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Uncertainty, vision, and the vitality of the emerging smart grid

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ABSTRACT

This paper answers an important question consensually identified as crucial for smart grid roll-out. Our objective is to highlight the reasons for economic, technological and regulatory uncertainty continuing in the smart grid sector. The argument of this paper is that to face uncertainty, actors adopted strategic positioning but not systematically favoring the emergence of a structuring and shared vision of smart grid. However, converging visions are necessary to limit uncertainty and thus secure the sector's development and durability in the coming years.

The results presented here are based on two methodological approaches. First, a social network analysis of worldwide relationships between smart grid actors has been performed to characterize the actors' positioning strategies. The paper identifies four categories of actors: local observers, global observers, experimenters, and central actors. Second, a qualitative analysis of semi-structured interviews with approximately 30 French smart grid stakeholders gave us information on discourses and perceptions of the sector's reality and constraints. It appeared that smart grid merges both long-established actors in the smart grid focal sector, i.e., energy, promoting a highly accurate but strictly energy-oriented perception, and new entrants coming from related sectors such as ICT, offering an open but indistinct perspective. Therefore, stakeholders diverge on the definition and potential source of added value.

These results help to elucidate the transition of socio-technical systems. Indeed, at this very moment when contextual uncertainty remains high, it appears that actors from the focal sector play a crucial part in driving the current sector development, whereas new entrants remain unable to modify the sector's regime decisively. One can interpret this situation as a sign of the failure of the smart grid sector to emerge as such. Conversely, one can see here an evolution of focal actors' strategies regarding uncertainty in an innovative socio-technical system in transition. To solve this issue, further studies should be conducted both on the smart grid sector to see how it will evolve and on other sectors to search for similar trends.

1. Introduction

This paper answers a crucial issue for smart grid roll-out, which is the reasons for continuing uncertainty in the sector. Indeed, uncertainty of various types (e.g., economic, technological, and regulatory) has been clearly identified in recent literature (Section 2) but has not yet been directly investigated. This article proposes to fill this research gap, showing that uncertainty mainly continues because of the inability of smart grid actors to favor the emergence of a structuring and shared vision of the sector. However, structuring and sharing such a vision for smart grid is necessary to limit uncertainty and thus secure the sector's development and durability in the coming years.

Based on insights from sociology and innovation studies, this paper offers an analysis of the smart grid sector conceptualized as a socio-technical system. We rely on an original methodology that combines two approaches for studying actors' cooperation strategies (Section 3). First, a social network analysis exploiting an original database gathering worldwide partnerships in smart grid projects has been performed to characterize actors' positioning strategies at the systemic level. Second, a qualitative analysis of semi-structured interviews with approximately 30 French smart grid stakeholders informed us on the discourses and perceptions on the reality and constraints of the smart grid sector.

This empirical material allows us to investigate the hindrance to the transformative capacity of the sector standing at the intersection of the actors' strategies and the smart grid socio-technical system. On this basis, the paper has two main outcomes (Section 4) that contribute to understanding and explaining how smart grid stakeholders have been reacting and positioning themselves

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in a complex and uncertain environment. First, we identified four categories of actors regarding their positioning strategies. Second, we demonstrated the importance of the heterogeneous nature of stakeholders to explain the discourse's oscillation between enthusiasm and reluctance regarding the potentialities of smart grid technology.

In the conclusion (Section 5), we argue that in a context of toughened competition and considering the positioning strategies previously highlighted, it appears that stakeholders are unable to build a shared vision, which prevents the smart grid sector from lowering uncertainty, which would allow prospective achievements. We also briefly open a discussion on the possible renewal of actors' strategies involved in innovative socio-technical systems in transition.

2. Literature review

Because the recent spreading of awareness that the Earth resources are finite, especially regarding increasing energy scarcity, a dilemma has emerged: how to handle the increase of electricity demand and consumption peaks in a context of energy supply deficit. One possible answer (mostly relevant in Europe) would be to increase energy production through the integration of renewable energies. Another solution (especially in North America) would be to avoid grid malfunctions (mostly during consumption peaks) and the high costs of the associated blackouts, by renewing aging grids. By seeking solutions to the tricky equation of matching electricity supply and demand, it has appeared that smart grid is a possible and realistic option [41,60]. Thus, for 10 years, real enthusiasm for smart grid has emerged all around the world—perceptible through the high number of dedicated publications, reports, strategic displays, and R&D projects—mainly conveyed by related industries, public administrations and politicians, all awaiting economic and environmental profits [50,63].

