Keeping your lights on.

The trouble with power cuts

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Introduction

In the 21st century, we take electricity for granted. Modern society is completely reliant on electricity, and getting power at the flick of a switch is taken as a given. As individuals, our dependency on electricity is ever-increasing – and our expectations and demands on the grid are getting higher as new technologies such as electric vehicles and evolving working practices like home working continue to rise.

The lack of general awareness surrounding such an essential service is perhaps surprising, given our complete reliance on electrical power. Behind the scenes, networks are managed by local electricity distribution companies whose highly skilled staff keep the lights on by making use of innovative equipment and technology to meet growing demands and keep customers satisfied.

So how do we keep the power on – and what happens when we don't? Losing power has a massive effect that can sometimes spiral. In this ebook we examine the key issues and what we can do to ensure that the next-generation network can keep providing a reliable supply of electricity..

It's a changing world, and the pressure is on for the grid to keep pace. With a Net Zero target by 2050 to meet, renewable energy plays a critical role in the power generation mix, placing new challenges on ageing infrastructure.

33%

WAS THE UK'S RECORDED RISE OF RENEWABLES' SHARE OF GENERATION IN 2018

10%

INCREASE IN RENEWABLE CAPACITY ACROSS THE UK

1/4

OF UK GENERATED CAPACITY IS RENEWABLES

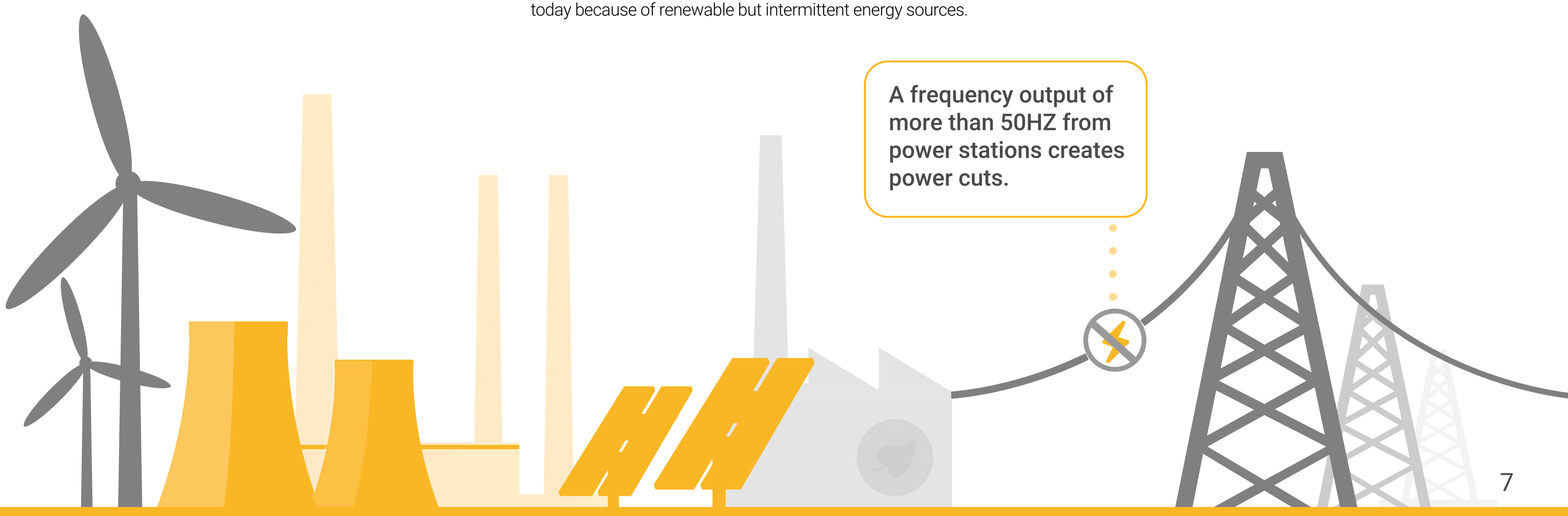
Plunged into darkness

The kind of catastrophic power cuts that hit the headlines – known as Black Sky events – may be pretty rare, but there are plenty of less dramatic power-outage incidents all the time. Smaller, localised power cuts are a lot more frequent than the general public might think and, on any given day, there might be as many as a couple of hundred small power cuts around the UK. Added to that is the occurrence of brownouts **(read our blog)**, where the power dips rather than cutting out altogether, often as a result of balancing demand on the network.

