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A REVIEW OF PROSUMERS' BEHAVIOURS IN SMART GRIDS AND THE IMPORTANCE OF SMART GRID MANAGEMENT

ABSTRACT

Purpose: The concept of the smart grid is relatively new. The first aim of the study is to understand the behaviour of prosumers in smart grids. The other goal is to raise awareness of the management tasks and risks of smart grids by highlighting the relevant issues of some business networks (PPP projects, outsourcing, strategic alliances etc.).

Methodology: Systemized literature review was used in the paper.

Results: The discussed management problems of various business networks indicate that management challenges can also be expected in smart grids, so it is worth preparing in time.

Conclusion: We found a lack of empirical research about the behaviour of prosumers and believe that studying the electric power grid of the future from a management perspective, that is, examining the possible behaviours and decisions of various actors, can provide valuable and useful information for smart grid design and safe operation insurance.

Keywords: Smart grid management, systemised literature review, business networks

1. Introduction

The classical electric supply chain was first established over a century ago, and since it has been growing in size and capacity (Wulf, 2000). The limited one-way interaction makes it difficult for the grid to respond to the ever-changing and rising energy demands of the 21st century. The term Smart Grid

(SG) was first referenced by Amin and Wollenberg (2005). Smart grids are automated, widely distributed power supply networks characterised by two-way electricity flow and information that can track and respond to everything from power plants to customer preferences to individual devices (Planko et al., 2017).

Our focus is on the behaviour and cooperation of the various actors of the smart grids, so we looked at how the actors work together in some widespread business networks and business models. The parties involved must work together during outsourcing to achieve the planned benefits. In the case of a strategic alliance, legally separate companies cooperate for a complex goal, during which there is significant interdependence. Not only companies participate in PPP projects, but also actors from the state and the public sector.

To better understand the actors of smart grids and the possible behavioural risks, we formulated the following research questions:

- What behaviour problems of prosumers were found in smart grids according to relevant literature?
- What management problems appeared in the examined business models and networks?

To answer our questions, we write a critical literature review and finally identify some actual research goals and recommendations.

2. Systemized literature review on prosumers in smart grids

In a traditional electrical supply chain, the flow of both electricity and information is essentially one-way, starting from the power plant and moving toward the end user. In smart grids, it is all a two-way process; in addition, communication takes place through a parallel and complex network of contacts due to the increased role of the participant. In smart grids, not only conventional power plants will be involved in electricity generation, but also renewable power plants. Electric vehicle owners (business and private) will also have an active role in electricity generation through the V2G (vehicle-to-grid) process, which recharges electricity from the electric vehicle to the grid (Hannan et al., 2017). In the age of smart grids, the importance of international electricity transactions is expected to increase. Electricity production is not only done by traditional power plants but also by the renewable power plants of (organisational or private) consum-

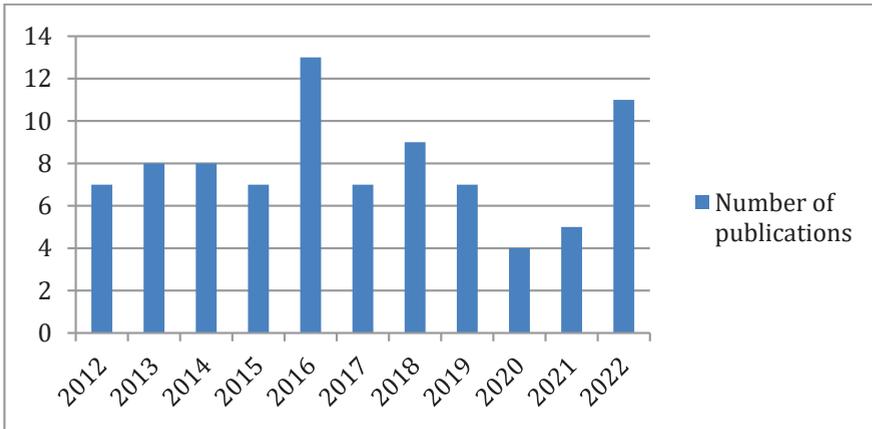
ers; therefore, these end consumers are also producers, i.e. prosumers (combining the words producer and consumer) (Yanine et al., 2021). An important difference is that production and consumption are separated in the traditional system but not in smart networks, so these activities must be optimised.

We planned to get a more objective picture of the relevant literature situation by using the method of systematic literature review. A systematic literature review is transparent, made with scientific methodology, and high-level comprehensive studies collected and analysed in relation to a given problem and all existing research results (Davis et al., 2014).

