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ELECTRICITY FOR EUROPE

Opening up the black box: electricity distribution made easy

Introduction

Distribution networks consist of electrical lines, which deliver electricity to its final point of consumption: Europe's households and businesses. Around **260 million European customers** are connected to electricity distribution grids. Around **2,400 electricity distribution companies employing 240,000 people across the EU** provide power with a high level of reliability and quality of supply to their customers.

Due to differences in grid structures, the tasks of distribution system operators (DSOs) differ both within and across Member States. DSOs are in an extremely technical business and, for this reason, they can be perceived as a 'black box' in terms of nature, functionality, and purpose.

It is vital to open up the black box and understand what lies behind power distribution systems. This brochure/paper intends to shed light on DSOs and how they operate electricity networks and how this will evolve in the future. Networks are becoming smarter to accommodate renewable generation capacity and require increased monitoring tools through communication technologies. The main task of the DSOs, which is to ensure reliability and quality of power supply, should not be jeopardised as they concentrate on efficiency and customer orientation. Thus, it is crucial to understand how they function and what purpose they serve in the new power industry paradigm.

What is the difference between transmission and distribution networks?

Transmission and distribution networks consist of electrical lines that deliver electric power from its point of generation to its final point of consumption: Europe's customers, businesses and industry. The companies owning and operating transmission networks are called Transmission System Operators (TSOs), whereas the owners and operators of the distribution networks are usually referred to as Distribution System Operator (DSOs). In some cases, owners and operators differ. Distribution companies owning the assets are referred to as Distribution Network Owners/ Operators (DNOs).

