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Opportunities and barriers to demand response in China

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ABSTRACT

China is quickly installing advanced metering infrastructure (AMI), which could provide tremendous opportunities in developing and utilizing demand response resources. Demand response may potentially create a profitable industry and contribute to efficiency improvement, cost reduction, and pollution mitigation of the entire electricity sector. However, China lags behind the developed world in utilizing demand response. Institutional barriers, including the lack of competitive electricity market and the resistance by the state grid corporations, are preventing the commercialization of demand response. In order to fully realize the potential of smart grid, China needs to push forward the reforms toward establishing an open access electricity market so the pollution-free demand response resources may compete with power generators on leveled field.

1. Introduction: demand response and its benefits

The operation of an electric power grid is a constant balancing act. Most of the power generators, such as coal-fired power plants and nuclear power plants, are most efficient when they are operating at stable output. The consumption of electricity, however, fluctuates constantly. Because the storage of electricity is difficult and expensive, grid operators have to constantly 'dispatch', which is to bring power generators online or off-line, to meet the fluctuating demand.

Traditional electricity tariffs are based on the average cost of electricity, so consumers have no incentive to adjust their demands according to the real-time cost of power generation. Conventional analog electricity meters can only record the total amount of usage without information on the time of use, and without real-time communication with the grid operator. Therefore, in the past, a grid operator had control only on power generators, but not on power consumers, so the dispatches were entirely on the supply side. The adoption of time-of-use (TOU) pricing motivates end-users to adjust demand in response to the variable price of electricity over time, and the introduction of smart meters enables the grid operator to remotely dispatch the interruptible demand loads.

The installation of smart grid makes it possible and easier to manage or dispatch the demand. Peak-load generators are typically small, inefficient, expensive and more polluting than base-load ones. By utilizing demand-side resources to replace the use of peaking generators, a grid operator may reduce both the overall cost and pollution of the electric power system.

Demand response (DR) is to adjust the demand of electricity by end-users in response to changes in the price of electricity over time, in order to reduce electricity use at times of high prices and to relieve the congestion of the power grid. The implementation of DR could be categorized into two types: non-dispatchable and dispatchable (Balijepalli et al., 2011). Non-dispatchable DR refers to the electricity end-users' changes in consumption in response to a TOU retail electricity pricing scheme. Dispatchable DR is the direct remote control of end-users' interruptible electrical appliances, which the grid operator can dispatch to temporarily reduce demand and possibly shift the demand to a later time when the cost of generation is lower. In addition to lowering the cost of peaking electricity, dispatchable DR also helps to maintain the reliability of the power grid. Therefore, dispatchable DR is equivalent to a virtual peaking power plant, which consumes no energy and emits no pollution.

The practice of DR can improve the efficiency of resource utilization and reduce pollution by closer alignment of consumer's electricity tariffs to the true costs of power generation (USDOE, 2006). The consumers who participate in DR programs may reduce their electricity bills by optimizing their time of use and earn incentive payments by selling their dispatchable demand loads to DR aggregators. By avoiding or reducing the use of costly peaking electricity, the system-wide costs of electricity is reduced. The standby DR resources can also be dispatched in emergency to avoid power outages, which often incur high economic costs, damages and inconvenience to consumers. Overall, DR resources are

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low-cost, pollution-free and could generate incomes to consumers and external benefits to the society as a whole.

According to an estimate by GTM Research, with its rapid installation of advanced metering infrastructure, China could have potential DR resources of over 30 GW by 2016 (Bojanczyk and Leeds, 2012). Unfortunately, the lack of progress in electricity market reforms has prevented the commercialization of DR in China.

2. Demand response in China

In the 1990s, the former State Power Corporation implemented a few demand side management (DSM) programs, including direct load control, load adjustment, peaking load pricing, and TOU pricing (Yu, 2012; Zeng et al., 2013). In April 2002, the State Council authorized the "Scheme of the Reform for Power Industry" and broke up the vertically integrated State Power Corporation into five generation groups and two grid corporations (Xu and Chen, 2006). The separation of generation and transmission was supposedly only the first step in the 2002 reform agenda, which aimed to establish an electricity market eventually. However, the reform hardly moved forward after 2002. The electricity market was not established. The National Development and Reform Commission (NDRC) have continued to set the wholesale and retail electricity prices administratively.

After the 2002 reform, the two state grid companies assumed the responsibilities for DSM. The focuses of the grid companies' DSM programs are on energy efficiency and peak-shaving. The government has promulgated several DSM plans and measures, which primarily focus on administrative and technical measures. However, there has been little progress in market-based DR development.

