Living Without Electricity Transcript

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Abstract

Storm Desmond brought unprecedented floods to Lancaster in December 2015 and electricity supplies were cut off and not fully restored for six days. The disruption revealed how dependent on electricity modern city life has become. What happens when power, communications, and transport are all disrupted, when shops cannot function, and when most people cannot find out what is happening? What lessons have been learnt?

Society's Dependence on Electricity

To most people under 40 the World Wide Web and GSM phones are part of life but, in reality, the WWW is only 22 years old. In the 1980s it was considered revolutionary to send electronic messages outside one organisation but, by the mid-1990s, international businesses were using programmes like Lotus Notes to communicate between sites on different continents. Individual email access was through the telephone network and it was usual for people involved in international business to carry round a bag of adaptors so they could unplug the phone in their hotel room and connect a laptop to a remote server – a complicated, slow and expensive connection. It was only in the late 1990s that Wi Fi started to become widely available.

Mobile phones first became available in 1985 but their widespread use only took off a decade later and, as it was not unusual to pay £700 for a handset, most purchasers were businesses. It was not until the new millennium that mobile phones and internet coalesced to form the seamless, ubiquitous information network we know today.

In the last 15 years, society has been changed dramatically by the mobile/internet revolution. Corporate memos have universally been replaced by email, physical notice boards by internet message boards, post cards by picture text messages. Video hire shops have closed and been replaced by Netflix; electronic books are read on Kindle; music is streamed; TV is watched through iPlayer. More ominously, corruption scandals are now more likely to involve hacking of data or mobile phones than "traditional" bribery and the proportion of theft committed on-line continues to rise.

Government has been quick to adopt this communications medium. Registering a car, paying income tax and applying for JSA are all on-line.

Over the first weekend in December 2015, Storm Desmond brought unprecedented flooding to North Lancashire and Cumbria, including to the industrial estate where Lancaster's main substation is located. At 22:39 hrs on Saturday, 5 December, electricity supplies to 60,987 properties in the city were cut. The loss of power quickly affected many other services that people take for granted. Most mobile phone coverage was lost and people who had replaced their traditional handsets with cordless phones were unable to connect. The internet was lost over most of Lancaster as were electronic payment systems, so shops were shut and ATMs (cash machines) did not work. The local TV booster station lost power, which also affected digital radio services. There are few high-rise buildings in the city but all lost power for their lifts and some upper floors lost water supplies. Access control systems stopped working.

The effects on lighting, heating and cooking were predictable. The effects on communications, although readily foreseeable, took many people by surprise as, increasingly, society has moved from paper-based to mobile phone and internet-based systems.

At the same time as our dependence on electricity has grown, the electricity supply network has become more indeterminate and with more complex failure modes. The model of the past 100 years of large central power stations feeding passive consumers is being replaced by complex networks where power can flow in any direction and with a diversity of sources of energy, many dependent on the time-of-day, the weather or the state of the tides. The introduction of smart meters will further blur the boundary between the electrical power network and data/control systems.

Resilience is affected in two ways – the severity of high-impact events is becoming greater, and essential actions to decarbonise other sectors are placing increasing demands on the integrity of the network. In parallel, dependence on electricity is more critical and resilience is thus far more important.

The Electricity Supply

For 100 years, the principles behind Britain's electricity sector remained largely unchanged and, before the First World War, the world's first ac distribution grid had been built in Newcastle upon Tyne. For the past 50 years, Britain's electricity supply has been very reliable. Major outages have been few and far between.

However, the last decade has seen the beginnings of a revolution: this is an international trend and one that will change the way established power systems operate. In Britain the Climate Change Act 2008 and similar regulations have triggered a paradigm shift in the way electricity will be produced. So far, we have seen relatively small changes but phasing-out coal-fired power stations and the widespread adoption of renewable energy will change the power system radically. [IET 2014 & 2016] Not least will be the change in the number of bodies involved. Until a decade ago almost all electricity generation was in the hands of a few dozen generating companies; in a decade's time, we can expect to see several million individuals and companies providing power to the network.