During a major power cut, reacting quickly is critical to managing the electrical frequency of the grid – how quickly alternating current (AC) is changing from one direction to the other. In the UK, this happens 50 times per second – so 50Hz is the designated frequency of the grid. All power sources have to meet that output as closely as possible. When demand on the grid exceeds supply, the frequency falls as the system struggles. And, while you might think that power cuts belong back in the1970s, there is a greater risk of power cuts today because of renewable but intermittent energy sources.

In this kind of situation, the impact can escalate from 'inconvenient' to 'dangerous' in a matter of seconds – traffic lights can fail, flights can be grounded and passengers incarcerated on halted trains.

A frequency output of more than 50HZ from power stations creates power cuts.



There are around 350 power stations in the UK, using a variety of energy sources, spanning coal, gas nuclear fuel and renewable energy sources including wind and solar. The energy generated feeds into the National Grid's transmission network.

What causes a power cut?

There are several reasons why the power can fail suddenly and without warning, and at the heart of this is the inescapable fact that the UK's 'super grid' network of interconnected power stations is over 50 years old. On top of that, much of the power network is located above ground, putting it at risk of a variety of types of damage. Key causes of power cuts include:

01

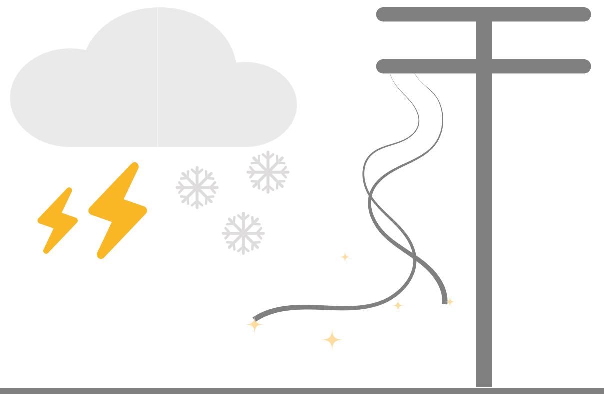
Technical problems from faults at power stations to transient or intermittent faults at substations, including deterioration or water seeping into an old cable with tiny cracks.

02

Meteorological damage cause by passing storms bringing down a power line, lightning strikes, heavy snow and even geomagnetic disturbance due to solar storms involving mass ejections of coronal matter. Geomagnetic disturbance has become an increasingly relevant issue in recent years as our power transmission lines have become longer, more interconnected, and therefore more vulnerable.

03

Human (or animal) damage involving break-ins, vandalism, arson and theft at substations, gardening incidents at home or construction projects that result in severed cables from digging and so on. These unpredictable events can take a while to pinpoint when a problem ensues. For example, one of the more random reasons for a power outage are birds flying into an overhead power conductor!



How do lights work?

Electricity flows into an energy conversion device – in this case, let's say an incandescent light bulb.

The electrical current is sent through a thin wire – the filament – which mostly consists of tungsten metal and has a large resistance.

The metal contains many electrons – as the atoms in the metal heat up they rebound against the currents high-energy electrons.

This process heats up the filament to the point where it glows, producing light. In an LED (light-emitting diode) bulb, electrons emit light simply because they are 'excited' by the electrical current, rather than becoming hot.

The impact of low carbon technologies

There is an additional factor to consider when keeping the lights on: increased network demands and the connection of new devices on the Low Voltage network, including low carbon technologies (LCT) such as photovoltaic generators (PV), electric vehicles (EV) and heat pumps (HP). The growing use of these new technologies can result in different load and voltage profiles on the Low Voltage network.

Detecting a fault

So what happens when something goes wrong? Does a warning light start flashing at Electricity HQ, accompanied by a loud klaxon? This might be the reassuring assumption of the general public – however, the reality is usually a long way away from this comforting imaginary scenario. In reality, Distribution Network Operators (DNOs) are, mostly, reliant on the general public reporting power outages. In particular at lower voltage levels. This in itself is problematic, as there is a lot of confusion among consumers surrounding where their electricity actually comes from.

When there's a power cut, many people don't realise that it takes a person to make the call to the electricity provider, who can then 'send someone out' to check out the fault issue – in the 2020s, this may seem surprisingly rudimentary, given that most other services are monitored in real-time. However, widespread live monitoring has eluded the electricity industry so far, by and large.

If the starting point for putting the problem right is that the people affected report the power cut, it's a big issue. Without receiving notification from those who are actually in the dark, electricity providers are also in the dark, figuratively speaking. It might come as a shock to the general public that, in the main, network systems aren't sophisticated enough to detect power failures on their own. Relying on someone to call the new 105 number (in the UK) to notify the DNO of the issue is a vital first step to initiate fault investigation.

