



Toward electricity retail competition: Survey and case study on technical infrastructure for advanced electricity market system



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HIGHLIGHTS

- We present a survey relevant to retail competition model in electricity market.
- We describe various distribution automation standards and access policies.
- We introduce various smart metering standards and privacy-security issues.
- We summarize how to protect the customer information in retail competition model.

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ABSTRACT

The retail competition in electrical power industry may produce benefits in perspectives of both business and environment. Customers can obtain monetary benefits through competition among service providers and exploit diverse electric services which can be more enhanced with the retail competition. In addition, employing distributed/renewable energy generation units can be accelerated by the retail competition, which leads a way for green growth of our society. In order to construct a new retail competition model or reform an existing one, we should conduct substantial amount of decision-makings on distribution automation technologies under an open access paradigm to enable stable grid controls and operations, smart metering for distribution network operators, and information exchanges between service providers and customers. Besides, we should also address critical concerns about security and privacy issues in the retail competition model since personal electricity information is supposed to be exposed, exchanged and exploited by most functions of the retail competition market. In this paper, we present a number of business models and price models which are shared viewpoints of the participants when deploying a retail competition market. We then introduce and summarize the distribution automation standards, and the smart metering interface and relevant standards. Subsequently, we make rigorous analysis on security and privacy issues, and finally we provide an overview of the retail competition model and a number of related academic issues. We envision that this survey will provide an overview of the entire retail competition market and common techniques in smart grid system to researchers and guide them on their research and developments.

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1. Introduction

The business competition in electricity generation, transmission, and distribution is an important feature of Smart Grid [1]. Competition models have been introduced in many countries and

will be introduced in many more [2,3]. In a retail competition model, an electricity market allows many participants including customers to compete with each other, through which monetary and environmental benefits can be obtained for customers and service providers [4,5]. Considering that renewable energy generation units will be employed in the future [6], we can expect anyone who has generation units can provide electrical energy and obtain profits from the provision through a retail competition market. Additionally, since diverse energy service providers provide their own pricing policies and services in the market, customers can

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choose the most suitable service for them [7]. This is the ultimate vision of both the distribution and the customer domain in Smart Grid. Therefore, in order to accomplish such vision about future electrical power industry, the retail competition is one of the important thing to realize a future electricity market [8]. However, even though distributed generation operators can sell their generated energy and service providers can provide electrical energy to customers through a retail competition market, the retail competition cannot be implemented without the support of advanced communications and networking infrastructures. The reason is that different types of information exchanges are required in retail market to deliver powers efficiently in the transmission and distribution domain and to enable customized power services in the customer domain. Accordingly, the retail competition should be implemented together with well-defined and precisely-designed network standards so as to support stable services and operations in the overall grid [9–11].

Prior to realizing a retail competition market, several issues, which are relevant to networking and information systems, should be fully addressed. Especially, automation in distribution networks, information exchange in a smart metering interface, and security and privacy in the information exchange are the most important issues in the market. Since the retail competition imposes dynamically changing electricity flows between the distribution and the customer domain and automation can virtually eliminate the need for manual handling while improving the productivity and throughput of the distribution operator, the distribution automation needs to be implemented preferentially in realizing the retail competition model. In addition, information exchange through the smart metering interface and the underlying IT infrastructures is also regarded as a critical component of the retail competition model because the retail market executes its functions based on various information collected from diverse sources including customers. Moreover, security and privacy issues should be reasonably addressed in designing the retail competition model since customer information necessary to decide adequate power services and to determine power price are frequently exchanged in unreliable network environments. Note that security and privacy issues, relevant to exchange of personal electricity information, have not been considered seriously up to now because seldom have we witnessed large scale information exchanges in the current power grid.

There are several distribution automation standards such as DNP3, IEC 61850, and IEC 61968/61970 [12]. Since each standard targets different parts of the distribution automation, the standards should be well-combined and applied to the distribution system in order to achieve stable and efficient operations. In addition to these standards, an open access framework should be implemented and guaranteed for the distribution automation. The open access means that any distributed generation units can connect to the transmission and distribution grid, and provide their generated electricity to the grid. However, such open access can have intimate connection with the stability of the distribution grid [13–15]; in other words, the specification and performance criteria of open access points can directly affect the operations and functions of the distribution automation. Therefore, much attention needs to be paid to designing the distribution automation when we decide to implement an open access concept in the distribution grid under the assumption of distribution generation being deployed. In order to present a clue on the distribution automation, we will present case studies on open access methods which have been used in several countries where a retail competition has been successfully introduced.

In order for electricity service providers to provide intelligent services for customers according to the current power usage and pattern, should be used bidirectional metering interfaces to obtain

customer information. Since customers not only purchase electricity from the market but also sell their electricity to the market in the near future grid, the bidirectional metering interface is required to realize a retail competition model. Therefore, communications capability should be implemented at the metering interface, and the interface should be bidirectional to keep track of both inbound and outbound electricity flows. The resulting interface is called a smart metering interface [16,17]. The smart metering interface assists both service providers and distribution operators. To provide suitable services for each customer, service providers need to collect metering information from each customer via the interface. Based on usage and generation patterns, service providers can offer appropriate customer services. Also metering information enables distribution operators to efficiently operate, control and manage their distribution networks since they can figure out the current situation about power demand and supply with the information; moreover, when many distributed generation units are deployed, the metering information becomes more critical because the distribution operators cannot optimize the usage of their network without the metering information. In order to examine specific examples of the smart metering interface, we will do case studies on regulations and policies that several countries have established on the smart metering interface. Also we will summarize relevant standards about the smart metering interface, such as ANSI C12, OpenADR, IEC 62056, and HomePlug which are introduced in [12].

As aforementioned, the smart metering interface lets service providers and distribution operators provide enhanced power services for customers and optimize network resource according to customers' power usage information, but we face another important issue which is security and privacy issue. In aspect of privacy, the exchange of metering information can expose customer's private information since the information contains the customers' identity and lifestyle, including absence or not, so that malicious or selfish adversary can use it to commit housebreaking or increase his (or her) personal benefit by abusing it. In aspect of security, because customer information is transmitted to service providers or grid operators via wired or wireless networks, it is vulnerable to being illegally intercepted by attackers. The attack does not simply mean personal data leak or abuse, but in some time it may cause a catastrophic disaster on the entire power system. Several countries have legislated statutes and regulations to protect the customer privacy, but such statutes and regulations are different in each country because each country has a different point of view on privacy. Note that since the retail competition model can be made across several domains (customer, AMI, business), each domain has different security issues and requires different technology measures to address them. Therefore, we will summarize various security and privacy statutes of several countries, and analyze common and public security issues which would be crucial in the retail competition model.

In addition to distribution automation, smart metering interface, and privacy & security issues, examining economic models such as business or pricing model is necessary to successfully realize and operate a retail competition market even if it is not directly related to technical (networking) issues. Components and relationships in the retail competition are diverse and complicated, compared to plain 'provider and customer' relationship in the traditional electricity industry. Especially, diverse scales of generator-owners or retailers can exist in the retail competition, which is different from traditional models where only large providers are present. In addition, third-party companies who not only generate or distribute electricity but also provide variant services, may appear to the market. These companies can produce and sell creative and useful services by processing the information that is the by-product of customers' electricity activities. Therefore, analyzing information

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