In this context, smart grid is expected to fulfill a set of specific functions, identified in the literature as being able to solve energy challenges (see among many others [1–4]), such as: (1) the efficient management of supply, including intermittent supply; (2) two-way communication between the producer and user of electricity; (3) the use of information and communication technology (ICT) to respond to and manage demand; and (4) the insurance of safe and secure electricity distribution. Doing so should turn a "dumb" electrical grid into a "smart" one [4,31].

Considering the high potential of smart grid for solving energy issues, we can legitimately wonder why it has not been massively implemented yet. The literature investigating this issue first notes that no consensual definition of smart grid has emerged yet (for a complete and synthetic review of the literature, see Ref. [40], which propose four types of smart grid definitions reflecting the absence of consensus: (1) "via requirements", (2) "via applied technologies", (3) "via desired applications" and (4) "no clear definition"). It is thus difficult to know precisely what one means when talking about smart grid. The roots of the heterogeneity of smart grid definitions have to be grounded in the geographical, economic and historical specificities of national electrical grids [4,6]. Indeed, national specificities (such as national energy mix, industrial policies, polity and corporate governance structure) have long favored the scattering of technological expertise into separate locations. This results in preventing the current homogenization of the smart grid concept [13,41,50]. As a result, it appears that smart grid deployment cannot be homogeneous worldwide because it is more likely to depend on the technical characteristics and specific structure of each electrical grid: the more decentralized an electrical grid is, the higher smart grid pervasion will need to be [47].

Thus, considering the lack of a shared definition related to the variety of expected achievements and local constraints, smart grid implementation currently faces major challenges that are considered in literature alternatively as barriers (see Fig. 1 in [2] and [5]) or incentives [18,34,54].

The first challenge is to remove uncertainty regarding the cost of smart grid, as many recent reports have noted its increasing deployment costs. Hence, some countries have questioned and even jeopardized smart grid implementation. For instance, despite the European directive on the electricity market [20], Belgium decided not to systematically deploy smart meters (considered the first step of smart grid) because the cost/benefit analysis was not positive. Following the upwards revision of smart grid costs, analysts have observed that market uncertainty concerning the smart grid's future evolutions has significantly grown [18,34,39], mainly concerning the opportunity to invest in such an uncertain technology [7,47,60].

Indeed, the reassessment of smart grid deployment costs is unanimously related to the literature on technical uncertainty. First, technical uncertainty has an impact on the possible developments of the energy system in its complexity, accentuated by the requirements for integrating intermittent and decentralized power sources [8,21–23,34,51]. Second, technical uncertainty also stems from the lack of (1) technology maturity [46,61,62]; (2) necessary technical skills and knowledge [47]; (3) open standards and advanced bi-directional communication systems [4,18,34,39,53]; and (4) real reflections about cyber security and data privacy issues [36,39,46,60,63].

When considering the rising costs and technical uncertainty of smart grid, most scholars wonder about the existence of a reliable business model for smart grid deployment when no stabilized technical solution currently exists [14,22,29,42,61,62]. At present, no clear answer prevails. If cost/benefit analyses have all agreed on a deficit gap between smart grid investment costs and created value; scholars are basically dividing into two categories: those wondering if a business model exists at all and those proposing alternatives to balance the smart grid business model.

In this second perspective, a first option for compensating the demand–response investments and supporting programs is a more accurate valuation of avoided costs thanks to smart grid in electricity generation, transmission, and distribution [3,33]. To find an equilibrium, some also argue that smart grid assessment ignores or underestimates added value induced by smart grid, for example, in the urban dimension and in city governance [31]. From these perspectives, the smart grid definition border tends to enlarge and thus involves issues, going beyond energy-grid concerns.

A second option to counterbalance the cost-benefit gap consists of focusing on value added for the energy market. For example, this counterbalancing could involve the introduction of dynamic tariffs during peak demand. It would provide economic incentives for end users to adapt their consumption to the energy supply: demand would be compliant with supply. This would require that end users benefit from adapting their consumption. From this perspective, smart grid actors should agree to pay for demand-side management, i.e., to share part of the value with end users. For instance, utility companies and distribution network operator companies could reward end users by offering dynamic tariffs, direct payments or the availability payments for a consumption change at an agreed time, for electricity not consumed, for greenhouse gasses not emitted, or for reducing the energy generation security margin, avoiding the building cost of new generation plants [15]. However, even so, it seems difficult so far to involve end users because the technological and economic aspects of smart grid remain quite complex and thus abstruse: people do not perceive what benefits smart grid could provide in their daily life or from an economical point of view. To overcome this difficulty,

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