The Institution of Engineering and Technology

Interdependencies and resilience in digital transformation

Looking at adaptability and interdependence across energy networks, communications, and infrastructure in an increasingly interconnected world.

theiet.org/energy

Contents

Interdependencies and resilience in digital transformation is published by the Institution of Engineering and Technology (IET).

Please note that the views expressed in this publication are not necessarily those of the IET. The report only intends to identify the relevant issues and to inform a public policy debate around the topic, rather than to provide a definitive solution.

The IET Energy Panel would welcome any comments you may have on the contents of this report and your ideas for future energy publications. Please get in touch by emailing **sep@theiet.org**.

1. About this report

This report has been produced by the Institution of Engineering and Technology (IET) to look at adaptability and interdependence, across energy networks, communications, and infrastructure in an increasingly interconnected world. The report uses the public switched telephone network (PSTN) withdrawal[1], and its impact on the gas energy networks' as a case study, to demonstrate interdependency across sectors including between energy and communications, and the need for a more joined up 'whole systems' approach. The report is written for government, engineers, regulators, industry, utility, digital and communication sectors.

The report discusses infrastructure resilience in a digital world, specifically looking at energy and communications. The case study and references show the importance of wider infrastructure issues, whole systems thinking, societal impact, interdependencies in planning and managing change, and the impacts on legacy infrastructure (particularly hidden services and uses).

BT Openreach announced in 2015 its decision to withdraw PSTN services and products; part of a long-term shift from analogue to digital. This has enormous benefits for the user but the PSTN and integrated services digital network (ISDN) withdrawal will affect both business and residential customers especially if they are used for databased services over a landline.

Most users will not notice, but there are several key situations where the PSTN is depended upon. One such use-case is the gas distribution networks. Gas network operators rely on the PSTN to connect to remote network assets for the purpose of operational monitoring and control. The impact of the PSTN switch off on the gas energy network, provides clear evidence of interdependency across sectors; in this case telecommunication and energy. An increasingly decarbonised electricity network is becoming much more complex and climate dependent with many more modes of failure; The further we go down the path of distributed renewables and digitalisation, the greater the complexity and the scope for unforeseen issues.

Digital transition is a key enabler for net zero achievement – the increasing importance of a secure, robust, and resilient operational telecommunications capability must be prioritised by the UK energy network operators[2] and Government.

This report was commissioned by the IET Energy Policy and Communications Panels, expert volunteer groups that create thought leadership and policy advice to inform Government, regulators, energy, and communication sectors. The authors are Dr Peter D. Couch and Professor Will J. Stewart.

Dr Peter D. Couch, MBA C.Eng. is the chief executive officer at Joint Radio Company working with energy utilities to establish the optimum regulatory regime to facilitate the Smart Grid future.

Prof Will J. Stewart FREng, FInstP, FIET, FOSA is an independent telecommunications-photonics professional, visitor at the University of Southampton and expert advisor to various foresight projects. He has wide interests in technologies from communications to biosensing and was educated at Imperial College in physics.

1 The closure of the public switched telephone network - CCS (crowncommercial.gov.uk).
2 Need for Increased Spectrum Allocation and Investment in Operational Telecommunications to Support Electricity Networks, Position Statement of the Energy Networks Association Strategic Telecommunications Group.

2. Recommendations

The experience of the gas network operators in overcoming the challenges of losing the 'hidden uses' such as local mains power of the PSTN in the digital switchover, has provided clear lessons on risk management when implementing change across systems in isolation. We have outlined ways to avoid the many issues being experienced by the gas networks and encourage the application of the lessons learned across other legacy infrastructure, systems and sectors.

1

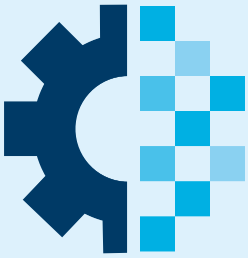
There is an urgent need for greater joined up thinking across government, multiple sectors, agencies, and systems.

- Engagement and communication must consider all stakeholders such as different sectors, regulators, industry, supply chain, local authorities, communities, and individuals.
- Resilience must be considered and managed as an interconnected issue.
- Risk appetite and a clear understanding of priorities must be the foundation of planning including mitigation strategies, in both the transition and delivery phases.

