Abstract

The Smart Grid is a complex system that encompasses many fields of expertise. For this reason, the various sub-elements of the Smart Grid have usually been modelled thanks to domain-specific simulation tools that can characterise the physical behaviour of each element deeply. Researchers often coupled these simulators to test future scenarios using co-simulation platforms, allowing the integration of domain-specific simulators into a broader context.

As the electrical system undergoes a paradigm shift, the introduction of agent-oriented approaches has been instrumental in considering socio-psychological and behavioural aspects, particularly those typical of the consumer side, and testing distributed control strategies. However, the integration of agent-oriented approaches with simulators of the physical system, especially when incorporating socio-psychological and behavioural aspects, has been rare. Yet, the behavioural sphere is a crucial element in the energy transition, with its complex dynamics necessitating a social-scientific perspective alongside technical knowledge.

Undoubtedly, the residential user is a pivotal simulation element in several scenarios in the energy transition context. The findings from various European pilot projects have underlined the necessity of comprehending the final customer to involve them in the energy transformation process and unlock their flexibility. Therefore, modelling the behaviour of individual users would give a deeper understanding of the underlying phenomena and a higher level of realism. Unfortunately, factors such as user behaviour in the energy context and non-financial barriers have often been overlooked in the analyses.

Current models are often limited to specific cases, hindering their reuse or expansion. This limitation underscores the urgent need for more generalisable models and frameworks. Therefore, the development of research methodologies that can effectively address the increasing complexity of social and technical phenomena is not just important but crucial. In the energy context, a modular and hierarchical agent-oriented framework for modelling and simulating citizens' behaviour to test new strategies and allow the reuse of existing simulators is missing.

This thesis introduces a novel hierarchical and modular agent-oriented framework to fill this gap and support the energy transition. In particular, the framework aims to consider the demand-side complexity to replicate the behaviours of actual users in the energy context. This tool must be flexible enough to implement multi-agent system analysis to test specific strategies and support agent-based models for better decision-making.

Indeed, the framework is capable of implementing multiple scenarios, offering ready-to-use models that are flexible enough to implement various strategies. Moreover, it allows for customisation and the addition of new models, simultaneously simulating multiple aspects.

Following the European Union's recommendations for more synchronised data dissemination and aiming at developing a reusable tool that allows for cross-country comparability, the proposed methodology makes extensive use of publicly available and widespread data to replicate mobility-related and house-related electricity consumption, which derives from the user's indoor and outdoor behaviour and socio-psychological mechanisms.

After introducing the human-like agent models, the thesis analysed several scenarios. Some scenarios focus on the behaviour of the end-user derived from several surveys. Other scenarios involve a fully or partially controlled system to, for example, schedule resources or appliances optimally. To this end, the thesis proposes different flexible optimisations. The variability of the scenarios demonstrates the flexibility of the proposed framework and gives insights into present and future citizens in the energy context.