Response to: Call For Input – The Future of Distributed Flexibility 2023

About the Author of this response:
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My doctorate concerned the study of flexibility solutions for power systems to residences, given anticipated charging demand from EVs. The study included V2G, demand side response, local energy stores, remote and local control.

The EV studies were "bottom up" i.e. looked at the residential situation (230V) and the electrical system immediately above them. Other studies are typically "top-down" as seen from the generation or national power system. These give different views, as the UK network (unlike the US) has significant limits to domestic power supply.

NB national standards vary between countries, effecting what is possible. The UK and US systems are very different in design and built ability below 11 kV. The US system needs to power many houses taking 10 kW (for home air conditioning). The peak UK loads are 1/10th of this; a cheaper system becomes possible. UK networks are built in a different manner.

This results in non-transferability of working practices / techniques for load management on networks under 11 kV from one country to another. This particularly pertains to advisors and off-the-shelf US or EU systems; they may not be applicable in the UK as reasonable assumptions valid in their home country are often "not so" in the UK.

Example: A US peak period "turn-down" which does not immediately effect customers may garner 5 kW (turn off home AC for 1/4 hr) whereas in the UK this may only be 100W (turn off the fridge-freezer for 1/4 hr). This is a 50:1 difference; a US solution expecting to manage turn-down at 5 kW per home would not work in the UK. Turn-up is perhaps a little better; the UK has some turn-up as residential networks to houses choke from c. 2 kW per home and above, when applied in large numbers on the same network.

Note also that UK local systems are very capital expensive; this arises from burying cables vs. suspending them on roadside poles (as in US). The UK has c. 600,000 km of buried 230V residential networks with a notional replacement cost in the mid £100 - 200 bn. About 80% of these networks are not fit to deliver more than 1 to 2 kW (depends on DNO area) per home.

Replacing these buried systems (digging up roads, pavements etc. en masse) is what drives the cost, as cable replacement is c. £180 per metre.

Jargon: Voltage (V, Volts) is electrical pressure. Current (I, Amps) is amount of flow. Watts (kW, sometimes kVA) is power (impetus, like the power of a car engine). Watt hours (kWh) is a measure of total energy (the amount of fuel in a car's tank). Power is Volts times current i.e. kW = V.I.

Detrimental physical effects (asset heating and energy loss, mechanical forces) are square-law phenomena (proportional to current squared i.e. a x1.5 current increase increases undesirables by x2.25). Heating is usually the limiting factor, although mechanical forces can be a problem. There are others possible e.g. harmonics, flicker and power quality issues.

Factors:
Most Low-Voltage (LV, aka 230V) networks are from 1940s..1970s. LV networks are the most expensive part of UK power system, so are built to save cost i.e. adequate for need when built (of

say 1960). By international standards, the UK has particularly weak LV networks, onto which domestic EV and latterly Heat Pumps (HP) will connect. EVs alone overload most networks.

Heat Pumps are worse, as these run for long periods in Winter. HP alone consume > 100% typical local network capacity, leaving no ability to supply normal domestic loads or any EV charging. In some parts of the UK with weaker networks, HP need c. 200% of built capacity i.e. of 100 houses, only 50 can be heated.

These limits are imposed by the in-place networks, not markets or flexible “Smart” control schemes. The in-place networks cannot support the anticipated duty increase; they were carefully built to be adequate for the domestic role of c. 1960 and no more, so to save cost.

Typical built power-home capability:

- UKPN (London, Kent, East Anglia) c. 1.5 kW per home,
- Scottish Power: 1 kW
- SSE: 1.8 kW
- Early 2000s normal domestic load is around 0.8 kW, peaking in the evening.
- EVs charge often for many hours at 7kW typical, peaking overnight.
- HP starts heating a cold house at about 10 kW falling to 2 kW after 10-24 hrs, in Winter often running continuously at c. 2kW for a very well insulated house, nearer 3 kW for an older retrofit insulated property (values estimated via past experience).

All-electric homes must use electricity to cook and heat water ("auxiliary appliances"), which add further demand.

Temporary overload "Rules of Thumb" (specific networks vary; p.u. is values normalised to 1)

- 10% overload (1.1 p.u.): weeks
- 20% overload (1.2 p.u.): days (damage accrues from this point)
- 30% overload (1.3 p.u.): hours
- 50% overload (1.5 p.u.): minutes (Gao states LV transformers have 0.5 probability of failing on reaching 30 minutes at x1.5 load)

Failure modes include:

- house fires from under-volted domestic appliances
- electric shock to customers (Gao points out that oil boiling in an overloaded local transformer reduces insulation between transformer windings, potentially allowing the primary 11 kV to arc to the domestic 230V system.