2

Government, regulators, utilities, telecommunications and the supply chain need to be aware of, acknowledge, and map the interdependencies (known and unknown) across systems.

- Risk needs to be considered and addressed holistically across the whole system such as infrastructure, sectors and uses.
- As interconnectivity increases, lessons learnt must be applied to the whole system – society, infrastructure and governance.
- Societal engagement is a must for influencing community understanding and participation.



3

Collaboration between all stakeholders including government, regulators, industry, and supply chain will drive effective, sustainable, and resilient outcomes.

- Consideration of community resilience including wellbeing, adaptability, and resourcefulness in the face of adverse conditions and/or change (such as analogue to digital) must be a priority.
- Do not underestimate the unintended consequences of change within a system which has evolved over many decades.

3. Introduction

Modern infrastructure is key to the smooth operation of society and we all depend upon it working reliably and effectively. However, the various infrastructures we depend on for energy, water, transport, data, and information are increasingly dependent upon each other. That is, a failure or a change in one, can have unexpected hidden impacts on another. The key message is the importance of these interdependencies, an awareness of them, their potential impacts, and accommodating them as appropriate.

We need to see them coming and plan for them, including any cascade failure effect from one infrastructure to another. This is particularly important for dependencies across other smart infrastructures on the data network. However, dependencies can run either way and not be immediately obvious, particularly if there are hidden or unanticipated uses.

An example of a current less obvious issue is the effect of the imminent turn off of the legacy public switched telephone network (PSTN) – an analogue telephone network, on sensors in the field. They monitor gas and other distribution networks, which are integral to the operational integrity of those networks. These sensors rely on the PSTN to send data back for monitoring and control purposes, but also depend upon the line power provided by the PSTN system, which will not be available from new digital lines. These sensing devices are used to balance pressure in the gas system. If the devices are not available, the system will operate at maximum pressure, which can result in excess loss and leaks, potentially causing significant environmental and safety impacts, and in the worst case, a risk of explosion.

These are examples where the original communications application has evolved to include the internet of things (IoT) sensors and, as such may not be the primary focus of the planned changes. Such interdependencies between the original purpose, voice communications, and other infrastructure requirements, in this case energy, cannot be overlooked. They must be part of a holistic and whole systems approach to wholesale technology migration such as PSTN, 2G and 3G withdrawal. It also begs the question, what other interdependencies are there that need to be addressed in any technology change programme?

This paper discusses such interdependencies for example between energy and communications, and their growing significance, specifically the PSTN withdrawal in 2025.

4. Public switched telephone network (PSTN)

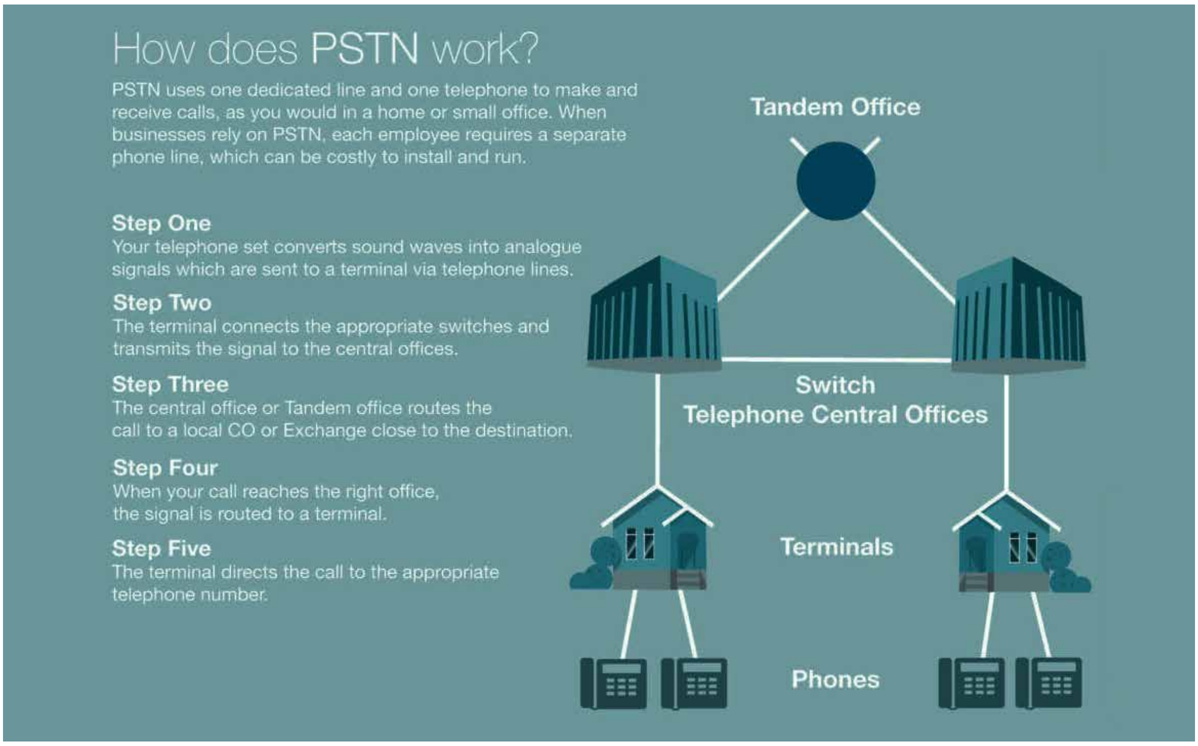
BT Openreach announced in 2015 its decision to withdraw PSTN services and products. This is part of a long-term shift in how information is carried and distributed from the old analogue regime, which was devised just for telephones, to a modern digital approach that supplies all our modern data needs.

