Great North Road Solar and Biodiversity Park

Technical Guide for Solar Power Generation, Storage, Maintenance and Decommissioning

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1 INTRODUCTION

1 This Technical Guide has been prepared to explain how the Great North Road Solar and Biodiversity Park ('the Development'), a solar photovoltaic (PV) solar park combined with a battery energy storage system (BESS), will generate electricity and interact with the wider energy system. It outlines the key technologies, their operation, and how the electricity is transmitted into the national grid.

2 DESCRIPTION OF THE WORKS

2 The Development consists of the construction, operation, maintenance and decommissioning of a ground mounted solar park with an intended design capacity of over 50MWp and an associated battery energy storage system.

3 The Development will be connected to the electricity network via a single Point of Connection at 400kV to the National Electricity Transmission System (NETS) network at the National Grid Staythorpe Substation, which is located within the Order Limits.

The Development can either connect into the National Grid Staythorpe Substation (Work no. 6) directly or via the Consented Staythorpe BESS (Work no. 7). The need for both options results from the Consented Staythorpe BESS not having yet been constructed. If it is constructed in time for the Development, then connecting via the Consented Staythorpe BESS substation allows for a shared connection, which is resource efficient and cost effective. Alternatively, the 400kV cable could run directly to the same connection point at the existing National Grid Staythorpe Substation.

3 HOW DO PV SOLAR PANELS PRODUCE ELECTRICITY?

4 Solar panels work by converting sunlight into electricity through the photovoltaic (PV) effect. While the technology has gained prominence in recent decades as it represents the cheapest form of sustainable electricity generation, the fundamental principle dates back to the 1830s, with the first commercial PV cells developed in the 1950s.

5 Each solar PV panel consists of multiple photovoltaic cells, usually 60 or 72 per panel, arranged beneath a glass surface and framed in aluminium. These cells are built from silicon, a semiconductor material. The solar panel's performance depends on the internal structure of the cells, which are manufactured with a top layer infused with phosphorous (to create a negative charge) and a bottom layer treated with boron (creating a positive charge). This configuration establishes the electric field necessary for electricity generation.

6 When light strikes the panel, photons from the light energy dislodge electrons within the silicon atoms. These free electrons are drawn toward the phosphorous layer and away from the boron layer. Metal strips embedded in the panel collect the moving electrons and direct them to a junction box on the rear side of the panel.

7 From there, the current travels via cable to an inverter, which converts the direct current (DC) electricity into alternating current (AC). This AC power is compatible with the electricity supply transmitted on the electricity networks and used by homes and businesses.

8 On a solar farm, PV panels are linked together in rows or ‘strings’, connected by electrical cables. These strings collectively are known as ‘arrays’.

4 WHAT DOES MEGAWATTS PEAK (MWP) MEAN?

9 The capacity of solar PV systems is commonly expressed in megawatts peak (MWp). This figure represents the theoretical maximum power output a system can deliver under ideal conditions.

10 While MWp measures installed capacity of a solar PV system, they do not express how much electricity is produced over time. This is measured in kilowatt-hours (kWh) or megawatt-hours (MWh). A 1MWp solar PV system operating under ideal conditions would generate approximately 1,000MWh of electricity per year. However, the actual amount of electricity generated will depend on the environmental conditions within which any particular solar PV system is operating i.e. sunlight levels, ambient temperature and geographic location.

5 ADVANCES IN PANEL EFFICIENCY AND POWER OUTPUT

11 Although PV technology has existed for decades, meaningful commercial progress only took off in the early 2000s. Attractive economics and supportive government policy triggered rapid global growth in panel production and helped establish solar as a mainstream renewable energy source. Today, the majority of panel manufacturing is concentrated in Asia, particularly China.

12 Over the past two decades, both the output per solar PV panel and efficiency (i.e. the percentage of sunlight that hits the solar PV panel and is converted into useable electricity) have significantly improved. In around 2010, typical solar panels used in UK projects produced outputs between 250–300Wp with around 14% efficiency. Now, panels producing 400–500Wp with efficiencies of 20–21% as standard. Some manufacturers have launched 600Wp modules, which are expected to gain traction over the next couple of years.

13 Recent innovations in PV technology include:

- **Bifacial panels:** These modules generate power on both sides, capturing light reflected off the ground (known as *albedo*). Depending on the surface material and system configuration, bifacial panels can boost total output by 5-10%.

- **Half-cell design:** Panels built with halved photovoltaic cells reduce internal resistance and enhance durability. Their layout improves performance in partially shaded conditions, offering better yield stability.

- **Tracking systems:** Trackers enable panels to follow the sun's arc across the sky, from east in the morning to west in the evening, increasing daily energy capture. While more common in high-irradiance regions like the U.S. Southwest and southern Europe, only a few UK projects have started to integrate this technology, given the limited technical benefits and higher lifetime costs.

14 As solar energy becomes an increasingly cheap source of electricity, there are likely to be further technological improvements to the design of the next generation of solar PV panels.