Power flows through the grid are also changing: rather than all power flowing from central power stations to passive consumers, electricity is being generated by solar PV panels on houses and businesses and by community scale renewable energy connected to the distribution grid. This can result in reversal of power flows that may not be within the capability of today's networks. There are also substantial new types of load coming on the system including high-power chargers for plug-in vehicle batteries and electrically-powered heat pumps. [RAEng 2010, DECC 2013] Many of these will be controlled by intelligent systems, provided by many different commercial organisations, driven by control algorithms not known to the transmission network operator.

These changes are making the electricity grid a far more complex system. Sidney Dekker has written:

"The growth in complexity in society has got ahead of our understanding of how complex systems work and fail. We are able to build things – from deep sea oil rigs to collateralised debt obligations – whose properties we can model and understand in isolation. But, when released into competitive, nominally regulated societies, their connections proliferate, their interactions and interdependencies multiply. And we are caught short." [Dekkar, 2011]

A complex system is not intrinsically more risky that a simple one – after all, the complexity might be a reflection on the availability of multiple suppliers using different technologies that reduces the risk of a systemic failure. But the complexity that is growing in the electricity sector will inevitably make the system less predictable and more difficult to manage in a crisis.

Lancaster's Experience

On 5 December 2015, the Met Office issued a red severe weather warning for rain in Cumbria and North Lancashire with 150 to 200 mm expected in some places. There had already been exceptional rainfall in Cumbria in the previous month; much of the ground was already waterlogged and the flood plain upstream of Lancaster was flooded. The River Lune, which runs past the Lancaster main electricity substation, rises to the north of the Howgill Fells in Cumbria and collects water from part of the area covered by the red warning. At peak, the

Environment Agency recorded a flow of 1,742 cubic metres of water per second – the highest flow of any river ever recorded in England.

After flooding in recent years, the main Lancaster substation had been provided with a new flood barrier. For most of Saturday 5 December, the water level remained below the top of the barrier but, in the evening, it rose significantly and threatened to flood the substation. High-capacity pumps and additional protection were brought in but were unsuccessful. On-site representatives of Electricity North West (ENWL), the police and the fire service took the decision that, unless the substation was isolated, there was a risk of major damage and, at 22:39, the substation was switched off. Supplies were lost to 60,987 consumers. [RAEng 2016]

75 large generators were brought into Lancaster from as far away as the West Country and Northern Ireland and were hooked up to local substations. These allowed 22,000 consumers to be reconnected during Sunday. By noon, the water had receded and the main substation had been pumped out, allowing safe access. Grid Transformer 1 was restored at 04:28 on Monday 7 December, which allowed supplies to almost all consumers by 15:30.

There were other problems later in the week where, during the flood, water had seeped into a high-voltage busbar chamber which subsequently caused a flashover. This was resolved by a major reconfiguration of the substation allowing all services to be restored by the end of the week.

Telephones and the Internet

The wired telephone system, powered from batteries in the exchange, continued to operate over most of Lancaster. Some areas were out of action but that was largely caused by flood water saturating the connection boxes, rather than the loss of electricity supply. Many people who had replaced wired handsets with wireless discovered that these do not work without a mains supply.

Mobile phone systems did not hold up. On most networks, the base station (the transmitter that provides the radio signal to communicate with phones in that area) is powered from the local 230V electricity supply. Some have a battery back-up that continues to provide a service for an hour or two but few, if any, cope with the 30-hour loss or supply experienced over much of Lancaster. Inevitably, the loss of a mobile signal resulted in the inability to send or receive text messages or to use 3G and 4G internet services.

Most domestic internet connections were also lost. This is because the equipment case (usually at the roadside) that houses the routers linking the high-speed fibre connections with the copper wires going to individual houses is powered from the 230V supply.

Local Radio

During the floods and the loss of the electricity supply, local radio was the best way of finding out what was going on. The first challenge for many people was to find a battery or wind-up radio capable of receiving the FM band, as the local digital radio transmitter was off-air. The second challenge was to find suitable batteries. The third was to decide which of the dozen or so FM channels available in Lancaster was most likely to include local news.