This has enormous benefits for the user but the PSTN and integrated services digital network (ISDN) withdrawal will affect both business and residential customers especially if they are used for machine to machine type services over a landline.

Most users will not notice, but there are several key situations where the PSTN is depended upon. One of these is the gas distribution networks. Gas network operators rely on the PSTN to connect to remote network assets for the purpose of operational monitoring and control. Moving to alternative solutions, such as public mobile communications, is not practical as there is typically no local power available to operate end devices. With PSTN the power for the device comes from the resilient power in the PSTN circuit (see Figure 1), hence overcoming the challenges of no local mains power and the inherent safety risk of mains power in proximity to gas systems.

There are over 200 exchanges across the United Kingdom, which are scheduled for the withdrawal of the PSTN solution between now and summer 2022, the vast majority in the next 12 months. The geographical spread is diverse and includes, but is not limited to; County Antrim, the Highlands of Scotland, the Midlands, the North West, Greater London, and Cornwall. There is also the scale of the changeover which is estimated to be in the range of 5000 PSTN lines per week to meet the deadline in 2025.

Figure 1: How does PSTN work? Courtesy of Structured Communications.[3]



[3] What does the end of Openreach PSTN and ISDN services mean for business phone systems? - Structured Communications.

Other examples of using PSTN line fed power include:

- Non-voice services that are delivered over PSTN lines such as cash machine comms, carer-call alarm systems, fax, electronic payments systems (for some small traders), fire and burglar alarms.
- Emergency 999 calls for the full duration of any power outage, plus NHS 111, and other semi-emergency calls.
- Fixed phone services for locations without electricity supplies including rural payphones, emergency phones, phones in high-hazard areas.
- Emergency calls where the location of the caller, rather than their identity, is important such as when reporting fires or crashes on the motorway, someone in difficulty in the sea, an intruder in a home.
- Social calls to family during a major power outage where a black start, the process of restoring power in the event of a total or partial shutdown of electricity, would take three or four days to sort out. During that time, millions of people are likely to want to check on relatives.
- During a power outage, organisations such as hospitals, schools, distribution network operators and energy suppliers will need to communicate with employees, patients, parents, and other stakeholders.[4]
- A means of disseminating information about the likely duration of a power outage such as where to find food and services.

Pressure management and control data logger - communicates status at the extremities of the gas network to inform usage models.

NRS healthcare home safety alert carer call and panic button system.

[4] There are alternative communications platforms, but these were never designed for resilience to power outages and as such any power autonomy is only very limited in duration.

5. PSTN and gas networks

The challenges associated with the PSTN switch off, outlined in this case study, are not unique to the gas sector. The impacts, solutions, time frames and costs do vary. The most significant concern, and one common to all to a greater or lesser degree, is the separation between the infrastructure and end user solutions.

