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Understanding the role of incumbent utilities in sustainable energy transitions: A case study of the smart grid development in China

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Abstract

Smart grids, although have been widely recognised as an enabling technology for delivering more sustainable energy futures, have however failed to reach significant deployment across the world. Drawing on the theoretical perspectives of governance, this paper critically examines and explains the role of incumbent utilities as an enabler or a barrier to sustainable energy transitions, with a particular reference of a case study of smart grid developments in China. We have two major findings in this working paper. First, China has developed an incumbent-led model for developing smart grids, in which two major state-owned grid companies have assumed central role in shaping the pathways and pace of the smart grid developments. Second, we specify that the grid operators played five major roles in the SG deployment. These include: 1) as planners, capital providers, builders, and managers of SG infrastructure; 2) as network operators; 3) as regulators; 4) as technology developers and knowledge creators; 5) as new energy service providers. This paper concludes by discussion future research agendas that emerge from a better understanding of the role of incumbent utilities in SG developments in China.

Keywords

Smart grid, incumbent utilities, governance, distributed energy sources, solar, China

Abbreviations

CEC	China Electricity Council (中国电力企业联合会)
CSG	China Southern Power Grid Co. Ltd. (中國南方電網)
DE	Distributed energy
DER	Distributed energy resources
DPV	Distributed photovoltaic
NDRC	National Development and Reform Commission
NEC	National Energy Administration
SERC	State Electricity Regulatory Commission
SGs	Smart grids
SGCC	State Grid Corporation of China (國家電網)

1. Introduction

SGs in general are electricity networks that use advanced information and communication technologies to modernize or "smarten" existing power systems, and thus to allow increased levels of distributed generation and demand responses programmes (IEA, 2011). Smart grids (SGs) have been increasingly recognsied as a critical enabling technology for facilitating deep reduction in carbon emissions, and realising sustainable energy transitions (IEA, 2011). Such grids are increasingly being adopted and implemented worldwide in recent decades, and particularly so following the Fukushima nuclear accident. Such developments are more notably in the US, the UK, Japan, and South Korea (Energy and Climate Change Committee, 2015; Executive Office, 2011; Mah, van der Vleuten, Ip, & Hills, 2012; Mah, Wu, Ip, & Hills, 2013).

China is a late comer in the global trends of SG developments. It was in 2009 that the State Grid Corporation of China (SGCC) marked the beginning of China's major SG initiatives by announcing its three-phase SG plan. When compared with SG developments elsewhere, China's approach is atypical in at least three important ways. First, China, as a late-comer, has the potential to leapfrog the deployment process of SG. In 2010, China already surpassed the US in total smart grid expenditures, with costs of nationwide grid upgrade projects estimated to be US$100 billion through 2020 (EIA/SAIC, 2011). China is already the world's largest market for smart meters. Smart meters in China is expected to grow from 139 million units in 2012 to 377 million units by 2020, reaching 74 percent market penetration (Alejandro et al., 2014). Second, China's focus on high-voltage transmission networks in its SG initiatives (Liu Zhenya, 2013) has also set China apart from other countries such as the US (where SGs tend to focus more on energy system resilience and reliability (Connor et al., 2014)) and Japan (where community-led demand-side management approaches seem to be most prominent (+refs). The third important feature is related to the prominent roles played by two large state-owned grid operators, the State Grid Corporation of China (SGCC) and China Southern Power Grid Co. Ltd. (CSG). While prosumers tend to play a more prominent role in the SG developments in the US as well as in Japan, the incumbent utilities in China have a more prominent role to play.

While such incumbent-led initiatives have led to some major achievements in China, most notably in smart meter roll-out, the overall progress has been slow in critical areas including distributed generation and demand responses. The extent to which, how and why, incumbent utilities facilitated or impeded smart grid deployments in China has remained largely understudied.

