1 Balancing electricity supply and demand

KEY LEARNING POINTS:

- Electricity supply must match electricity demand at all times
- The electricity system operator is responsible for ensuring this happens
- System operators have a number of tools to do this

Unlike many commodities, electricity cannot currently be stored economically in large quantities and for long periods.

To do so would require very large batteries, flywheels or capacitors, although these cannot retain their charge for very long periods. Or it would require the conversion of electricity to other energy forms which can be stored for long periods (for example, to hydrogen by electrolysing water). Whilst these methods of storage are technically viable, at present they are relatively expensive.

As a result, the generation of electricity must equal the demand for electricity at all times.

Actually, the quantity of electricity generated per second (which we call the power output) must be greater than the quantity demanded in that second (the power demand), since electricity is "lost" as heat along transmission and distribution wires which connect electricity generators to electricity users.

It is important that electricity supply and demand are in balance, not only to ensure that demand is met, but also to keep the electricity system stable.

If the supply-demand balance is not maintained, the electricity system's frequency (which measures the rate at which electrical current flow alternates in the system) moves away from the specified target frequency of the system. As a result, the system could become unstable, leading to transmission loss and damage to its components.

To record the supply-demand balance, electricity generators are metered on how much electricity they generate within each time slot.

The length of these time slots depends on the particular electricity system in question. For example, the Great Britain electricity system uses "settlement periods" that are 30 minutes in length. In the United States, the system operators measure what happens over 5-minute "dispatch intervals", but typically they average prices and quantities over an hour when determining payments. Generators offer a specified quantity of electricity that they will supply in a given settlement period. In Great Britain, they can change their offer of electricity generation quantity up to 1 hour before the settlement period, at which point (called gate closure) no further offers can be made.

Offers to generate electricity for a particular settlement period may be made years in advance.

In many electricity systems which operate a market-based electricity trading system, the vast majority of each period's electricity demand is met through electricity generation offers made long in advance. This helps generators and system operators predict what will happen and reduces uncertainty. Forwards and futures markets allow generators to offer electricity generation many days, weeks or even years before a particular settlement period. These markets allow generators to trade with large customers or the retailers who will sell power to smaller customers. Shorter-term power markets (sometimes called power exchanges) allow offers to be made days or hours ahead of the settlement period.

Generating companies with multiple plants will normally decide which plants to use in each period based on each plant's marginal operating costs.

For example, if there is plenty of wind energy available in their generation plant portfolio, they will prefer to deploy wind power, since the marginal operating cost of producing wind is much lower than for other traditional plants, because the cost of providing one more unit of electricity (e.g. 1 kWh) is negligible for a wind farm that is already built. The generation of electricity from the lowest marginal operating cost plants first, and more expensive to operate plants later, is called the merit order.

It is ultimately the responsibility of the electricity system operator to ensure that all generation offers meet the required demand level for the period.

With rapidly changing electricity demand, it is likely that the sum of generation offers for a given period do not precisely meet the demand level. It is the responsibility of a central electricity System Operator (SO), sometimes called Transmission System Operator (TSO) or independent system operator (ISO) depending on the country context, to ensure that electricity supply and demand for the period is fully balanced. In the UK the TSO (National Grid) does this in the hour-long period of time leading up to the start of the settlement period. It would cause chaos if too many people were trying to trade to keep generation equal to demand, issuing contradictory decisions. Bilateral trading between generators and retailers has to stop at some point (which is known as gate closure in Great Britain), and only the system operator can trade after this time (one hour before real time in Great Britain). At the end of a given period, the system operator settles any imbalances in generation supply and electricity demand that it has had to deal with.

System operators have a number of tools at their disposal to balance the system.

System operators can for example instruct generators to increase or decrease their output. Sometimes, large customers are also able to reduce demand at short notice, in return for a payment. The Great Britain system operator now sometimes pays customers to increase demand, if the system would otherwise have a surplus of power that it could not absorb. System operators may also make electricity trades themselves, to change market-driven transmission flows if there is a risk that these would otherwise overload the system.