The NDRC announced the "Electricity Demand-side Management Measures" in 2010, which required the grid corporations to implement load monitoring and load control through electric load management system. The load monitoring capability is required to reach 70% of regional maximum load, and the load control capability to reach 10%. All users of 100-kilo-Volt-Amps and above are included in the scope of load management system. The load management systems should have provided the grid companies with the technical infrastructure for the implementation of DR.

Article 11 of the "Electricity Demand-side Management Measures" charged the governmental pricing departments with the tasks of promoting TOU tariffs, encouraging off-peak energy storage, and implementing seasonal tariffs in selected regions and different prices for high-reliability and interruptible demands. By 2015, the TOU tariffs have been adopted in 16 provinces and cover about 65% of industrial and commercial electricity users (Stern, 2015). In China, the TOU tariffs are administratively determined and often not based on the cost of electricity supply. Typically, the peak price is set at about 1.5 times of the average price, while the off-peak price is set at about half of the average price. To the author's knowledge, there is very little publicly available information on the effects of these TOU pricing schemes.

In 2012, the NDRC and the Ministry of Finance jointly created a fund for DSM pilot projects (Table 1). With the support of this fund, four cities: Suzhou, Beijing, Foshan, and Tangshan conducted DSM pilot programs, including interruptible tariffs, real-time pricing, peak-load pricing, and cooling storage pricing. No dispatchable DR was included in these pilot programs.

In 2013, Tianjin Economic-Technological Development Area (TEDA) and Honeywell conducted China's first automated demand response program (Honeywell, 2013). The scope of this program is rather limited, including only two commercial buildings and two industrial buildings. The program demonstrated the peak-shaving capacity of 15–30%.

In the summer of 2014, Shanghai conducted a DR pilot program consisted of 33 commercial and public buildings and 31 industrial enterprises, with over 100 MW aggregated load capacity. However, due to the lack of electricity market, the aggregated DR cannot be traded in a market setting. The central government, Shanghai city government, and the Energy Foundation funded the financial scheme for utilizing DR in the Shanghai pilot project (Stern, 2015). The objectives of the DR pilot were to demonstrate the capability of the technology and coordinate with existing electricity load management system, and to explore the potentials of a trading scheme among large electricity end-users (SGCC, 2014). Due to the lack of wholesale electricity market, demand response is not allowed to compete with peaking power generators.

In 2014, the NDRC issued a notice on the electricity pricing policy for electric vehicle charging facilities, where the TOU pricing is mandated. It is still too early to tell how the TOU pricing may influence the charging behaviors electric vehicles and whether electric vehicles will become significant demand response resources.

In March 2015, China initiated a second round of electricity reform with limited scope. The Central Committee of the Communist Party and the State Council officially announced the reform agenda as the document on "Deepening Reform of the Power Sector" (Dupuy and Weston, 2015). The main objectives of this reform are to open up retail electricity markets and implement revenue-capped transmission tariff regulations. The prospect of competitive wholesale electricity market has remained uncertain.

3. Strengths due to state-owned monopolies

The State Grid Corporation of China (SGCC) and China Southern Power Grid Company (CSG) operate two of the world's largest power grids. The state-owned monopolistic status provides China's grid companies with many advantages in financing and building smart grids, as well as in standardization of advanced metering infrastructure (AMI).

3.1. *Rapid installations of AMI*

China is leading the world in smart grid investment, with more installed smart meters than the rest of the world combined (Gonzalez, 2014). By the end of 2013, China has installed over 250 million smart meters, which covered about 70% of households. The State Grid Corporation of China expects to achieve 100% smart meter coverage in 2017.

Smart grid technology is a capital-intensive investment. The technology is expensive to install, but relatively inexpensive to operate. Once a capital-intensive AMI is in place, it would be economically beneficial to keep it in use for as long as possible (at least for decades). The financing of such tremendous upfront capital investment could be challenging in many countries, but not in China, because China's state-owned grid companies are financial giants. For comparison, the revenue of SGCC was US$333.4 billion in 2014, while the revenue of PG&E, the largest utility company in the United States, was merely US$17.1 billion in the same year. The sheer sizes and financial capabilities of China's grid companies make it possible to install smart grid very quickly.

3.2. *Economy of scale thanks to wide area interconnection*

The economy of scale through wide area interconnection offers great potential advantages in aggregating disperse demand response resources (Yang, 2009). The SGCC and CSG are among the largest grid operators in the world. For comparison, in terms of annual electricity delivery, total length of transmission lines, service area and population, CSG is roughly comparable to PJM, which is the largest transmission operator in the United States,

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