Research by the Energy Networks Association (ENA) in establishing the need for centralised fault reporting showed that the vast majority of the public don't know who to call or what number to use in the event of a power outage or network-related problem; even with the advent of 105 as a quick reporting mechanism, finding out what to do in a hurry can prove difficult and result in delays in contacting the DNO, calls to the wrong organisation or failure to make contact at all.

ESTABLISHING THE NEED FOR CENTRALISED FAULT REPORTING

*RESEARCH BY ENERGY NETWORKS ASSOCIATION (ENA)

72%

OF PEOPLE DON'T KNOW WHO TO CONTACT IN THE EVENT OF A POWER OUTAGE

442,613

FAULT INCIDENTS ON THE ELECTRICITY DISTRIBUTION NETWORK NATIONALLY BETWEEN JANUARY - DECEMBER iN THE LAST RECORDED AUDIT

MANY PEOPLE INCORRECTLY BELIEVE THAT THEY NEED TO CONTACT THE COMPANY THEY PAY THEIR ELECTRICITY BILL TO

6.5%

OF FAULTS ON NETWORKS WITH AUTOMATIC FAULT DETECTIONS

Ofgem agreed that customer contact is, "critical as it may be the first knowledge a DNO has that a fault has occurred on its network".

PUBLIC DOESN'T UNDERSTAND ROLE OF DNO OR WHO TO CONTACT WITH A POWER OUTAGE

93.5%

OF FAULTS REQUIRED CUSTOMER TO NOTIFY NETWORK OPERATOR BEFORE FAULT IDENTIFICATION & SUPPLY RESTORATION COULD BEGIN

Use of tech to detect disturbances

A vast, interconnected power grid makes it hard to predict failures. However, it is possible to identify and resolve network faults without the need for an engineer to visit the site.

For example, traditional substation fuses are problematic, with link boxes being buried in the ground to connect substations together. They allow the engineer to manually reconfigure the electricity networks during maintenance when dealing with faults or balancing supply and demand. However, doing this manually is time-consuming. But the **technology is now available** to deal with a short circuit, cascading failure, fuse or circuit breaker operation remotely by temporarily automatically shutting off the fault and re-routing the electricity supply. **View our ALVIN video.** Intelligent automation and fault restoration on low-voltage networks has a significant role to play in keeping the lights on, reducing engineering costs and increasing customer satisfaction. For more tactics and tech to improve power networks, **read our blog.**

Contact us to find out more

What's the impact and value of lost load (VoLL)

Power cuts have financial and social impacts on customers, particularly those who are vulnerable. In terms of the severity of the effect, there are variables to consider, from which season to time of day, customer load and customer type. As the global COVID-19 pandemic demonstrated, working from home makes the reliability of supply for domestic customers vital – when the power flow goes off, so does the Wi-Fi router.

DNOs get fined for outages and, while the VoLL model used in the UK has placed the same value on all customers, it's been argued that defining the VoLL more accurately by customer segment can help with network planning and strategic investment.

Electricity North West identified two key ways to alleviate the costs of loss of supply to customers:

1. **Proactive network investment to reduce the length and frequency of supply interruptions.**
2. **Communicating with them during power cuts to provide accurate information about when power will be restored. The DNO's research shows that while there is tolerance for limited planned work requiring outages, tolerance for these declines when customers have experienced more than three full-day interruptions over a three-year period.**

Managing customers' expectations

In the real world, it's impossible to completely eliminate power outages – but taking the right approach can help to ease the pain for consumers. Research by Electricity North West shows that:

Customers are more tolerant of planned supply interruptions than unplanned interruptions, as they can prepare in advance

The monetary figure customers are willing to accept (WTA), in compensation for loss of supply, is much higher than the amount they are willing to pay (WTP) to avoid a supply interruption

SME customers have a higher VoLL than domestic customers

The domestic customers with the highest VoLL are the fuel poor, people in rural areas, those in low-income groups, those classified as vulnerable, and current users of low carbon technologies (LCTs), particularly drivers of electric vehicles (EVs)

Domestic customer segments with the lowest VoLL are those with recent experience of a large scale, lengthy supply interruption and urban customers.

For SMEs, customers who've experienced one or more unplanned interruptions in the last three years have the highest VoLL (those with no interruptions in the same period have the lowest VoLL).