15 The design of each solar park is determined by a number of factors such as location, terrain, solar exposure, available technology, and market economics. Each solar park undergoes detailed modelling to find the right balance between panel type, inverter capacity and grid constraints. Although emerging technologies have the potential to produce better outputs, they are not always the optimal solution for every solar park.

6 ELECTRICITY GENERATION PROFILE OF A UK SOLAR PARK

16 The amount of energy a solar park generates annually is strongly influenced by location. Solar irradiance (the amount of sunlight received at ground level) varies across the UK. For example, a solar PV installation in Cornwall might yield 20% more electricity than an identical system in Scotland, even if the technology and layout are the same.

17 UK solar irradiance ranges from:

- ~960 kWh/m² in the far north; and
- ~1240 kWh/m² in the southwest

18 Solar generation follows a predictable daily and seasonal pattern. Output increases in the morning, peaks around midday, and declines toward sunset. Naturally, this profile shifts with the seasons, i.e. days are longer in summer and shorter in winter, resulting in roughly 70% of annual generation occurring between April and October.

19 Although solar panels are designed for long-term durability, their performance slightly degrades over time. Manufacturers now commonly guarantee at least 85% of original output after 25 years, with many quoting degradation rates as low as 0.3% per year. Independent studies of older

systems suggest real-world degradation typically falls between 0.36% and 0.64% per year.

20 This continuous improvement in both panel quality and degradation rates has extended the expected operational lifespan of solar parks. While 25 years was the standard benchmark a decade ago, most projects today are designed for 40 years or longer.

21 Whilst the availability of sunlight is a key consideration for the siting of a solar farm, access to the electricity network is also a critical factor.

7 HOW SOLAR POWER IS INTEGRATED INTO THE ELECTRICITY NETWORK

22 Once electricity is generated by the solar panels, several steps are required before it can be delivered to homes and businesses. PV modules produce low-voltage direct current (DC) electricity, which is not directly compatible with the national grid or household appliances.

7.1 INVERTERS

23 The first step in making the power usable is to convert DC to alternating current (AC). This process is completed by inverters. The Illustrative Design shows 'central' inverters distributed around the site These devices rapidly switch the direction of the current, which is compatible with the grid AC.

7.2 TRANSFORMERS

24 After conversion, the voltage remains relatively low, typically <100V. To match the grid's operational voltage, this needs to be increased. The Development is designed to connect at 400kV, which is the highest-voltage level in Great Britain and suitable for connection on to the NETS. To achieve this, the electricity passes through a series of transformers, starting with intermediate transformers at the inverter level (increasing the voltage to 33kV), followed by the intermediate substation to increase the voltage to 132kV and culminating at 400kV at the main site substation (Work no. 5b 400kV Compound). This voltage increase ensures grid compatibility and stable transmission.

7.3 CONNECTION TO THE DISTRIBUTION NETWORK

25 Once transformed, the electricity enters the NETS at the designated Point of Connection, where it becomes part of the wider energy system contributing towards the country's sustainability and Net Zero ambition.

26 The grid connection for the Development is self-contained and independent, meaning its operation is not contingent on or influenced by other local generation projects.

27 Once exported, the electricity may serve the local area, or be bought by remote corporate entities through Power Purchase Agreements (PPAs). These agreements allow businesses to purchase clean electricity directly from producers, supporting their decarbonisation goals while providing the solar park with predictable revenue.

28 Electricity from the Development may also be used for grid services, helping balance supply and demand in the national system.

8 BATTERY ENERGY STORAGE SYSTEM (BESS)

29 A Battery Energy Storage System (BESS) is a crucial component of modern solar projects. It allows surplus energy to be stored and released when needed, such as during evening demand peaks or when solar output is low. National Grid now recognises BESS as a critical enabler of a low-carbon electricity system.

30 Lithium-Ion (Li-ion) Cell Chemistry is currently the dominant choice for grid-scale storage due to economic viability. First popularised in consumer electronics, Li-ion batteries offer a compact, efficient, and cost-effective solution. They consist of cells that include:

- A cathode (positive electrode);
- An anode (negative electrode);
- A separator to prevent short-circuiting; and
- A chemical electrolyte to carry lithium ions between electrodes during charging and discharging.

31 As the battery charges, lithium ions flow from the cathode to the anode, storing energy. The flow reverses during discharge, releasing electricity.

8.1 BENEFITS OF CO-LOCATING BESS WITH A PV SOLAR PARK

32 By integrating a battery system directly with the solar park, operators gain valuable flexibility. They can either:

- Export electricity immediately when it is generated
- Store it for release later in the day, such as during the evening peak
- Or split the output dynamically between export and storage, depending on demand, pricing, or contract requirements.

33 This ability to control output timing is especially valuable when participating in electricity markets or providing system balancing services. In addition to selling power through PPAs, operators have a number of other options:

8.1.1 The Capacity Market

34 This government-backed mechanism pays generators to be available during times of high national demand. Batteries are ideal for this as they can react quickly and reliably.

