Smart Grids Power On

By Dr Richard Bujko PhD,MBA,MSc, BSc

A common definition of a smart grid is a digitally enabled electrical supply system that simply collates and distributes value added energy data. This data is activated by information from the functions of all participants including generation suppliers, network operators and energy demand consumers. The aim is to improve the efficiency, resilience, economics and sustainability of future electricity services and products serving these stakeholders.

Key global drivers accelerating the development of the smart grid include the transition to a decarbonised and decentralised energy business model. This is occurring as the percentage of renewable energy on both UK and EU networks rapidly increases and electricity demand is expected to increase with the advent of electric vehicles and heat pumps.

Renewable energy sources (RES) represented close to 26 per cent of UK generation in 2019 due mainly to a rapid expansion of onshore and offshore wind farms together with some further expansion of large scale solar farms. When taking into account other low carbon sources such as the existing fleet of nuclear plant and the newly converted large scale biomass stations, the penetration of low- and zero-carbon sources in the UK has risen to 37 per cent. The EU in their European Smart Grid Technology Platform report (EUR 220400) anticipates that electricity demand across the whole of Europe will continue to increase annually on average by 14 per cent to 2030 and for RES to sustain its long term growth trajectory from a current baseline of 13 per cent to reach 26 per cent over the next decade.

The proliferation of household solar photovoltaic (PV) panels in the UK, now numbering over 1m individual units is also reducing net electricity demand at the domestic sector level. However, this is gradually being outweighed by other sources as the UK Government’s Climate Change Policy prioritises decarbonisation and its current target to achieve net zero greenhouse gas (GHG) emissions by 2050. In accordance with this sustainability agenda, conventional transportation is being replaced with low-carbon alternatives including plug-in hybrids (PHEV) and battery powered electric vehicles (BEVs). Traditional forms of space and water heating and cooling solutions originally supplied by fossil-fuel boilers and air conditioning systems are gradually being replaced with lower carbon propositions such as (reversible) heat pumps, biomass boilers and solar thermal systems.

‘Gateway’ to smart grids

The rollout of smart meters across the whole of the residential sector in the UK will provide a ‘gateway’ into the smart grid and allow the individual consumer to become an active player in the new energy marketplace. Owning back-of-the-meter self-generation in the form of roof-top solar PV panels in conjunction with battery storage, BEVs and thermal storage, means the growth of the ‘prosumer’. This new generation will be empowered to offer energy and balancing services to the local distribution network operator.

The mass of granular data will demand increased digitisation and encourage the development of micro-grids at the community level and virtual power plants. The idea has been postulated by ABB Energy Industries at a large-scale grid level. It capitalises on special software to allow intelligent trading of energy and capacity services within the new sophisticated energy marketplace.

From the 1930s to the late 1960s, power grids comprised mainly of a number of large centrally controlled power generation stations fired predominantly by fossil fuels which supplied electricity via high voltage transmission lines - national grid - in bulk to major load centres. Electricity was subsequently transported by numerous distribution networks to a wide-ranging portfolio of industrial, commercial and residential customers.
The main benefits derived included improved security of supply, reduced operating costs and relatively lower transmission and distribution losses. Over the past decade this traditional ‘business model’ has gradually been transformed with the availability of competitively priced large scale renewable energy sources in the form of offshore and onshore wind farms and solar photovoltaic (PV) farms. In addition, electrical demand has become more dynamic and variable with the replacement of conventional heating systems with low-carbon alternatives and fossil fuelled transportation commonly referred to as e-mobility. The transition to renewable energies and distributed but weather-dependent power generation continues to impact the new energy landscape and the challenges of delivering safe and secure operation of the developing smart grid is becoming paramount. This is exacerbated by the significant increase in the total number of small scale and decentralised power generation units which are beginning to dominate the new energy network and compound the unpredictability faced by modern smart Grids.

Ensured perfect balance
In the past, electrical systems simply acted as a continuous supply chain which matched instantaneously the supply of electricity from large power stations to customer demand. This ensured a perfect balance as there was little scope for storage to facilitate ‘smoothing’ of critical peak demands especially during the winter months. This challenge will be exacerbated by the acceleration in the number of small-scale distributed generation units whose output will be determined by whether the ‘wind blows’ or ‘the sun shines’. This will be further compounded by the increased complexity associated with flexible and less predictable customer demand and behavioural patterns due predominantly to changes in the frequency, duration and level of charging (in the short to medium term) of a wide range of BEVs and the variation in the output of heat pumps during the winter months.

Therefore to operate the electricity system of the future - the smart grid - both securely and safely there will be more reliance on the expertise of skilled control engineers and sophisticated, intelligent control and monitoring systems. The three main parameters that need to be controlled for a smart grid are:

- **frequency** - matching generation and demand on a second-by-second basis to guarantee stability of the system and ensure delivery of electricity at a frequency maintained within designated limits;
- **voltage** - generators and transformers ensure that voltages remain stable and electricity is supplied within specified limits; and
- **current** - provision of spare capacity ensures that the current limit of every component and circuit comprising the electrical system is not exceeded and consequently limits the risk of damage or failure and mitigates the potential impact of blackouts.