This paper aims to explore the role of incumbent utilities in SET from the perspective of governance, with a particular reference to the smart grid developments in China. This paper is a qualitative, detailed case study. Our findings are based on desk-top studies and semi-structured face-to-face interviews with 18 interviewees in 11 interview meetings which took place in Beijing, Tianjing and Guangdong in 2014 and 2015. Our desk-top studies have reviewed government documents and reports, journal and professional publications, newspaper articles, and website information. Our interviewees come from major stakeholder groups of SG developments in China, including the government, grid companies, academics, and consultants. Most of them hold senior positions in their agencies, institutes, or companies and are knowledgeable informants in the field. All the interviewees were audio-recorded and transcribed. Some follow-up email correspondence and calls were made for update.

This paper is organized into five sections. Following the introduction, Section II provides a theoretical discussion and develops a conceptual framework for analysing the role of incumbent utilities in SG deployment. Our framework is then used to guide our analysis of the case study of China. Section III provides an overview and contextual characteristics of SG developments in China. Section IV discusses the features of China's incumbent-led approach for developing SGs, and specifies the major roles of the two grid operators in the developments of SGs. The final section offers some discussions on the future research agendas.

2. The role of incumbents in SG deployments: A theoretical discussion and a conceptual framework

While smart grids may be defined and deployed in various ways in different contexts, these grids have been increasingly recognised as an enabling technology for supporting a broad set of advance energy technologies in both supply-side (e.g. large scale integration of renewable energy and distributed energy sources) and demand-side of energy management (e.g. demand responses). These advanced forms of technologies are enabled by the intensive use of IT and communication technologies over the entire generation, transmission and distribution systems of electricity sector (Z. Liu, 2013; Mamo, Mallet, Coste, & Grenard, 2009).

In the last decade, there has been a growing body of research on the developments of smart grid. Some have documented important progresses, most notably in technological advancements, smart meter rollouts and demonstration projects, some have shed light on a wide range of challenges including technological, market and institutional barriers. This paper adopts the governance perspectives to provide a better understanding of smart grid deployment.

In the governance literature, the notion of socio-technical regimes proposed by Geels (2005), cited in (Szatow, Quezada, & Lilley, 2012), instructively uses the concepts of regimes and path-dependency to explain how and why it is difficult to achieve a short-term transition towards more sustainable energy futures. Geels (2005), cited in (Szatow et al., 2012) argues that energy systems have their own ideas, culture, identify, practices, and technical competences that developed over time, and tend to be biased towards incumbent energy systems. The existence of path-dependency or "lock-in" effect of establish energy technology has therefore made fundamental regime changes that threaten the vested interests of incumbents difficult to achieve (Szatow et al., 2012).

A growing body of the literature on SGs however suggests that energy systems which are more accommodating to smart grid developments would require major structural systematic changes. Such regime shifts are needed in order to realise the potential benefits of new energy options, most notably large-scale penetration of distributed energy sources and demand response programmes, which are provided by smart grid developments. The literature suggests that in contrast with established centralised, vertically integrated systems, systems which are conducive to SGs are characterised by a more fragmented energy markets where incumbent electric grid operators have reduced monopoly power - incumbents need to manage different types of DE resources which are intermittent in nature, and to deal to new market participants including new energy suppliers and prosumers (consumers who both produce and consumer electricity (ten Heuvelhof & Weijnen, 2013). SG developments in essence require regime shifts through which one -way flow of electricity would be replaced by a multi-directional flows of electricity and information between grid operators, DE suppliers, and prosumers.
Another theme of the governance literature on smart grid has shed important light on the scholarly debate of a theoretical question: could major breakthroughs to socio-technical regime shifts come from incumbents or new market participants?

Incumbents are established firms, or regime actors, of the focal sector. They are highly intertwined with the core technologies, business models and user-practices of the regime (Sabine Erlinghagen & Jochen Markard, 2012). It is important to note that electric utilities, which generate, transmit, or distribute electricity and recover the costs through a regulatory framework (DOE, 2008) have the tendency to become incumbents because utilities, particularly grid/ network operators, are a natural monopoly (Governor of NYS, 2014). *New entrants*, on the other hand, are actors that have entered the focal sector. Often they are recently founded and part of a niche.