BT Openreach is managing the infrastructure changes but has little or no direct contact with or understanding of the end user applications. The structure of the market is 'arm's length'; it is therefore not surprising that interdependencies and unknown use cases were not foreseen or captured at the planning and risk assessment stages.

Although BT Openreach has worked to establish various solutions in terms of communications/connectivity to address consumer requirements for voice services, they are, in reality, quite distant from the end user when it comes to machine to machine type applications. The end user will usually purchase services from a communications provider and the BT Openreach activity (including any changes) is often both technically and commercially remote.

This also means that subsequent tiers and their operational requirements are not visible to BT Openreach, such as what connects at the end, a credit card machine or gas system sensor/remote telemetry. Furthermore, the intermediate suppliers, for example a communications provider, have no real incentive to flag the issue to the end user, as they just wish to sell a bundle of connections and communication services.

Development timeframes for technical solutions can also complicate and exacerbate the problem. This also means that end users are often the last to know the specifics of proposed changes or replacement technologies, making it almost impossible to trial potential solutions within the customer or end user context.

The scale of the challenge can be estimated based on a single operators perspective, in this case the control and monitoring of the low pressure network:

- **5.9 million customers** connected.
- **3,500 assets** to be served.
- Estimated cost per system upgrade **£7,800**.
- Total cost per single gas distribution network circa **£31m**.
- Total programme timeframe – **5 years**.

Note: The case study and single operator perspective can be estimated to be a quarter of the actual system as there are four gas network operators within the UK. For example the estimated cost is in excess of £120m based on this single use-case. Moreover, the numbers quoted do not take into account the disruption anticipated.

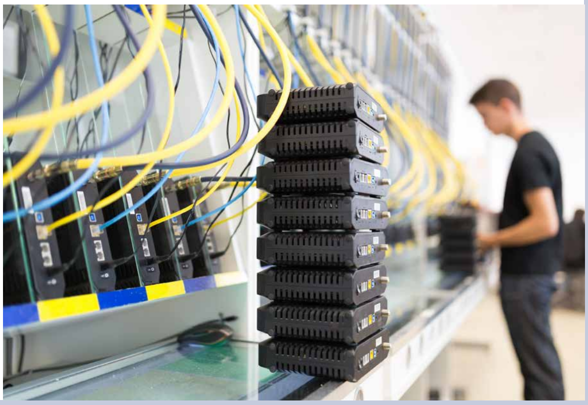
The gas telemetry solution is a bespoke industry solution that has evolved over many years. Whilst alternative solutions for the credit card machine can be easily presented to a trial/living lab (to see what needs to be changed or adapted), this is not the case for an energy distribution system requirement, which is typically deployed in remote locations.

There is a lack of whole systems understanding/ awareness for example of the unintended consequences, disparate use, and growth of multiple-user systems over many decades. The issue is not a reluctance of the end user to adopt and embrace the digital transformation, but rather a lack of credible and resilient alternative solutions to migrate to, that address the end users' needs.

The first BT Openreach field trial is now happening in Salisbury, UK and even there BT Openreach has had some challenges in accurately mapping where the PSTN lines run as layouts and maps are rarely accurate or up to date/maintained 100%. Once this trial has been completed, and final decisions made on the connectivity and communication hierarchy, only then can this be cascaded down through the supply chain, and ultimately to the end users. However, it is still not clear whether there will be a range of alternative solutions to address remote telemetry requirements, currently served by the PSTN system.

In summary, various uses of the PSTN system have evolved over many decades. To this end, discrete subsystems have been established. For example, gas telemetry enables the operational integrity of UK gas distribution networks, but their operation is not obvious to BT Openreach and hence the structure of the supply chain has limited the potential for governance and/or oversight of these types of embedded systems. The need for greater coordination will become increasingly important as systems become more interconnected in the future.

The Plum report[5] states, 'It is clear however that the digital infrastructure sector cannot be complacent and may need to accelerate our work engaging with data service providers as well as potentially engendering greater alignment between operators' communications to consumers, and particularly vulnerable consumers'.



5 Preparing the UK for an All-IP future: experiences from other countries (broadbanduk.org).

6. Engagement and awareness

While there is significant awareness and engagement at an industry, regulatory and government level, it is clear that there is still some way to go in terms of local business and communities – if only to highlight the key changes, timelines and ultimately to reassure (particularly the vulnerable) that any changes are understood, and will ensure a seamless transition from analogue to digital. Nevertheless, society does need some means of communicating in the event of a widespread loss of power supply.