The most used channel was The Bay radio. Their studio is on the Quay overlooking the river. The ground floor flooded but they set up a temporary studio on an upper floor with a generator power supply. However, their only link with the outside world was via a single phone line. They sent one of their reporters home, to Heysham which still had power, to look at the internet and phone in to say what she could find out that could be relayed to listeners. A second source of information came from listeners who phoned in with something interesting – useful snippets such as where in Morecambe it was possible to get wireless internet reception or which roads were open. By contrast, other regional stations were based outside the area and, with no phone coverage, had no way of finding out what was going on. It is ironic that, in these days of internet and broadband, the most reliable news source used technology that would have been familiar to the operators of Radio Caroline, the 1960s pirate radio station.

The University

Lancaster University has about 12,000 students, 7,000 of whom live on campus. During the 1984-1985 miners' strike, when the government cut back on electricity generation to conserve coal stocks and introduced rolling nationwide blackouts, students stayed in their rooms and used candles. Since then, health and safety standards have moved on. Candles are banned in rooms because of the fire risk; student residences have to be fitted with emergency lighting and smoke detectors.

Emergency lighting systems relying on batteries are designed to ride through a short interruption of supply or to give occupants time for an orderly and well-planned evacuation in the event of a more serious event. After about three hours, the batteries are exhausted. The fire detector system runs for longer but still for less than a day. At 23:00 on Saturday, it was decided that the safest plan was to leave students in their accommodation, despite the lack of emergency lighting.

Many students do not carry cash. Under normal circumstances, more than half of coffees and snacks bought on campus are paid for by a swipe card. With no electricity, there was no internet and thus swipe cards did not work. The University decided to hand out free food, as did at least one restaurant in the city centre, to great acclaim.

By 11:00 on Sunday, the news from the local network operator was that the power was likely to be off until Tuesday evening, so the decision was taken to close the university a week early. However, the usual way of communicating with students is email or a notice on the university website. With power supplies restricted to a few buildings, Wi-Fi was only available sporadically across the campus and many students' phones or tablets had flat batteries – so the university staff reverted to the more traditional technique of knocking on doors. Communicating with students living in flats in the city was more difficult and relied partly on face-to-face briefing of students on campus and hoping that they would pass on the message. Inevitably the message became corrupted: according to the police, a crowd of several hundred overseas students arrived at Lancaster police station expecting to find transport.

The situation was not made any easier by the closure of Lancaster railway station from dusk to dawn. Lancaster is on the West Coast Main Line (WCML) of the rail network. The WCML is electrified at 25 kV but the power for trains in Lancaster is drawn from the 132 kV lines at feeder stations near Garstang and Kendal, rather than from the local network. Thus trains could continue to operate despite the loss of power in Lancaster.

Railway stations have auxiliary supplies taken from the local electricity network. These feed platform lighting, heating and lighting in offices and control rooms, de-icing heaters on points, the public address and information systems, ticket machines, lifts and many other pieces of equipment. With the loss of the supply, all these stopped working. Without lighting or any of the normal means of communicating with passengers, the station operator took the decision to close at dusk.

Life in the City

The problems at the university were merely part of a wider situation in the city. Schools that usually communicate by text messages, were unable to tell parents when they would reopen; ATM machines and electronic tills in shops were not working; traffic lights and bus stops were dark; petrol pumps couldn't deliver fuel; electrically-operated garage doors wouldn't open; lifts stopped; swipe-card access systems didn't respond, and water supplies to upper floors of blocks of flats failed.

Investigations since the floods have identified that things could have been worse. The city's water supply is from a large reservoir in the hills, 100 m above the city, capable of storing thousands of tonnes of water. Had we relied on water towers the supply would not have lasted more than a few hours. The sewage system continued to cope without its usual source of power for pumps. We were also lucky that the flood occurred on a Saturday evening; organisations, such as schools, had all Sunday to decide what to do.

People at Risk

Lancaster is a small city in a rural part of the country. For healthy people, with some spare cash and a full larder in their self-contained house, loss of power was not a serious problem. Those who had log-burners, camping cookers and a few bottles of wine in the cellar were able to invite neighbours round for an impromptu and convivial supper. For some others, the experience was much less positive. A care home with 70 frail residents lost light, heat, hot water, the ability to cook food, the phone system, call alarms, access control, electronic patient records and the power for hoists and other equipment. The home also lost all television, which can be a major source of entertainment and distraction for residents. The chef braved the storm and made a barbeque in the garden to produce food for the residents; relatives of one resident arrived in their camper-van and used their bottled gas to make a steady supply of teas and coffees.