The literature somehow presents a mixed picture of such incumbent-challengers relationships. incumbent utilities have been documented as resuming a central role in low carbon transitions, e.g. Electricité de France (EDF), a dominating electricity producer ((Electricité de France, EDF) in France ((Bertoldo, Pourmadere, & Rodrigues Jr, 2015)). Some work has showed that incumbents such as state-owned generation enterprises can create important forces of change within regimes. Some argue that incumbent utilities can play strategic roles in smart grid developments, notably by acting as distribution network operators who manage distributed energy sources (Governor of NYS, 2014). Utilities can also be "smart integrator" or "orchestrator" (Lehr, 2013). Some suggest incumbent utilities exhibit unique incumbent advantages, or structural advantages, over challengers, which explain why they capture first-mover advantages in developing new energy options, including smart grids. These incumbent advantages include access to strategic alliances (ref – utilities/ strategic alliances) resilience to regulatory and market risks (Radcliffe, Taylor, Davies, Blyth, & Barbour, 2014), pre-existing competencies in infrastructural planning, asset management and operation (Curtis & Khare, 2004), customer loyalty (Curtis & Khare, 2004). In contrast to the private investors, state-owned/controlled utilities may support energy innovation experimentations because of strategic considerations rather than short-term economic benefits (Radcliffe et al., 2014).

Work by Lehr (2013) and Martinot and McDoom (2000), on the other hand, instructively provided a critical perspective to explain why uilities are the "last place in business where innovation can rationally be expected to occur". Utilities may lack incentives to take risks while having strong incentives to prevent market entry by competitors (Lehr, 2013). It is especially the case in monopoly and state-protected enterprises where managers may have little incentive to minimize costs or innovate (Martinot & McDoom, 2000).

Another theme of the literature shed light on the role of new market players in initiating radical forces of change which may converge and challenge socio-technical regimes of energy systems. Some studies examine "new challenges" (e.g. ICT firms

(S. Erlinghagen & J. Markard, 2012), property sector and housing organisations in decentralized energy systems (Szatow et al., 2012).

While the success of these challenges is still to be tested with empirical evidence, the literature suggest that there are several reasons for explaining the potentials of these newcomers. (Szatow et al., 2012) in their study on Australian electric power systems and DE, a property company, expands its business functions and becomes an energy service provider, it has the potential to integrate master planning and building design considerations with provider of energy, water, waste and other services in a way that can provide clean energy services (e.g. renewable electricity) more cost-effectively; the property sector can access finance and resources at a scale and price that enable it to compete with the incumbents (Szatow et al., 2012).

It is important to note that although new entrants may deviate radically from existing business practices (often sources of technological innovation as well as BM innovation (Shomali & Pinkse, 2015) , they often lack financial resources, technical skills, and political influence to initiate large-scale system change (Zhang, Wu, Feng, & Xu, 2014).

The literature is however limited in illuminating how and why incumbent utilities influence SET within the system, and how it interacts with new market players, and the extent to which influence forces of change both within and outside the regimes. The literature is particularly limited in the context of China.

We will address the following specific questions in the case of China:

1. How did the incumbent utilities respond to new developments of SGs?
2. What specific roles did they play?

Our focus on China is of academic significance. Most literature on smart grid developments is in the West. The literature on smart grid in the Asian context is limited, the discussion on socio-technical regimes is particularly limited. Whether there exists a variety of governing approaches in developed and emerging market contexts, and in democratic and authoritarian contexts need to be better studied. Based on our theoretical discussion, we develop a conceptual framework as a guide to our analysis.

3. Smart grids in China: the contextual background, major developments, and latest status

A number of unique socio-economic, policy and institutional conditions that characterise Chinese power sector have significant influence on the development pathways of smart grids in China.