8.1.2 Frequency Response Services

35 National Grid must maintain system frequency at 50Hz ±1%. Even small deviations can destabilise the grid. To help manage this:

- Dynamic Frequency Response adjusts output in real-time based on frequency variations.
- Static Frequency Response provides immediate support when the frequency breaches pre-set thresholds.

36 A notable example of why this matters occurred in August 2019, when a lightning strike caused multiple generators to trip offline. The resulting drop in system frequency led to a large-scale blackout, affecting over a million customers. BESS can respond within milliseconds, helping prevent such events.

8.1.3 The Balancing Mechanism

37 This is the real-time tool that the National Energy System Operator (NESO) uses to resolve short-term supply/demand mismatches. Operators can offer to increase or decrease generation or consumption to help restore balance. Batteries are particularly valuable here due to their responsiveness and flexibility.

8.2 CONTROL AND OPERATION

38 Modern BESS units are remotely monitored and controlled. Their systems are integrated with the solar park's monitoring platform to ensure coordinated operation. Smart algorithms decide whether to export, store, or curtail generation based on:

- Available solar output
- Battery charge status
- Market prices
- Grid constraints
- Contractual obligations

39 The timing of BESS charging depends on solar production and system losses. As a general guide, a 100MW battery could be fully charged in about 1.25 hours by a 100MWp solar array operating at peak output.

9 PROJECT MAINTENANCE

40 Following construction, the successful operation of a solar and storage park depends on how well it is monitored and maintained. This will ensure that the electrical infrastructure of the solar park will operate reliably and safely over the lifetime of the Development.

41 Typical maintenance activities for the Development include:

- 24/7 remote monitoring via Supervisory Control and Data Acquisition (SCADA) systems;
- Analysis of performance data to identify faults or underperformance;
- Preventative maintenance and periodic inspections;
- Rapid on-site response to alarms or failures;
- Security (e.g. CCTV);
- Vegetation management to avoid shading or fire risks; and
- Periodic cleaning of panels to remove dust, bird droppings and pollen

42 Remote monitoring is a key activity and SCADA systems allow operators to monitor real-time performance of every inverter and transformer. When a fault is detected, data analysis helps determine whether a site visit is needed.

43 Routine inspections are generally scheduled every three months, with technicians checking electrical connections, mounting structures, and overall equipment condition. Additional visits may be triggered by performance issues or system alerts.

44 Panel cleaning, while less frequent in the UK than in desert environments, is still important. Specialised tracked machines may be used for this purpose, ensuring even and efficient coverage.

10 WHAT HAPPENS WHEN THE PROJECT IS DECOMMISSIONED?

45 At the end of its operational lifespan the Development will be decommissioned, and all equipment will be removed from the site. This process will be undertaken in accordance with the applicable UK regulations, which promote recycling and recovery over disposal.

46 The key components of the Development that will be removed and the recycling routes for these components is outlined below:

10.1.1 Solar Panels and Mounting Systems

47 Most panels used today are based on crystalline silicon and contain the following materials:

- ~76% glass;
- ~10% polymer (e.g., encapsulant and backsheet);
- ~8% aluminium (mainly from the frame);
- ~5% silicon;

- ~1% copper, silver, tin, and lead (in wiring and contact lines); and
- Mounting System typically made of highly recyclable steel or aluminium.

48 The recycling process is expected to comprise the following steps:

- Frames and junction boxes are removed.
- Panels are mechanically shredded into smaller pieces.
- Glass and polymer layers are separated and cleaned.
- Semiconductor materials and metals are recovered for reuse in new PV products.

10.1.2 Battery Energy Storage System (BESS)

49 The BESS consists of steel containers housing lithium-ion batteries, along with associated equipment like transformers, inverters, and switchgear.

50 Large-scale UK recycling facilities for lithium-ion batteries are currently limited but are currently in development. Operators typically partner with international facilities in Europe and Asia, where recycling efficiencies of up to 90% are achievable. Many battery suppliers include end-of-life recycling as part of their supply contracts.

10.1.3 Substation Equipment

51 Substations contain high-voltage transformers, circuit breakers, and control systems. These components are largely recyclable and are typically dismantled by specialist contractors. Recycling rates for this equipment typically exceed 95%, thanks to the high metal content.

10.1.4 Inverters and Transformers

52 Inverters include semiconductors, capacitors, and printed circuit boards, all of which can be recycled. Most are dismantled and shredded before materials are separated for recovery.

53 Transformers consist of steel casings, copper or aluminium coils, ceramic bushings, and insulating oil. While the oil requires specialist handling, the rest of the unit is commonly stripped and refurbished or recycled.

10.1.5 Switchgear and Cabling

54 Switchgear (e.g., relays, fuses, breakers) and electrical cabling (typically copper or aluminium) are widely recycled throughout the UK, with established processes in place for recovering both metals and plastics.

10.1.6 Mounting Structures

55 Panel support frames and mounting systems are generally made from galvanised steel or aluminium. These materials are fully recyclable and easily reprocessed in the UK's scrap metal sector.

56 Decommissioning will be carefully planned and executed to minimise environmental impact, maximise material recovery, and return the land to its pre-development condition.