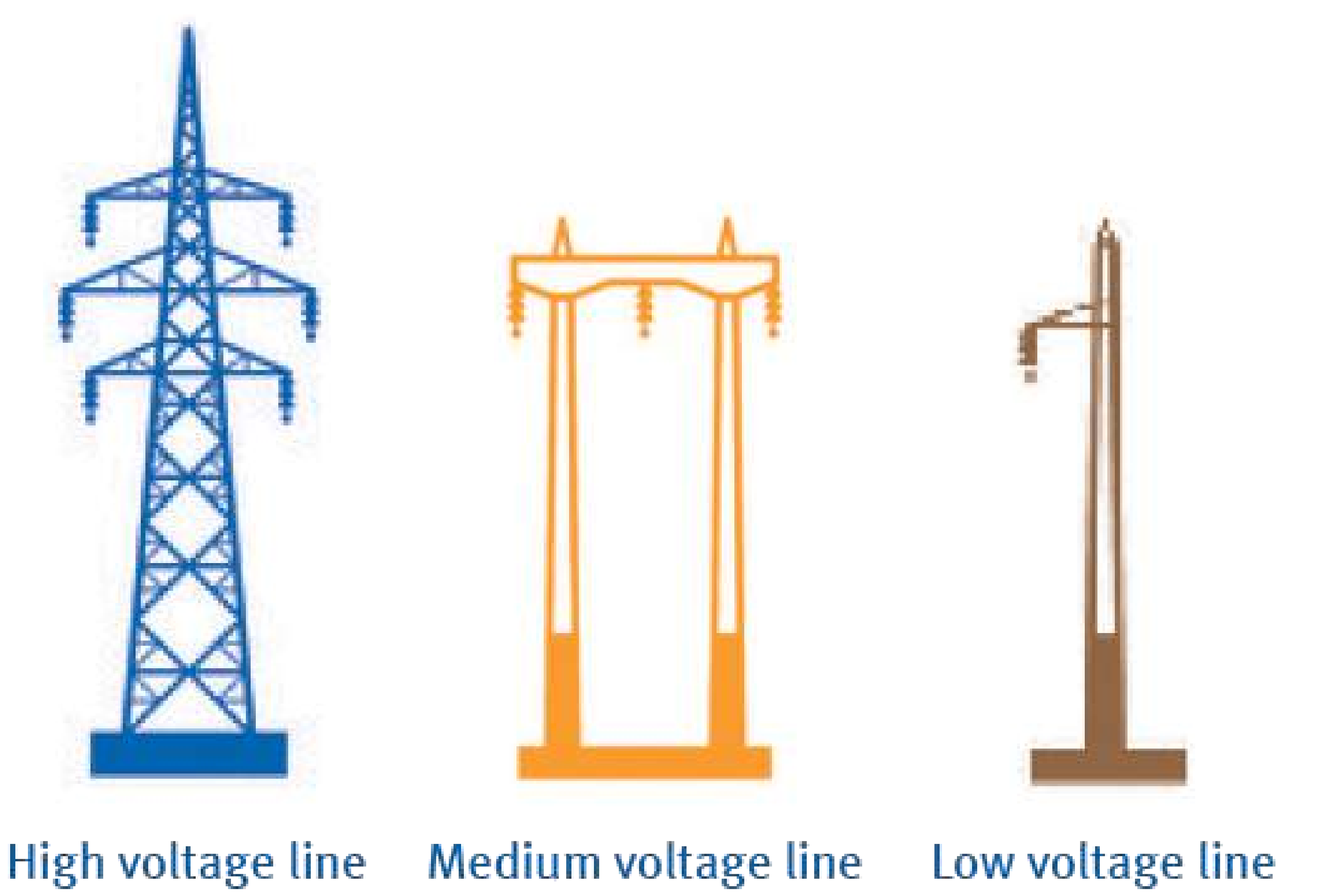


Figure 1 Transmission and distribution networks

Transmission lines usually transport high voltage (HV)[1] electricity over long distances from generation sites to electrical substations. Electricity is transmitted at high or extra high high or extra high voltages (EHV) to reduce losses. Transmission operators can minimise losses by reducing line resistance and/or current. According to the Joule effect, the current reduces when the voltage increases, this being one of the reasons why electricity is transported at HV.

Distribution networks are divided between primary and secondary lines. Primary lines carry medium voltage (MV) electricity to industrial, commercial, and domestic users. Secondary lines carry low voltage (LV) electricity to households. (Figure 1) Distribution system operators use transformers to reduce HV electricity to MV and LV.

Depending on historical choices and regional factors, voltage threshold values may differ between HV, MV, and LV across countries. Most European DSOs partially operate HV networks. Only those from Cyprus, Estonia, France, Italy, Latvia, and Lithuania exclusively operate MV and LV lines.