Firstly, the urgent need to look for effective ways to manage energy and environmental challenges in a cost-effective manner presents the socio-economic factor for motivating China to develop SGs. As a senior government official in NDRC puts it, "the potential economic benefits of SGs are important motivations for China to develop SGs. There is no free lunch. We need to pay for environmental improvement. What matter is how to has the job (environmental improvement) done with minimal economic costs." (Interview/ BJ/04/2014).

The second contextual feature is related to the reliance on a loose policy framework for guiding the developments of SG in China. Unlike some countries such as the US and South Korea which have introduced national smart grid roadmaps or plans, China has not developed specific plans or roadmaps for SG at the national level. China's SG initiatives started with a SGCC's announcement of its SG plan in 2009. Since then, this industry-level initiative was gradually elevated to a strategic national priority (Hart, 2011). SGs have been included as a key task for delivering energy transition in the 12th Five-year Plan of National Economic and Social Development, and the upcoming 13th FYP (2016-2020) – for which the Chinese government is seeking public feedback on its draft. (Yuan, Shen, Pan, Zhao, & Kang, 2014). In 2012 and 2015, two important policies announced by the NDRC effectively strengthen the policy framework for SGs. These are the 2012 NDRC's special plan title "the industrialisatin of SG key science and technology" and the 2015 NDRC's "Guidance Note on Boosting SG Development". The 2012 special plan (the former) provides policy guidelines on industrialization, standard systems as well as demonstration projects of SG technologies. The 2015 Guidance Note reaffirms the 2020 target to establish a SG system, and outlines a relatively comprehensive strategies which extend policy support in the areas of IT systems, economic viability, international standardization and new business model development (NDRC & NEA, 2015). Theses five-year plans and NDRC documents are further supported by a large number of SG-related policies at both national and local levels, which cover a broad of energy technologies, from renewable energy, energy efficiency, micro-grids, to electric vehicles and green industries.

Under this loose policy framework, China has made some important progresses in SG developments. However, there are still a number of problems associated with SGs. SG projects are still in an early stage of development, mostly as demonstration projects and are small in scale.

Third, SG developments in China are heavily shaped by the on-going electricity market reforms and the associated changes in the market structure. The electricity sector is in the midst of a transition from a vertically integrated, state-owned monopoly to a partially liberalised market. The major reform in 2002 dismantled the State Power Corporation, which had owned 90 percent of China's grid assets and 46 percent of power generation assets, and replaced it by two state-owned grid companies and five power generation companies. (Mah, 2010). SGCC and CSG, five IPPs (Big Five), and four anxiliary corporations (Ma & He, 2008). A new market regulatory, State Electricity Regulatory Commission, was set up as a major component of the 2002 electricity market reform.

So far, privatization of the power sector has been completed, but competition has been introduced only to power generation segment. In this somewhat stalled state of reform the two grid operators which control electricity transmission and distribution are state-owned incumbent monopolists, and a large and influential (Interview BJ/03/2014) (RAP, 2008).

Table 1: Chronology of smart grid policy developments in China

2009	SGCC announced three development phases of SG ((Xu, Xue, & Wong, 2014; Yuan et al., 2014) Phase 1 (2009-10): Initial planning and piloting, where the master plan and selected pilot projects are created and put into action; Phase 2 (2011-15): Comprehensive construction involving breakthroughs in key technology and equipment for achieving extensive application; and Phase 3 (2016-20): Upgrading, enhancing, and optimizing grid performance with respect to resource allocation, security, and efficiency, interplay among power grid, power generation and customers.
2010	CSG announced overall objectives and principles for SG development, as well as a two-stage plan. The first stage (2012-2013) involves planning, research and demonstration. The second stage (2012 and after) involves demonstration and implementation. (Yuan et al., 2014).
2010	The then Chinese Premier Wen Jiabao announced that construction of a national priority, with completion planned for 2020 (EIA/SAIC, 2011).
2011	The 12th Five-year Plan of National Economic and Social Development included "advancing smart grids" as a key task for delivering power system transition, indicating that smart grid has been included in China's national energy policy. (Yuan et al., 2014).
2012	NDRC announced a special plan titled "The industrialization of SG key science and technology", which aims to acquire key SG technologies, formulate an independent technology and standard system for SG, as well as integrated supply chain; and complete the construction of modern smart grids. It also includes over 75 SG-related demonstration and industrial projects at different levels (Yuan et al., 2014).
2015	NDRC and NEA jointly announced the Guiding Suggestion on Boosting Smart Grid Development (NDRC & NEA, 2015) which aims for the initial completion of a national smart grid system by 2020, with assisting measures in support and technical assistance, mutual compliment of renewable energy sources, IT and cloud systems, disaster response and economic viability, international standardization, encouraging new business model development.