System operators must also ensure the provision of reserves that allow for generation capacity to be used if demand exceeds supply, or vice versa, for a short period.

Reserves often consist of flexible conventional power generation plants, but some countries such as Australia are using large batteries, and still others are using demand response and variable renewable energy generators like wind and solar, to provide such reserves as well.

As the share of variable output renewables like wind and solar photovoltaics increase in electricity systems, the requirement for flexibility to help system balancing will increase.

A greater share of variable renewables means that there is more variability and less overall predictability in how much electricity can be generated by the system for each period. So the challenge to accurately predict and schedule appropriate generation for each period increases, and hence more flexibility will be needed to balance the system. But as shall be explained in the rest of this course, there are many cost-effective and readily-available ways to do this which are already being used across the world.

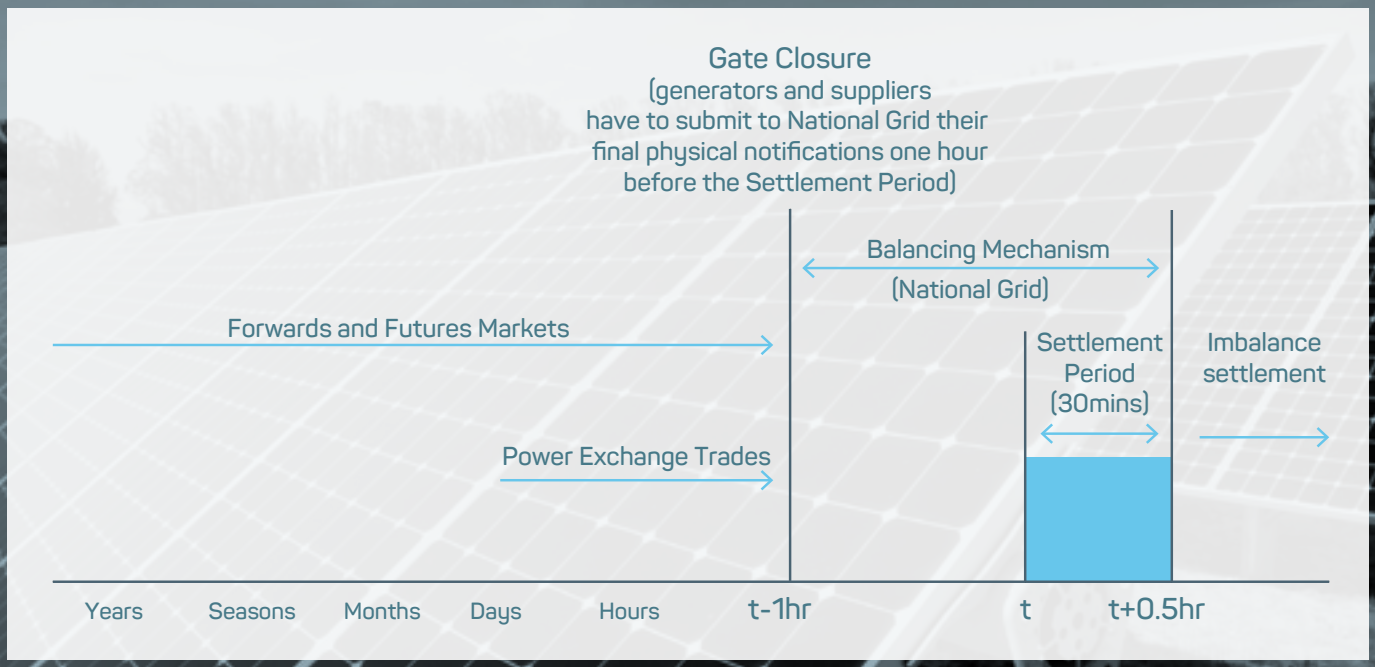

Figure: The balancing mechanism in the Great Britain electricity system. Adapted from UKERC (2016)

References

ETSO, (2003), Current State of Balance Management in Europe

National Audit Office, (2014), Electricity Balancing Services

UKERC (2017) The Costs and Impacts of Intermittency – 2016 update.

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