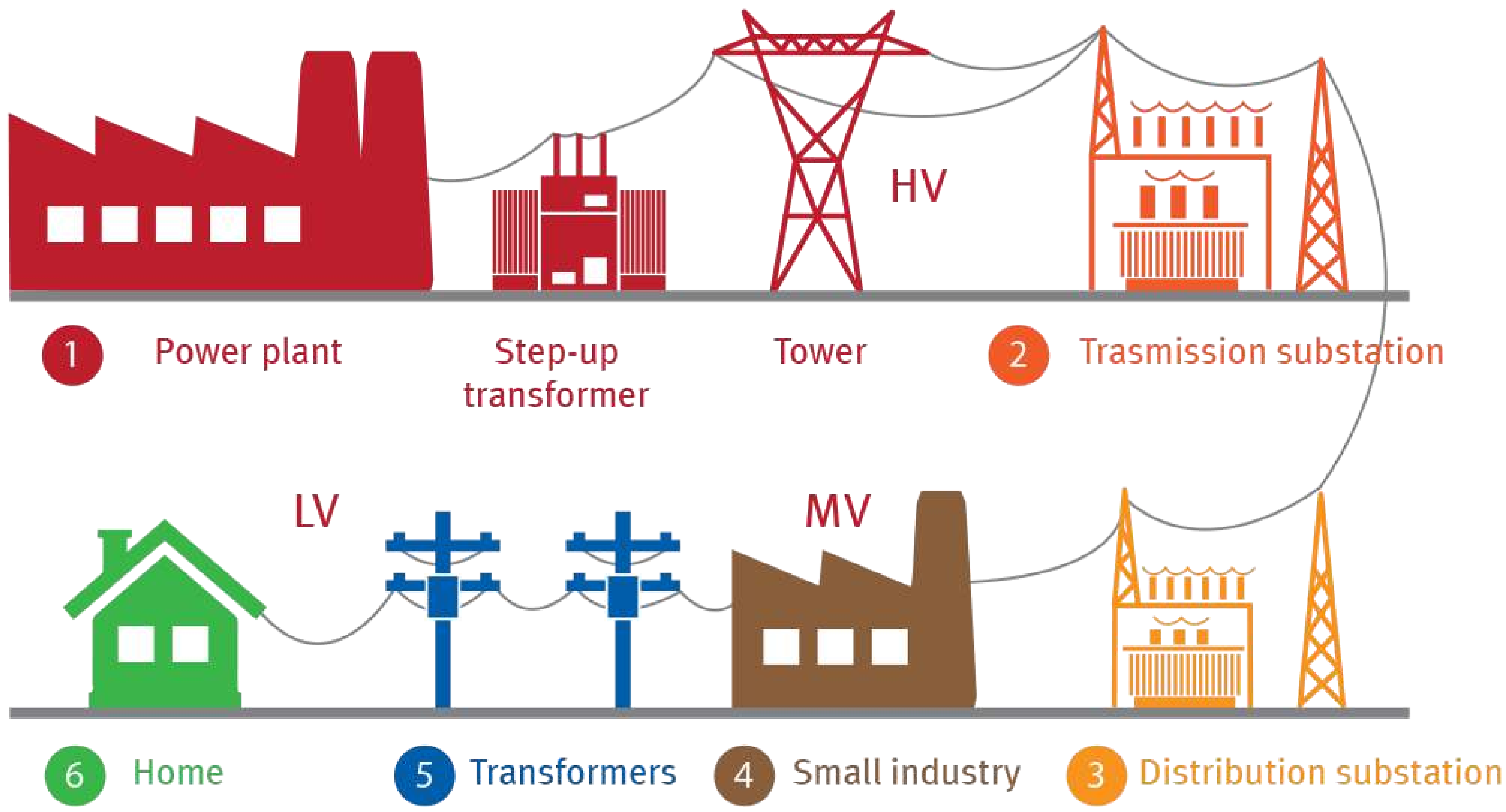


Figure 2 Current electricity infrastructure

Transmission lines

Transmission lines transfer a substantial quantity of energy from generating power plants to electrical distribution substations located near demand centres. Usually transmission lines, which are used for long distances, are three-phase alternating current (AC)[2] lines when overground (overhead power lines, such as those lines Figure 2) or direct current (DC) when underground. However, all three-phase lines can share the same supporting infrastructure.

Three-phase AC electric power is the most common method of power transmission and distribution. It is usually more economical than single-phase or two-phase systems because less conducting material is used to transfer electricity, but also because AC voltage may be increased or decreased with a transformer, which reduces power losses during transmission.

Overhead lines take up more space, have a strong environmental impact, and are very sensitive to climate. They are, however, more economical than underground cables and often times are preferred for this reason. Underground cables usually entail higher costs because they need to be insulated and excavated into the ground.

1 Voltage levels according to European standardisation bodies CEN/CENELEC are: LV (⇠ 1 kV), MW (1-36 kV), HV (⇢ 36 kV), EHV (⇢ 345 kV)

2 Alternating current (AC) is an electric current in which the electric charge flow periodically reverses direction, whereas in direct current (DC) the electric charge flows in one direction only.

Distribution lines

Distribution lines connect transmission lines from electrical distribution substations where voltage is decreased to be compatible with retail electrical equipment. In urban and suburban areas, distribution lines are three-phase systems since they need to feed industrial, commercial, and domestic load. However, distribution in rural areas can be only single-phase if only intended to serve smaller customers. Similar to transmission, distribution lines may be either overhead pole lines or - in densely populated areas – they can be underground (buried) cables. Transformers are used to step voltage levels down to consumer standards. In addition to substations, transformers can be found on utility poles (so-called pole-mounted transformers) or mounted on concrete pads and locked into steel cases as part of underground cables (pad-mounted transformers).

The European Distribution System

Km of distribution lines in the EU

The features of electricity distribution networks across Europe are very diverse, mostly depending on the amount and nature of users connected to the distribution grid and on the level of ownership unbundling[3] in each country. Distribution networks are linked to transmission systems by around 10,700 interconnection points in Europe. There are more than 4 million distribution transformers. Overall, approximately 10 million km of power lines serve almost 99% of European customers connected to the distribution grid.