4. Discussion

4.1 A utility-led model of SG development in China

In China, SGs have been developed in ways that differ from other countries in many important aspects. The US's approach has focused on energy system resilience and reliability (Connor et al., 2014)) while South Korea's is export-oriented with the establishment of the iconic large-scale demonstration project on Jeju Island and the Japanese model is business-driven and community-based (Mah et al., 2013). In contrast, the Chinese model is characterised by its utility-led approach.

In China's utility-led approach, although the Chinese government is responsible for planning and regulating the power sector, SGCC is the SG champion in China (EIA/SAIC, 2011): 6, acting as the driving force behind the Chinese government effort to build a nationwide SG (Zpryme, 2011). CSG is known to has taken a secondary role in development SG technologies, waiting for SGCC to take the lead (Zpryme, 2011). And yet, both SGCC and CSG play a decisive role in the construction of SG in China (World Energy Council, 2012).

The two grid operators are motivated to develop SGs primarily for political obligations. SGCC, serves over 1.1 billion people in 26 provinces, covering 80 percent of electricity transmission and distribution in China, SGCC holds a belief that SGCC needs to take the lead in developing SGs otherwise China will lag behind its counterparts in realising the potential benefits of this energy options (Interviewxxx) . SGCC has also been motivated by some material benefits: through strengthening its own grids, and empowering a corresponding Chinese equipment industry, particularly for the smart meter market (Schleicher-Tappeser, 2012).

Table 2. Basics of SGCC and CSG

	SGCC	**CSG**
Geographical scope	-Serves 26 Provinces (including autonomous regions and direct-controlled municipalities) of over 1.1 billion people, covering 88% of electricity transmission and distribution in China	-Serves 5 Southern Provinces: Guangdong, Guangxi, Yunnan, Guizhou and Hainan -Electrical transmission and distribution coverage of 1 million sq. km, serving roughly 230 million people, and 72.92 million clients
On-grid total Installed capacity (2014)	1049 GW	246 GW
On-grid Energy mix (by installed capacity in 2014)	Thermal – 739.99 GW[1] (70.54%) Hydro – 198.82 GW (18.95%) Wind – 75.52 GW (7.20%) Solar Photovoltaic – 21.92GW (2.09%) Nuclear – 12.75 (1.22%)	Thermal Power – 126.95 GW (51.54%) Hydro Power – 103.46 GW (42.01%) Wind Power – 7.67 GW (3.12%) Nuclear Power – 7.21 GW (2.93%) Solar Photovoltaic and Others (Biomass, waste, geothermal) – 0.99 GW (0.40%)

[1]

4.2. Where did the two grid operators move in new business areas in response to the potential opportunities offered by SG developments?

The two grid operators have introduced important initiatives as well as moving into new business areas in response to the opportunities provided by SGs as follows:

(1) As planners, capital providers, builders, and managers of SG infrastructure

In 2010, the then Chinese Premier Wen Jiabao announced that construction of a SGas a national priority, with completion planned for 2020. Then SGCC, which controls 80 percent of electricity transmission and distribution in China, announced that construction will begin on major nationwide grid upgrades in 2011, and the cost of the associated projects is estimated to be US$100 billion through 2020 (EIA/SAIC, 2011): 17. As such, China surpassed the US in 2020 in total SG expenditure, and is anticipated to remain as the global leader in SG expenditure for several years at least (EIA/SAIC, 2011).