Increasingly people with chronic illnesses are cared for in the community. Without electricity, dialysis or oxygen therapy machines did not work and the lack of stair lifts was restricting. Luckily there are few high-rise flats in the city as the failure of lifts, lighting, cooking, heating, water, intercom systems and access control would make life very difficult for those relying on wheelchairs.

Lancaster has one of few professional producing theatres in Lancashire – the Dukes. In the months following Storm Desmond, the theatre worked with local organisations supporting homeless people to produce After the Floods, an original production by a group called Alternative Outcomes in which the audience were invited into blacked out tents – inspired by the story of one performer's journey after waking in the middle of the night to find the river had risen around his tent whilst camped on the banks of the Lune. [The Dukes]

"The floods of December 2015 will go down in the collective memory of Lancaster as the days which brought the city together through adversity. Alternative Outcomes' perspective on that night has come together in a creative expression of community." Cat Smith, MP for Lancaster and Fleetwood

Increasing Challenges for an "Always On" Culture

When considering the resilience of the electrical system, we have to take into account not only the supply but how it is used. These are two aspects to resilience – what is the likelihood of failure under challenging conditions and what are the implications?

Twenty five years ago mobile phones were expensive, large and clunky; their user were mainly business executives for whom the phone was sometimes a status symbol, rather than an essential tool. Today whole groups of people do not have a corded phone and a mobile is their main means of communication. Among the general public, computers were predominantly used by hobbyists or as replacements for calculators or as word processors. Web browsers, as we now know them, had not been invented.

In the intervening years, computers, tablets, mobile phones and the internet have become omnipresent. Paper-based and face-to-face systems have been phased-out and replaced by electronic data. Medical records, government documents, music, films, meter readings, hospital appointments, newspapers, job applications, business meetings, photo albums, diaries, pharmaceutical prescriptions, address books, train timetables, phone directories, letters and even applications for social benefits are all dependent on the internet.

The Department for Culture, Media and Sport has a policy for superfast broadband coverage to 95% of the UK by December 2017. The downside is that, the better the internet becomes, the more people will rely on it and the effects of the loss of the internet will quickly spread through the community. While the internet and mobile phones, which are central to our way of life, rely on mains electricity, the effects on resilience of its loss are more severe.

Many seemingly disconnected changes in society have increased dependence on communications systems, and thus on electricity. For example, when schools were managed by a local education authority, head teachers had a local person to whom they could turn for advice or coordination. Increasingly heads report to an academy chain that may be based in a different part of the country and services have been contracted-out to a lowest bidder.

As discussed earlier, the provision of resilience is becoming more complicated. We are no longer looking simply at the availability of adequate numbers of thermal power stations. To meet policies on climate change, sources of supply are becoming more diffuse, more intermittent and more susceptible to the unpredictability of the changing climate. The proliferation of electronic systems to control this plethora of generating sources and controllable loads also introduces new risks due to increased complexity. All this poses challenges to our internet-based “always on” culture.

Challenges to the Grid

This loss of supply in Lancaster was caused by an intense storm. Commentators talked about a “once in a 100 years event”; however the fundamental characteristic of climate change is that the present is – and the future will be – different from the past, so statements like this are meaningless. In the four months between November 2015 and March 2016, there were eleven named storms that affected the UK or Ireland: Abigail, Barney, Clodagh, Desmond, Eva, Frank, Gertrude, Henry, Imogen, Jake and Katie. All caused wind damage, flooding or both. With increasing climate volatility, it is likely that environmental factors will result in a greater frequency of events that could lead to loss of supply.