The issues raised emphasise the societal need for a resilient means of public communication in the event of mains power loss. Options include a digital phone system with a 72-hour uninterruptible power supply for all infrastructure, full-fibre internet with battery backup in domestic Wi-Fi hubs and voice over internet protocol (VoIP) phones, and wired phone networks - but one size may not fit all.

Recent events[6] across the UK clearly demonstrate why a suitable backup is required. Climate change will only increase the frequency and impacts of such events, even as we transition to net zero in an attempt to mitigate, if not solve, the damage that has already been done.

Furthermore, five years ago, during Storm Desmond, the whole of Lancaster lost its electricity supply[7] for a couple of days – some areas for longer. In the intervening years, more services have moved online – including retail and government, supported by the Department for Digital, Culture, Media and Sport's objective of digital connectivity.

The report Engineering the Future - Infrastructure, Engineering and Climate Change Adaptation – ensuring services in an uncertain future[8], shows the interdependencies between sectors, infrastructure, and impacts. Although published 10 years ago it demonstrates that such challenges are not new.

[6] Information about the 9 August power cut and the ESO | National Grid ESO.
[7] City's four-day power cut offers lessons for whole UK – new report highlights - Royal Academy of Engineering.
[8] Infrastructure, Engineering and Climate Change Adaptation - ensuring services in an uncertain future.

7. Conclusion

In summary, the consumer dimension must be acknowledged and understood by all stakeholders. The PSTN is a clear example of interdependency across sectors such as energy and communications.

PSTN will be resolved but does highlight key issues identified at least 10 years ago and we need to be more agile, less reactive and apply a whole systems mindset.

Operational communications for energy utilities presents a real challenge. With currently no alternative commercial solutions available to address the industry's bespoke requirements, there is a need to approach the sign-off and verification from a whole system perspective.

With increased homeworking, there is a need to consider the wider impact of the digital transition. With the increasing use of IoT, artificial intelligence digital technology interdependency will only increase.

Adaptability and interdependence must be considered in the transition to net zero across all sectors. Digital transition is a key enabler of the net zero outcome and is dependent on the deployment of resilient operational telecoms capability, which address the needs of the energy network operators.

An increasingly decarbonised electricity network is becoming much more complex and climate dependent with many more modes of failure - not all of which will have been foreseen. A complete shutdown is always possible (coming just below a pandemic in the 2019 National Risk Register[9]), and a black start is expected to take the best part of a week.

The further we go down the path of distributed renewables, smart meters with time-of-use tariffs, IoT appliances, programmable electric vehicle chargers and heat pump systems, the greater the complexity and the scope for unforeseen issues. A secure, robust, and resilient operational telecommunications capability must be prioritised by Government and the UK energy network operators.

8. About the IET

We are the IET – a charitable engineering institution with over **158,000 members in 153 countries** – working to engineer a better world.

As a diverse home across engineering and technology, we share knowledge that helps make better sense of the world in order to solve the challenges that matter. It's why we're uniquely placed to champion engineering. We bring together engineers, technicians and practitioners from industry and business, from academia and research, and from government and the third sector.

We are member-led, independent and impartial. We cover engineering across industries from design and production, digital and energy to healthcare, transport, and the built environment. We champion engineers and technicians by offering networking, volunteering and thought leadership opportunities.

To find out more contact **sep@theiet.org**

[9] CCS's National Risk Register 2020 (publishing.service.gov.uk).

The Institution of Engineering and Technology

Our offices

London, UK
T +44 (0)20 7344 8460
E faradaycentre@ietvenues.co.uk

Stevenage, UK
T +44 (0)1438 313311
E postmaster@theiet.org

Beijing, China
T +86 10 6566 4687
E china@theiet.org
W theiet.org.cn

Hong Kong
T +852 2521 2140
E adminap@theiet.org

Bangalore, India
T +91 80 4089 2222
E india@theiet.in
W theiet.in

New Jersey, USA
T +1 (732) 321 5575
E ietusa@theiet.org

@TheIET

theiet.org

E6D21002/Energy/0821