The planned rollout of smart meters at the household level has facilitated the monitoring and control of energy usage in real time at the commercial and domestic level as well as mitigating the inherent intermittency of renewable generation. Apart from the main benefit of being capable of reading meters remotely, smart meters will enable accurate and timely measurement of solar panel-derived electricity exported to the grid and facilitate payment measures. In addition, smart meters will help utilities and independent energy suppliers to formulate different electricity tariff structures which reward consumers for demand management services. This is already leading to increased adoption of smart appliances in the domestic sector and home energy management and control systems such as Nest and Hive.

The new business model for the supply and consumption of energy that is now evolving places more emphasis on the consumer. The latter can both self-generate and store electricity locally providing them with the possibility to become self-sufficient and go ‘off-grid’ and even export any surplus power back to the new grid structure. In the past, power flow have always been in one direction from the centralised power stations which controlled both the security and quality of electricity supplies but future smart grids will enable bi-directional energy flows and encourage the growth of ancillary services in flexibility, voltage and frequency management to maintain future security of supplies to critical businesses.

Zero energy emissions
One of the key drivers for the development of smart grids is the global transition to achieve a target of zero energy emissions by 2050 or sooner. This has involved decentralisation of legacy fossil-fuelled power generation stations and the associated decarbonisation of key activities such as heating and transportation. The universal rollout of smart meters has enabled more accurate monitoring and control of both micro-generation and dynamic demand but has resulted in a plethora of granular energy-related data. The latter has to be constantly synthesised and manipulated by sophisticated communication networks relying on artificial intelligence and detailed algorithms to deliver reliable and resilient power delivery and informative actions.

Apart from the domestic sector, local councils are also embracing new developments in technology such as smart LED street lighting systems. These are gradually being integrated with battery storage to provide fast charging of electric vehicles (EV) capability particularly for future EV owners without off-street parking. As the battery capacity of future EVs increase, a number of utilities are exploring the potential commercial benefits of vehicle to grid (VTG) technologies – as well as similar concepts such as Vehicle to Home and Business applications. Aggregators and partnerships between car manufacturers and utilities - such as Nissan and EOn – have been formed to trial the provision of demand management services from a collection of to exploit advances in VTG technologies and virtual power plant (VPP) software. This would also allow the incorporation of hydrogen-fuelled technologies and fuel cells. Some of the key benefits of smart grid are to:

- enhance the connection of low and zero carbon generators;
- encourage and reward the entry of new demand management service providers to stabilise the operation of the grid;
- facilitate further growth in electricity demand that minimises the reinforcement of existing network capacity or avoids the commissioning of new transmission lines;
- reduce the overall carbon footprint of the grid in compliance with the UK Government’s Climate Change agenda and 2050 net zero emissions target.

Therefore, unlike traditional network grid structures, a smart grid-based system facilitates two-way communication between established utilities of third party renewable energy providers and their direct and indirect customers allowing future networks to respond dynamically to variable power demand profiles and stabilise network operation.

The key challenges include:

- the opportunity to immediately manage voltage and frequency on grids to guarantee security and quality of supplies mitigating the impact of total power failure - blackouts – or diminished power delivery capability -
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SMART GRIDS

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QUESTIONS

1) The establishment of the main transmission grid began in which decade?
   - 1940s
   - 1930s
   - 1960s
2) Which key parameters need to be controlled by smart grids?
   - Voltage and frequency
   - Frequency and current
   - Voltage, current and frequency
3) What’s the main source of large-scale renewable generation connecting to the grid?
   - Biomass
   - Wind farms
   - Solar farms
4) What are the main forms of variable electrical loads connecting at the household level?
   - Electric vehicles and heat pumps
   - Smart meters
   - Home automation devices
5) What is the main threat to smart grids?
   - Cost of implementation
   - Cyber attacks
   - Lack of experience and expertise
6) What are the main benefits of smart grids?
   - Reduce the need for centralised power generation
   - Encourage connection of electric vehicles
7) What does the abbreviation VPP stand for?
   - Volume purchase programme
   - Voluntary protection programme
   - Virtual power plant
8) Electricity cannot be stored in large quantities by householders?
   - False as only large utilities and industrial/commercial energy providers can provide storage facilities
   - False
   - True as householders can store electricity in standalone batteries or when charging their electric vehicles
9) What is the main benefit of smart meters?
   - They avoid the need for meter readers
   - They provide accurate and timely information on power flows across the smart grid
   - They facilitate the export of surplus electricity from household solar PV panels
10) What does the technology VITG represent?
    - Variable Geometry Turbocounters designed to allow the effective aspect ratio of a turbocounter to be altered as conditions change
    - Volume of Trapped Gas associated with respiration
    - Vehicle to Grid enabling EV batteries to discharge to the grid to ‘smooth’ high electricity peak demand profiles.

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