In general terms, the lower the voltage level is in a Member State, the higher the share of underground lines. 55% of lines below 1 kV are underground, whereas this number decreases to 11% for lines above 100 kV.

Why is distribution a regulated sector?

Electricity distribution is a natural monopoly. The fixed costs of constructing a distribution grid are so high and the marginal costs of distributing electricity so low that competition (i.e., network duplication) is usually infeasible given current network technologies. Empirical evidence suggests that monopolies are the most efficient form of production organisation in electricity distribution. This also means that each consumer from a particular area can only be cost-efficiently provided with electricity from the DSO that owns/operates the network in that area. DSOs have different sizes throughout Europe in terms of network length and connection numbers. Some DSOs are municipal (e.g. in Germany), whereas others can straddle several regions (France, Italy). Because of their monopolistic nature, DSOs are fully regulated companies in most European countries. Their allowed revenue is determined by national regulatory authorities (NRAs) and collected through distribution tariffs. These tariffs can be established either by the NRA or by the DSO. Through these revenues, DSOs must cover the costs of improving and operating the traditional grid, and - in more recent times - smart grid investment, too. They must also keep an eye on supply quality and reliability as well as becoming smarter in energy digitalisation. Therefore, DSOs require stable, but dynamic regulatory schemes supporting change through innovation incentives.

DSOs balance generation and consumption

DSOs own and operate distribution networks and connect transmission lines with consumers. They are also responsible for developing and expanding networks, to maintain them and to manage power flows, ensuring secure and safe operation (which involves managing congestion and voltage on their grids), quality, and continuity of supply at all times. The DSO is increasingly responsible for controlling imbalance variations within the distribution system, linking wholesale and retail markets, as well as enabling self-generation and consumption. The increase in distributed generation (DG) across Europe (mainly from renewable sources) connected to the distribution grid strengthens the need for DSOs to act as active system operators and be prepared to overcome new challenges. DG can contribute to ensuring security of supply, reducing

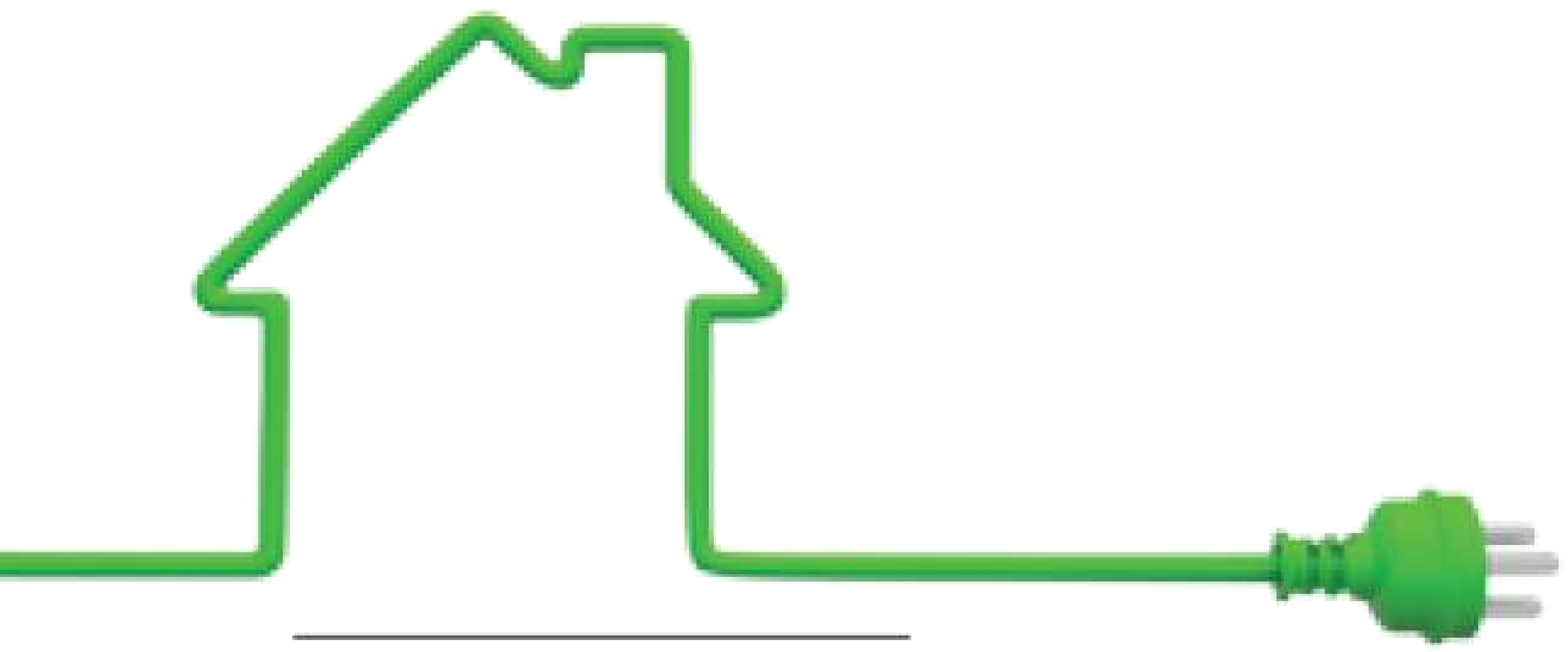
3 Under full ownership unbundling, a separate company owns and/or operates the distribution network. This is also known as vertical disintegration between regulated distribution networks, regulated transmission networks, and non-regulated commercial activities.