Intense storms are not the only possible cause of a blackout. Other natural triggers include geomagnetic disturbances or solar flares [RAEng 2013]. There are also man-made causes of a blackout; on 23 December 2015, more than 100,000 people in and around the Ukrainian city of Ivano-Frankivsk suffered a six-hour loss of power caused by cyber-terrorism. A month later, the Israeli power system came under attack from hackers. Much of the UK’s electricity infrastructure is in open country where protection from a determined and widespread physical attack would be almost impossible. There are also possible, if improbable, sequences of technical events that could shut down large areas of the National Grid. On 30 September 2012, a combination of failures caused a rapid change in frequency that came close to the rate that could have triggered widespread disconnection of generators and power outages.

Where Should Resilience Be Located?

Storm Desmond demonstrated the need for greater resilience in several systems on which people rely – in particular communications systems. This raises the question of where that additional resilience is best located. At one extreme, responsibility for coping with supply intermittency could be placed squarely on individual businesses and households – resilience is the responsibility of those affected. Such an approach of rugged self-reliance might send the message “If you rely on a mains-powered dialysis equipment, buy a petrol generator in case the power goes off”. The downside to this policy is that those most at risk may be the ones least able to invest directly in effective resilience.

At the next level, it would be possible to place the responsibility on a service provider. For example, Ofcom could place a requirement in mobile phone operator licences that operators had to continue to provide a service under conditions of loss of power for at least 3 days. Alternatively, there could be a regulatory obligation on the distribution network operator (DNO) to provide duplication to maintain a supply of electricity under such circumstances.

Another option would be for regulators to allow a much greater rate of failures of the electricity supply and/or communications systems but to overlay this with a rapid-response mobile back-up system that could restore services on a temporary basis, while the main systems are being repaired. However, within the privatised telecoms sector and the diverse ownership of the internet, it is not clear where this responsibility should, or even could, reside.

It is not possible to choose one of the above strategies in isolation. Some, such as requiring mobile phone companies to maintain a service for several days without external power or requiring a DNO to hold 100% standby power for a large area, could be prohibitively expensive. The scope of emergency provision will depend on the scale of the disruption envisaged. ENWL had to scour the UK to find 75 generators to supply Lancaster; providing 750 to supply Birmingham would be a problem of a different order of magnitude. Coping with a four-day "black start" of the whole of Great Britain's electricity system would be another two orders of magnitude in scale.

The electricity supply system in Great Britain is generally very reliable. The Storm Desmond loss of power in Lancaster was noteworthy because of the number of people affected and the duration. Most consumers experience power cuts of no more than a few hours per year, if any. In cities like Lagos or Baghdad, where 12 hours of power cuts per day are not uncommon, it is not difficult for consumers to make a case for investing in standby generation. In Britain, few people would be prepared to pay for equipment that will be unused for years on end and may reach the end of its life without ever having been needed.

Conclusions

The importance of the resilience of the power system is related to how dependent society has become on "always on" electricity. Experience from Storm Desmond suggests that it is central to society and is becoming increasingly important. We have reached this situation almost by accident, with little strategic thought to the risks of this direction of travel.

Decarbonisation of the electricity system could be seen to make it more resilient as it breaks the dependence on fossil fuels, most of which are imported and subject to political interruption. However this form of dependence is being replaced by dependence on aspects of weather conditions that are themselves variable and could develop unpredictably as a result of climate change.

Increasingly, the electricity generating system is becoming linked to the internet and intelligent systems. Some of these systems will be owned or managed by the system operator, others may be owned by technology companies with different objectives. We could thus see a network of disruptive influences on the robustness of the electricity system – variable and unpredictable sources of energy, multiple owners, each attempting through complex software systems to optimise their corner of the system and possible interventions from hackers attempting to destabilise the network. This situation would be overseen by regulatory and management structures, based on a neoliberal commitment to "the market", that were designed for last century.

We are beginning to see well-researched technical solutions to re-engineer the network to make it suitable for its new role in a multi-player energy system and thus underwrite its resilience. Less well developed are possible replacements for the commercial and regulatory structure. The lifetime of investments in energy systems are 25 to 50 years from initial concept to decommissioning and so time is short.

Perhaps most importantly, we need a public discussion on how we are moving towards dependence on electrical systems. This cannot be simply a forum for esoteric debate between systems engineering experts: our experience in Lancaster showed that it has to involve all groups in society.

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