In addition to grid upgrades, the two grid operators have also made considerable progresses in smart meter installation. To date, smart meters have already widely installed across China. These nationwide grid updates and smart meter installations have become a key enabler for SG deployment in China.

(2) As network operators

One important new function provided by the two grid operators is that they now also act as distribution network operators to manage distributed energy sources. Under a growing body of Chinese regulations regulating grid access and pricing policies for DEs (see Table xx), the two grid operators are required to provide grid connection and electricity metering *free-of-charge* (Liang, 2015, June 3). They also provide national subsidies on behalf of the national government. According to China's price subsidy policies (not called feed-in tariffs here), Distributed PV: submsidize 0.42 yuan/kWh for all electricity produced" (Liang, 2015, June 3).

SGCC provided grid access services to 1052 DE projects, involving a total installed capacity of 2,600 MW and 6,936 consumers by end 2014.[2]

[2] http://www.sgcc.com.cn/big5/shouye/tbxw/323670.shtml

(3) As regulators – through setting standards

Standards setting is critical to energy technology innovation because codes, standards, and certification can reduce commercial and purchase risks as well as negative perceptions of technology performance. Certification and testing agencies can allow manufacturers to easily verify compliance with standards and provide purchasers with performance assurance (Martinot & McDoom, 2000).

It is important to note that two grid companies, SSGC and CSG have also introduced smart grid-related regulations, which are mostly relating to technical requirements on smart grid-related technologies. SGCC has published 166 enterprise-class standards, with 42 national and industry standards being developed and amended under contract" (Z. Liu, 2013).

(4) As technology developers and knowledge creators

It is to a large extent through conducting a large number of pilot projects on various technologies associated with smart grid developments that SGCC and CSG have played an important role of technology developers and knowledge creators. SGCC alone has implemented about 230 SG pilot projects to solve technical issues, test design, and develop management systems in the first phase of it SG plan (between 2009-2010) (Zpryme, 2011).

(5) As new energy service providers

It is evident that SGCC and CSG have explored new service areas in response to the opportunities offered by SG technologies. SGCC, for example, has conducted studies exploring options of new business models. In one of its case studies of business model innovation, SGCC explored the possibilities of providing value-added services associated with the use of power optical fibre cable to its clients in Shanghai (Interview BJ/o7/2014). CSG has also set up a subsidiary providing energy audit services to clients.[3]

[3] http://ny.csg.cn/xwzx/xwzx/201507/t20150731_101673.html

5. Conclusions and future research agendas

The paper examined the role of incumbent utilities in sustainable energy transition from the perspectives of governance. Our case study of smart grid developments in China provided empirical illustration of five major roles that incumbents can play in these transitions. We found that in China's incumbent-led model of SG developments, the two major state-owned grid companies have assumed central role in shaping the pathways and pace of the smart grid developments. They played five major roles. These include: 1) as planners, capital providers, builders, and managers of SG infrastructure; 2) as network operators; 3) as regulators; 4) as technology developers and knowledge creators; 5) as new energy service providers.

This better understanding of the roles of incumbent utilities suggests that there are at least three important questions that future research needs to address:

- Can sustainability transition be influenced by incumbent utilities and, if so, how and to what extent?
- In what ways did they exercise incumbent advantages or act as barriers to SG deployment?
- What are the outcomes of the incumbent-led model on smart grid deployment in China? To what extent this model worked or did not work, without involving many new market actors, to scale up SG deployment?

While the literature has been instructive in shedding light on the mixed picture on the role of incumbents in sustainable energy transitions, future studies which can address these three questions will contribute to the theoretical development of who, under what conditions, and the extent to which, incumbents can act as an enabler and/or a barrier to our sustainable energy futures.

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