distribution peak load[4], congestion[5], and the need for further long distance transmission. In practice, however, integrating distributed generation into DSO grids represents a challenge for DSOs due to DG's production and locational profiles. DG does not always coincide with demand because of its variable nature and is not always compatible with the optimisation of distribution-level constraints. Therefore, DSOs will have to play an increasingly pro-active role in the network development and operation.

What do DSOs do when an isolated home asks for electricity?

When an isolated home, which is not connected to the distribution grid, asks for grid access, the DSO operating in that area is obliged to build a connection from the grid to that home.

The DSO will then evaluate the state of the grid in the proximity and will assess, together with the owner of the isolated site, the required supply capacity for cabling installation (measured in kilovolt Ampere or kVA).



4 Peal load takes place at the highest point of electricity demand in the network for a given timeframe.

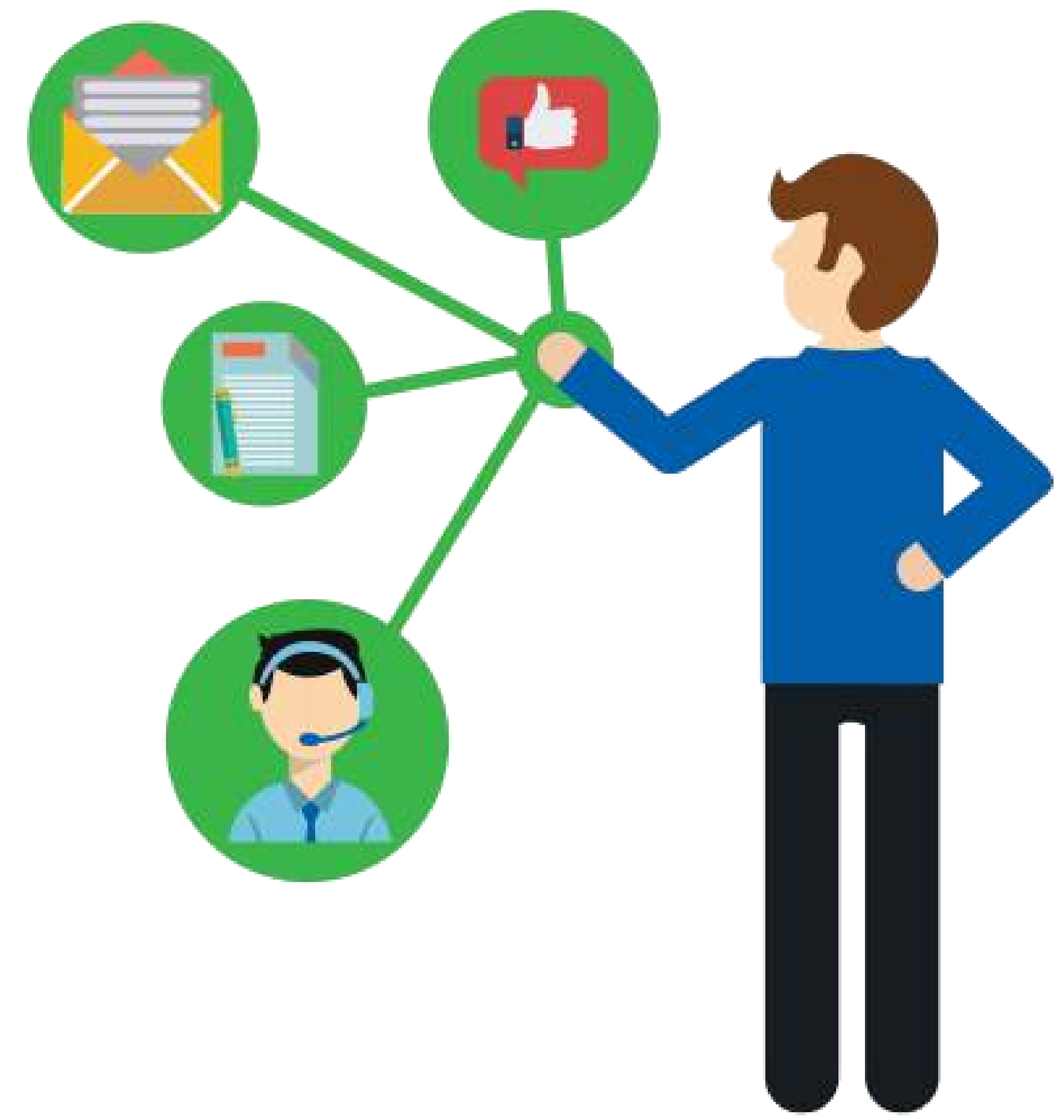
5 Bidirectional and uncertain power flows may result in congestion at certain points of the distribution network. Consequently, assets are overloaded, voltage deviations can occur, and failures may take place - possibly jeopardising system reliability and quality of supply.

The difference between distribution and retail costs in the end-user bill

Retailers purchase electricity from power plants either through power exchanges or via over-the-counter contracts. They provide retail services to consumers - such as billing, customer contact and in some cases metering. Electricity prices charged to consumers by retailers are made up of several components: wholesale energy and supply costs, network costs, taxes and levies, and a profit margin. Network costs (connecting and disconnecting customers, operating and maintaining grids and information systems, providing meter reading services) as incurred by the DSO are recovered through distribution charges, which are fully regulated. In most Member States, retailers provide one overall bill to consumers and, in some cases, network and supply tariffs are not separately shown. In some Member States however, two bills are provided: one for network services (transmission, distribution), and one for supply services to final customers.

