Development of load prediction models of end users on the hosting capacity for low-carbon technologies on distribution grids

The roll-out of the digital meter in Flanders over the coming years presents a unique opportunity to analyse the current consumer behaviour, as well as to predict and anticipate future behaviour. This electricity consumption behaviour on the low-voltage distribution grid is rapidly changing. The introduction of on-site generation in the form of residential PV installations, combined with the expected electrification of both mobility (electric vehicles - EV) and heating (heat pumps - HP) demand, presents an ever increasing challenge to the grid operators, as they want to avoid excessive future investments in existing distribution grids due to the increasing peak demands and uncontrolled upstream injection. These three categories of upcoming technologies (PV, EV, HP) can be described under the umbrella term of 'low-carbon technologies'.

In this PhD research, the so-called 'hosting capacity' (HC) of these three technologies is analysed based on both deterministic and probabilistic methods. A HC describes how much of a certain novel technology can be connected to the grid without endangering the reliability or voltage quality for other end users. As such, several properties can be considered to be the limiting factor for this HC, meaning different metrics have to be considered simultaneously to accurately evaluate a HC.

The initial step of the PhD research involves a necessary in-depth characterisation of the consumption and peak demand behaviour of end users at the low-voltage distribution grid. Using a combination of newly constructed clustering algorithms based on machine learning methods and analytical models such as load-duration curves, consumers can be categorised into clusters with similar properties. Special attention is given to the stochastic nature of the demand peaks for different types of end users, given their relevance for grid operators and energy management systems.

Second, a new grid-level simulation tool is developed which can be used to calculate these limiting factors for end users, such as the voltage quality, and predict the HC for various scenarios, ranging from pre-defined representative grids to fully customisable communities, which can be of use for future energy communities. While artificial yield profiles of PV installations and synthetic profiles for the heat pump loads are used, realistic stochastic profiles are constructed for the various loading scenarios for electric vehicles. Special attention is given to the possible synergies between different types of low-carbon technologies, e.g. charging an electric vehicle when solar yield is high, to determine realistic best-case and worst-case scenarios for the considered hosting capacities.

Finally, methods to further enhance this hosting capacity of new technologies are explored. This includes communication between different end users to coordinate responses, leveraging the consumption flexibility present for different types of end users, as well as possibilities for grid operators to stabilise the grid, such as battery energy storage systems in case of voltage quality issues.

Several case studies will be selected for in-depth simulations in each step of the research, with different layers of uncertainty. While all parameters and profiles are known in the initial deterministic approach, more complex simulations will require a probabilistic approach and forecasting of the load profiles in order to perform the necessary validations of the proposed methodologies and simulation framework.

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