Quote from Gao: *A threshold peak load of around 1.5 p.u. is observed that distinguishes transformers in high risk from others under Extreme-range scenario. This observation could be applied to assist the asset management under future EV scenarios that the peak load of distribution transformers should be restricted below 1.5 p.u. to prevent potential failure due to bubbling.*

Reference: Y. Gao, "*Assessment Of Future Adaptability Of Distribution Transformer Population Under EV Scenarios"*, PhD Thesis, University of Manchester, 2016

11 kV arcing onto the 230V system (caused by transformer overheat and bubbling) is very dangerous. Example: anyone holding a Smart phone on charge during such an event would likely be killed. Many household appliances would be damaged.

Be aware that power is transported at lethal high voltages (multiples of 100 kV); the residential systems operate at 230V. Power is the product of volts and current (kW = V.I), so for a given power delivery reducing the volts means increasing current. Delivering more current needs bigger cables. Thus, the 230V LV networks have large (= expensive) cables. These are buried and cost c. £180 per metre installed (c. 2022).

Ofgem's definition of flexibility is: 'modifying generation and/or consumption patterns in reaction to an external signal such as a change in price, to provide a service within the energy system'.

Responses the Questions:

Q1: a brief (c. 5 years) respite from initial problems, then likely exacerbating problems e.g. overloads and failing systems in the hours after DSR releases (deferred loads such as EVs now charge simultaneously => major overload and bang). This is also being pointed out by other engineers, however at Ofgem/NG level this seems not to be recognised.

There is notional aid to directing the charging of HV and MV BESS, so to maximise renewable enrgy utilisation.

Q2: a brief (c. 5 years) respite from initial problems, then likely exacerbating problems e.g. overloads and failing systems in the hours after DSR releases (deferred loads such as EVs now charge simultaneously => bang).

Comment:

1. flexibility is wanted, to reduce overall costs
2. customers are connected via inadequate LV systems, unable to deliver required power
3. networks to customers must be upgraded (a c. 15 year project, likely costing c. £200 bn.) without which LCT cannot be delivered
4. upgrading other systems (to no longer need “flexibility”) is a trivial cost on top.

My Q: Why do flexibility if we are forced to spend the money anyhow?

Q3: Other than reported issues (which are not given a degree of severity, rather presented as a list of complaints) the reader wonders - why make such changes, given a power system has been in place for the last century which has demonstratively worked. What is broken so badly that the system needs to change?

Reportedly, there is no common vision for distributed flexibility - but (other than polemic assertions, sans citations and proof) neither is there a direct need shown for such to exist.

Exactly why are the systems used for the last century no longer adequate? Some metrics based on direct examples, rather than verbiage is needed here.

Please bear in mind that technical fall-backs are always needed, as society cannot tolerate power systems failure. Given that, out of necessity, such systems will be in place - what does flexibility bring to the table? A cost benefit analysis is needed, which includes the costs of when flexibility gets it wrong and bad things happen.

Q4: The author suggests that the present power system is not sensibly organised for markets, for that is not the power systems nature. However, in the limit, markets may not be sensibly organised to run power systems.

Perhaps an exercise in developing a new vision based on markets is needed, using blue-sky thinking (the goal of this document?) A following analysis might describe means to pilot these, and how to transition to the selected form.

Q5: Yes, but any final form will always be attacked as “not permitting innovation” i.e. market disrupters.

A means needs be found as to how to assess the benefits a new disruptor brings to the economy.

Given such a means of assessment (which should include passing power-system practicality tests), it would be useful to apply the test to all the proposals put forward, including why it is a good idea to abandon further development of an established working system, in favour of a new flexible digital form.

Q6: The need, if any, is likely immediate as both development and roll-out may take decades. It should be started on ASAP, given awareness that:

- there is no proof of absolute need,
- large complex systems built from scratch often fail,
- costs are likely very high
- there is no certainty that any developed system will indeed be used (it may be discarded)
- it is likely to not save much £ simply as major capital spend is forced by moving the UK to LCT to rebuild the distribution networks, likely costing c. £200+ bn.

Clearly this should be a private venture, aware of all the risks - and able to cover the cost of network failure (a London-wide outage for days would result in major costs). Also note that, as water in the UK is electrically pumped, any wide-area power loss would have an attributable mortality rate if lasting much over a week (dehydration, Fire Service inability to quench fires).

The author suggests considering the advantages of being "2nd to the party". Let us watch what works or fails for others; leading the pack exposes us to great risks, for perhaps marginal benefit.