Power cuts: what does the future hold

With all the futuristic advances predicted by films (we are now in the era of sci-fi classics Blade Runner, set in 2019, with 12 Monkeys just around the corner in 2028, after all), it might seem a little disappointing that we're only just seeing the widespread installation of smart meters in 2020.

But change is on the horizon out of necessity, thanks to increases in distributed generation through technologies that generate electricity at or near the point of use, including solar panels and combined heat and power. The adoption of this tech is forcing a change on the role of DNOs as they transition into system operator functions, such as active network management, using new-technology and real-time data to make interventions on the network. This is referred to as a transition from DNO to Distribution System Operator (DSO).

While tackling the real-time imbalance between generation and load to avoid power cuts, predicting faults and quickly rectifying power outages are likely to remain challenges, proactive network investment and the use of new diagnostic technologies can help to ensure that the lights stay on.

9 August 2019: a perfect storm

Black Sky events are a rarity – but what can happen when everything goes wrong at once? On 9 August 2019, a major blackout unfolded rapidly in the UK. Here's what happened...

At 4:52pm on 9 August 2019, just before the Friday rush hour, around 1 million customers lost power following a series of events on the electricity system. The ensuing disruption to people at home, at work, and to commuters trying to get home, had a huge impact around London, with some rail services being badly impacted because the protection systems on some trains failed to operate as expected.

The chain of events

To set the scene, the weather was typical for the time of year – warm and windy. Electricity demand was predicted to be as normal for a Friday. Then a lightning strike hit a transmission circuit – but the line returned to normal operation within 20 seconds. At the same time, there was a loss of about 150MW of small embedded generation connected to the distribution network, caused by vector shift protection – a normal outcome during a lightning strike on a transmission line.

Unfortunately, immediately after the lightning strike, Hornsea offshore wind farm dropped its energy supply to the grid by 737MW and Little Barford power station's steam turbine tripped, thus decreasing its energy supply to the grid by 244MW. This generation wouldn't be expected to trip off or de-load in response to a lightning strike, so it was a very rare and unexpected event, leading to:

A cumulative loss of 1,131MW of generation, causing... A rapid fall in frequency, leading to... The disconnection of an extra 350MW of embedded generation from the system.

1481MW

THE TOTAL GENERATION LOST FROM ALL THESE INCIDENTS

1000MW

LEVEL REQUIRED UNDER THE REGULATORY APPROVED SECURITY AND QUALITY OF SUPPLY STANDARDS (SQSS).

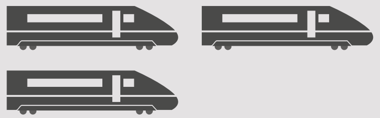
As the system began to recover from this cumulative oss, all of the back-up power available had been used. The frequency then fell to 48.8Hz – a huge dip – so secondary backup systems acted automatically to disconnect approximately 5% of demand, as per the Low-Frequency Demand Disconnection (LFDD) scheme. While this allowed the frequency to recover, ensuring the safety of the network, the second gas turbine at Little Barford then tripped at 187MW, meaning the total loss of generation was 1,878MW.

The LFDD scheme kicked in

The LFDD scheme automatically disconnected customers on the distribution network in a controlled way as per DNOs' parameters. Around 1GW of the UK's electricity demand was disconnected, the first such occurrence in over 10 years.

The result

1.1M CUSTOMERS WERE WITHOUT POWER FOR A PERIOD BETWEEN 15 AND 45 MINUTES.



60 TRAINS SHUT DOWN WITHOUT WARNING WHEN FREQUENCY DROPPED BELOW 49HZ

On losing power, the trains would automatically have switched to back-up batteries to maintain essential systems. However, getting the trains moving again once the power came back was not straightforward – in some instance, the on-board computers had shut systems down more fully than expected, requiring manual intervention, which took several hours in many cases.

At the height of the power cut, roughly half a million people were affected in Western Power Distribution's area (including some in Wales) and 110,000 Northern Powergrid customers also lost power. In London and the south-east, 300,000 people were affected, according to UK Power Networks, and another 26,000 customers lost power in north-west England. Northern Powergrid also reported problems at affected Newcastle Airport and on Newcastle's metro system. At Ipswich Hospital, where a back-up generator failed to start, and Newcastle Airport were also affected.

It could have been worse, without access to standby power and the help of six megawatts (MW) from five large lithium-ion batteries on a solar farm near Luton Airport, in particular. Within seconds of problems hitting the grid, a fleet of batteries dotted around the country responded, pumping enough power into the system to stop a rapid drop off in transmission frequency.

Read the full technical report here

technology

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