We chose the Google Scholar database because of its extensive coverage. Since the smart grid is a relatively new concept, and we were also interested in the management side, possibly empirical research, we chose the last ten years as the period of the study, i.e. the years 2012-2022. For the sake of a focused search, we did not search for keywords in the text, but in the title, since the terms 'management' or 'project' can easily appear in a text without the publication specifically talking about it. In the examined period, the terms 'smart grid', 'management' and 'project' appeared in 12 publications. The search for 'European smart grid management' gave six results.

Then we tried other keywords. The special actors of smart grids are the prosumers, and we are interested in their behaviour, more precisely, how it appears in research. That is why we used the words 'smart grid prosumer behaviour', for which we found 126 hits. We worked with these 126 results. We reviewed them all and – where possible – copied the abstract. Some publications did not have an abstract or a similar text (e.g. ppt in pdf format); therefore, the scope of the study was narrowed down to 86 publications. The year of publication is shown in Figure 1. The last ten years examined do not show a steady increase, but there was a slight jump in 2016 and 2022. A more extended period could more accurately portray the increase in the importance of the topic.

Figure 1 Number of publications on 'smart grid prosumer behaviour'

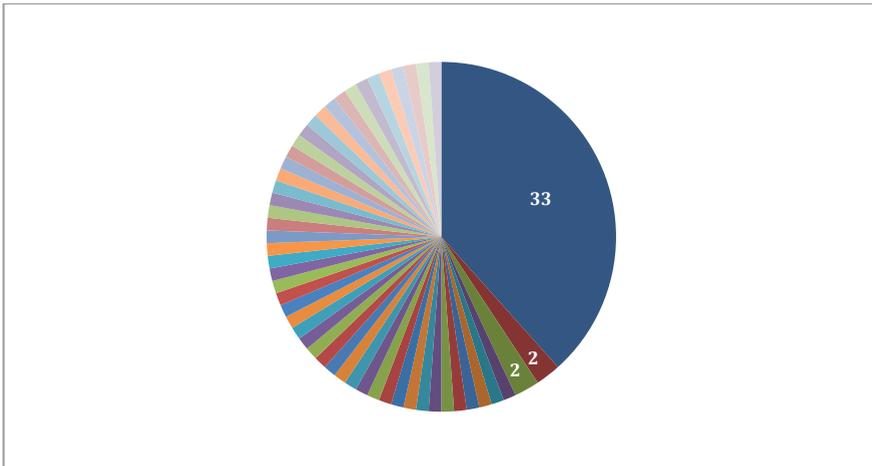


Source: Author

Figure 2 provides information on the source of the 86 publications. 33 articles are in the IEEE database, two publications are in the journal Energies,

and two publications are from the Delft University of Technology library. All other sources provide 1-1 publication.

Figure 2 Reviewed publications by source



Source: Author

The word cloud in Figure 3 was created from the abstracts of the 86 publications examined. The search keywords in the title were 'smart grid prosumer behaviour', but the most dominant term is energy. Yes, the smart grid is the electrical network of the near future. However, most of the articles are theoretical and propose 1-1 models based on simulations and other calculations, which is why the word model appears larger too. Other important words in Figure 3

are "price, data, time, purpose, system, and control", indicating the direction of the papers. Papers dealing with the management side of the smart grid often take methods from game theory or artificial intelligence (fuzzy systems, machine learning etc.) showing various simulations. Furthermore, this topic appears in connection with the Internet of Things (IoT) or V2G/G2V issues. About ten of the 86 publications examined deal with the empirical research of prosumers.

management knowledge or acquisition of new ones, and gain new markets (Pangarkar et al., 2017). The number of such cooperations is increasing while involved companies can decrease business uncertainties (Hoffmann et al., 2001), improve their competitive advantages (Townsend, 2003), encourage organisational learning (Hulbert et al., 2012), and contribute to the general growth of firms (Powell et al., 1996). According to scholars, the potential limit of strategic alliance can be handling interdependence (Hannah, 2016) and cultural diversity (Elia et al., 2019). The success of a strategic alliance requires trust from parties (e.g. Wong et al., 2017), depends mainly on how companies can cooperate (Rosenkopf & Almeida, 2003) and how they can integrate and systematically use different knowledge (Subramanian et al., 2018).