DSO communication with the customer

To simplify communication with consumers, on every piece of communication such as the energy bill, the supplier must provide its customers with an emergency contact for the DSO. The DSO would contact consumers only to send them information on network performance such as: connection, end-use contract/terms, network tariffs, metering services, planned and unplanned service interruptions.



Tomorrow's distribution system: actively managed grids and smart grids

Conventional distribution grids without decentralised electricity from renewables are called 'passive' grids because power transportation over such grids is a unidirectional flow from power plants to end users. Electricity flows over passive grids are predictable and do not require any extensive management and/or monitoring tools.

Passive networks were designed according to peak demand. On the contrary, active distribution grids must make room for bidirectional energy flows because of the amount of renewables connected to the distribution grid (Figure 3).

Actively managed distribution grids integrate autonomous systems interacting with each other (e.g. storage and electric vehicle infrastructure) and must ensure coordination, cost efficiency, and reliability of supply. 'Active' and 'smart' grids are not synonyms. In fact, smart grids are more intelligent active grids which can also affect energy consumption through communication systems helping relieve the grid when necessary.

Smart grid operators manage data and information flows through digital and communication processes. DSOs manage millions of daily real-time signals through satellite, powerline communication systems, radio, fibre-optic lines, and other communication technologies. Data management will continue being one of the key features of smart grid design, together with infrastructure digitalisation and automation. Current DSO capabilities - combined with big data, the internet of things, and the advent of a fully digital era more widely - will allow DSOs to play their role in the new economy.