Also note that tackling a smaller problem ("shrinking the problem") may help. The author developed an automated system capable of supporting EV, DSR, V2G and other domestic loads, for a group of 100 houses.

Whilst these covered expected CER and was still subject to the eventual need to rebuild the LV networks, the solution offered:
- a means to reduce complexity to manageable blocks (groups of houses)
- resolving fast-changing variation in demand, likely faster than any market
- needed no demand forecasts, working purely in real-time
- greatly reducing data flows (limiting data to a local area, also aiding security)
- still offering flexibility services via a single remote command.

Once such a group is in place and working, a layer on top of that group of say 100 houses could, notionally, offer a market of services - the group could be turned up or down "as one". Note that if commanded to turn too-far down, houses would go cold and EVs not charge. People would notice and sidestep the control mechanisms.

The "group command" approach described implies ceding control over each home's Smart Meters. Retailers would still gain load readings, but would not manage the group.

Q7. What should a common digital energy infrastructure look like, and why? Please consider the archetypes or develop your own proposition.

There needs to be a common customer-anonymised yet load-specific standard, accessible in near real-time e.g. 10 seconds. Some have suggested shorter then 1 second (research ANM / Advanced Network Metering).

The privacy silos created by separating retailers (resulting in the present retrospective supply of SM residential load data) means that the total load, location and necessary strategies to manage any system are - unknown in real-time. And cannot be known, as these change on a second by second basis.

3rd parties offering systems or services to manage / optimise Smart residential systems need also be included.

Without this, turn-down / turn-up groups are impossible to form as the manager does not who is doing what and where. Postcode groupings are likely too broad; the system needs to reflect built network architecture.

Q8. What is your view on the desirability and feasibility of the archetypes or your own alternative proposition?

Base a solution off of known developed working systems, the most likely being the TCP/IP system used by the internet.

Q9. Should a common digital energy infrastructure be new-build, or should it build-out from existing infrastructure?

Build new; then use pilot studies to see if existing infrastructure is adequate to accept service migration.

Q10. What are the important areas for consideration when designing institutional delivery models for a common digital energy infrastructure?
Computing and power are a bad mix as proliferating interdependencies introduce vulnerability. Any features or system introduced now will likely be a dependency in 10 years.

NB you are in a security arms-race here. See recent articles re quantum computing can now crack all prior to c. 2023 in-use encryption methods; may have to use novel techniques to ensure the UK power system cannot be faulted by hostile action (ranges from overseas to Facebook). Suggest random one-time pads (old school method; increases network traffic) with dual-end encryption. Parties A and B each think of a new, different encryption random pad; A encrypts a message, sends it to B. B encrypts it, sends to A. A now un-encrypts it, sends to B. B un-encrypts it which gives a plain-text message. All traffic was encrypted. There are likely other methods; these need to be checked for resistance to quantum computing.

Plus. If you want to run power levels near network capacity, you may get into the area of "protection". This topic is about network faults (which do happen) and is at least an order of magnitude more complex; there are a vast number of possible fault scenarios (an N! problem) each of which need to be considered and a backstop (to halt problem proliferation) devised and put in place. Protection systems operate in milliseconds; your controls need to be fast.

The traditional way to limit this issue is to have network loads running at say 1/2 network capacity; i.e. to have margin. But we are not doing this.

Q11. What are the important areas for consideration when designing financial delivery models for a common digital energy infrastructure?

No skills here, although do see the financial systems can suffer extremes (i.e. crash). Backstops need to be in place such that when financial crashes happen, the system can continue to operate (for perhaps months) without somehow crippling the power networks.

Further, the financial crash could be in an overseas economy. In December 2022, cloud services hosted in the US failed several times. Worldwide, users of that cloud went down. If any UK solution had used those overseas services (think Amazon AWS) would the UK grid have survived? AWS could be deleted / fail / withdrawn from service for financial, weather, their own system failure etc.

It is important that any support services are wholly run from with the UK. Then they can be militarily hardened; the original objective of the "National Grid". Now a company, the initial NG was used during WW-2 to keep power flowing to Coventry during bombing.

Knocking out power => no water pumping, no water pressure => fires cannot be put out due to lack of water. The early grid saved Coventry during the 1940 Blitz. Coventry power generation was targeted and destroyed, but power for pumping was supplied by generators in other cities, via a regional grid.

Given the 50s, 60s Cold War and UKs proximity to potential adversaries, such arrangements quietly ensured the UK can cope with major outages provoked by enemy action.

It is important that this is not unpicked; wars happen.

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