudden loss of a large generator or fast ramps of embedded assets.

We are responsible for ensuring there is sufficient inertia and short circuit level on the system to meet our stability requirements.

As the electricity system decarbonises and the grid becomes more dynamic, the magnitude and location of stability needs will change. At the same time, new technologies such as grid-forming inverters are providing innovative ways to deliver stability from different locations in the network. To ensure we can meet our requirements, we secure stability services through a range of mechanisms, including but not limited to:

1) **Balancing Mechanism and Operational Actions:** We use the Balancing Mechanism to schedule and dispatch units that provide inertia and short circuit strength in locations of need.
2) **Long-Term Market:** The Long-Term Stability Market provides a mechanism to secure stability services well ahead of the need. Procurement starts 4 years before delivery. This market enables investment in network services from assets such as synchronous condensers and grid-forming technologies.
3) **Mid-Term Market:** The Mid-term Stability Market allows us to procure additional stability capability closer to real time. Procurement starts 1 year before delivery. It leverages existing assets that can offer services beyond their standard obligations, providing flexibility and cost efficiency as system conditions change.

Thermal

Components of the electricity system are limited by their physical capacity to move electrical energy. This places restrictions, or constraints, on the amount of electricity we can move around the grid. This needs to be managed to ensure electricity demand can be met by the available electricity generation.

We are responsible for managing thermal operability of the electricity transmission system in real time. This can be achieved by re-dispatching generation via the Balancing Mechanism or optimisation of transmission network arrangements e.g. circuit selection or assets that can manage power flows in transmission lines. We manage these operational thermal constraints via Market Mechanisms, which solve congestion by balancing supply, demand and flexibility assets across the transmission and distribution systems. This includes the Local Constraint Market and the use of Intertrips. These market mechanisms benefit consumers by reducing balancing costs and reducing/deferring investment in network infrastructure.

Some thermal constraints arise from a mismatch between the location of electricity generation and demand and others due to planned and unplanned outages on the network. We work with the market and Transmission Owners to provide network and non-network solutions for the medium and long term to manage thermal operability**.** This includes identifying where new thermal capacity is needed and how that can be delivered with new infrastructure and by enhancing existing equipment with non-network solutions. Our strategic planning strategies will align the location of generation, demand and network infrastructure.

Investment in new network is not always the most cost-effective long-term solution, and some level of constraint cost will be inevitable even in an optimised system. When planning solutions which reduce constraints, we must balance the long-term costs of balancing actions against the cost of investing in network upgrades and against the cost of other commercial and technical techniques. We are embracing new and innovative solutions that increase the capacity of the network. One method we use to do this is the Constraint Collaboration Project. Through this project, NESO and industry work together to find implementable solutions for thermal constraints.

Adequacy

Resource adequacy assesses the potential risks to security of supply and whether there are sufficient available resources to meet electricity demand throughout the year.

As reflected in the Reliability Standard, we are responsible for ensuring that there are sufficient resources to meet electricity demand every minute of every day. In Great Britain, adequacy has historically focussed upon ensuring that there will be sufficient electricity generation available for when demand is highest in winter. We publish regular assessments on adequacy including recommendations of how much capacity to procure through the Capacity Market.

Meeting future adequacy needs requires technologies that can competitively deliver clean energy for hours and days at a time. This includes, but is not limited to, new nuclear, low carbon dispatchable power (e.g. hydrogen power generation), renewable generation and seasonal/long duration electricity storage.

Restoration

Restoration is the ability to restart the grid in the unlikely event of a National Power Outage (NPO).

By 31 Dec 2026, we will have an obligation under the Electricity System Restoration Standard (ESRS) to be able to restore 60% of GB transmission demand within 24 hours, and 100% within 5 days, of an NPO.

We secure restoration services via tenders. In 2029, we will launch, for the first time, a bundled long-term contract for delivery. This will procure restoration, stability and voltage services together. Our restoration strategy will increasingly include non-traditional generation and storage for restoration services to ensure continued compliance with the ESRS.