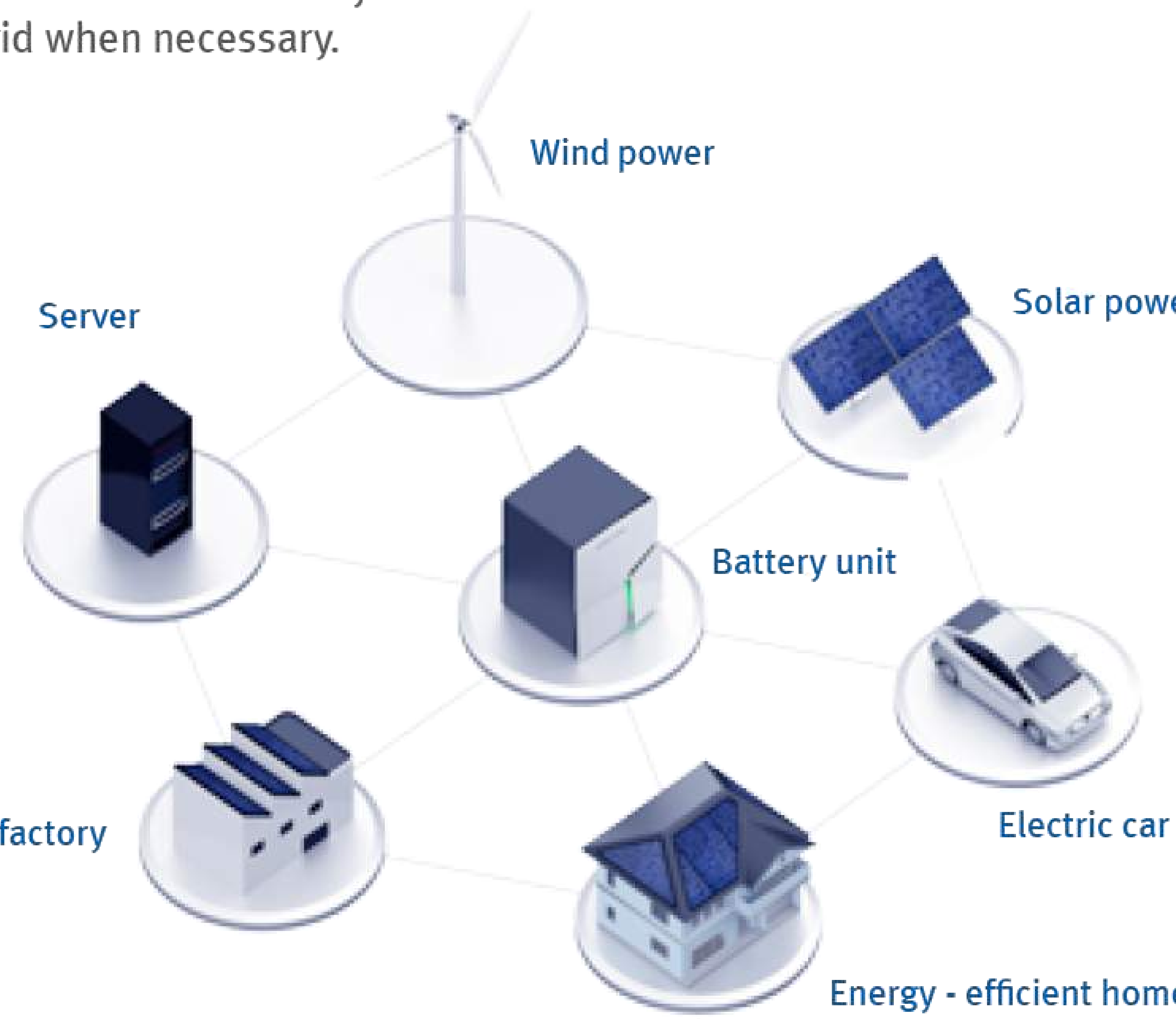


Figure 3 Elements connected to the distribution smart grid

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