PPP (Public Private Partnership) is a form of cooperation in which the state involves the private sector in the project. Typically, the private sector is responsible for designing, operating and financing these activities. It is most common in developing infrastructure for roads, bridges, tunnels, railway lines, public utility investments, sports facilities, health investments etc. (Grimsey & Lewis, 2002). This form of cooperation began about 40 years ago (Bovaird, 2004), and its success is perhaps due to the fact that it combines the different skills and approaches of the private and public sectors well. With the help of the private sector, resource utilisation seems more efficient, with lower costs and higher innovation (Schemm & Legner, 2008). However, different control and management mechanisms provide a number of conflicts during PPP collaborations, such as constant struggle over risks associated with partners (Majchrzak et al., 2015), management of driving difficulties (Bamford et al., 2003), different solutions for control (Wilkinson et al., 2013), constant disagreement on formal and informal control and management mechanisms (Ansari et al., 2014). Moreover, Uiterwijk et al. (2013) argue that inadequate risk management can undermine the success of PPP projects in the long run. Several authors highlight the role of knowledge transfer and the complementarity of the parties' knowledge (e.g. Kerkhof et al., 2016), additionally the opportunistic behaviour of the parties, or the limitations of their approach may hinder the processes (Das & Teng, 2001). Umar et al. (2018) interviewed roughly 200 experts globally and stated that the "Private involvement in infrastructure provision

has generated more controversies than the problems it was meant to solve" (p. 11). As a possible solution, examining more than 300 PPP projects, Jayasuriya and co-authors (2020) concluded that the effective involvement of stakeholders is a major contributor to the success of this kind of project.

Outsourcing exploded into the business world at the time as it promised to cut costs. However, it took decades for the organisations involved to reap this and the other benefits of outsourcing. The strategic alliance as a business model is also very popular, but in everyday life, there are more management challenges that businesses have to deal with. Perhaps the management problems experienced during PPP projects and their solutions are the most relevant for us because, in that case, the public and private actors have to work closely together for many years. In fact, from this point of view, smart grids can also be considered a special variety of PPP projects.

4. Discussion about potential behaviour risks in smart grids

In different smart grids, individuals, organisations, municipalities, small and large electricity producers, and electricity traders operate closely and systematically, even in several roles. On the one hand, it is important to note that in smart grids, "traditional" actors also have expanded roles (e.g. Mohsenian-Rad et al., 2010; Schiavo et al., 2013); on the other hand, new mechanisms (information flow, changing of monopolies, self-monitoring, achieving resilience etc.) and new, alternative energy sources are integrated into the system (additionally determining the role of weather).

Skjolsvold et al. (2021) consider the forces driving the development of smart grids to save money and manpower, new technologies/digitalisation, and the common understanding of decarbonisation and electrification by society. A sustainable economy and environment are commonly wished for; however, we think individuals' theoretical desires may not be so strong when they have to cooperate closely and limit themselves (e.g. to reduce peak electricity consumption periods). Perhaps the answer can also be the other driving force mentioned by the authors, such as the shared economy and its various branches and solutions. These are indeed very popular among the younger – especially higher-educated – generations, but smart grids will not only be actively used by young, educated, open people.

“How can we avoid producing new high-tech ghettos for the wealthy while enabling participation in the transition for the less fortunate? Energy justice literature tends to emphasise the distributional, procedural, and recognition-based aspects of energy justice.” (Skjolsvold et al., 2021, p. 16).

The management lessons of the briefly presented business networks allow us to conclude that conflicts may occur in smart grids operating not only in pilot projects due to the different routines, approaches, knowledge and beliefs of various actors. Designers and main organisers of smart grids should be aware of the various differences (ownership structure, management mechanisms, decision-making processes etc.) of organisational actors and be prepared to handle them or establish relevant resilient solutions to avoid the challenges mentioned in cases of strategic alliances and PPP projects. Organisational actors need to learn to communicate in the right amount in an understandable way. At the same time, the knowledge of private consumers (prosumers) needs to be expanded in the area of their new duties and responsibilities.

5. Conclusion

More scholars (e.g. Möller & Svahn, 2003; Planko et al., 2017) see a research gap in the management of networks operating in emerging markets. Geelen et al. (2013) suggest investigating smart grids from the aspects of end-users and energy providers. Skjolsvold et al. (2021) see that relevant regulations “take social aspects for granted” (2021, p. 15). Binder et al. (2019) recommend the study of the unpredictable behaviour of end-consumers and electric vehicle owners.

There is also a need for a variety of training for professional and non-business players in smart grids that can reduce some concerns and prevent the spread of misinformation and assumptions. We see that people at different ages have learned to use different technologies and systems, but it also requires knowledge, time, and patience, and these three are permeated by communication.

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Appendix 1 The list of reviewed 86 publications:

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