

Feasibility Study on Low-Voltage Consumers' Participation in Power Resource Aggregation

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1. Research Background

With the trend of energy management shifting from centralized to decentralized, using microgrids with energy storage equipment provides favorable conditions for consumers to participate in power dispatch and demand response. Currently, the application development of high-voltage consumers in Taiwan is relatively mature. However, due to factors such as a small electricity consumption base and scattered locations, the participation of low-voltage consumers in demand response may be ineffective and costly. Therefore, expanding the popularity of demand response among low-voltage customers and developing a standardized development model that suits the needs of various sectors in Taiwan and has a considerable scale is a key project that Taiwan Power Company, private companies, and academia are actively promoting. In reviewing international cases, the application of energy storage equipment in demand response has become increasingly popular. Therefore, this research explores customers' electricity consumption behavior and demand response participation patterns with and without energy storage equipment.

2. Research Content

This study analyzes the current status of low-voltage customer participation in the electricity market in countries such as the United States, Australia, France, Japan, and Singapore. Targeting low-voltage commercial customers in Taiwan, this research considers that operators may be limited by business needs and unable to flexibly cooperate with demand response. Therefore, this study combines the installation of energy storage equipment to explore the

usage habits and needs of low-voltage commercial customers for small-scale energy storage systems and understand their electricity consumption and storage patterns. Moreover, this research aggregates several low-voltage commercial customers to understand their behavior and scenarios in participating in demand response and conduct a feasibility study on demand response aggregation. Based on this, we can grasp the key factors and potential opportunities for low-voltage customers to participate in demand response and further find development suggestions to promote the participation of low-voltage customers in demand response aggregation.

3. Research Result

This study has completed case studies in the United States, Australia, France, Japan, and Singapore (Figure 1). These advanced countries have implemented demand response and electricity trading for a long time and are gradually promoting them to low-voltage customers. Although the ancillary service market rules have been adjusted by considering the fair participation of distributed energy resources, low-voltage resource participation is still concentrated in the retail market stage, with only a few successful cases participating in the wholesale market. Reviewing the development of Taiwan in recent years, the participation of low-voltage customers in demand response has become a future trend. However, the electricity trading platform has high entry barriers, qualification restrictions, and economic considerations. In the short term, the feasibility of low-voltage customers participating in the electricity trading platform is not high (Figure 2).

To understand the impact of customer behavior under different scenarios, this research has planned different proposition implementation scenarios, including experimenting with different reward schemes and the impact of time factors (Figure 3). It also uses the Lienchi Technology Home Energy Management System APP product to allow customers to receive dispatch notifications, query their electricity consumption, and understand the experimental methods, execution results, and reward statistics. The experimental results show (Figure 4) that the average achievement rate of all customers is 49.86%, with the highest achievement rate among household customers, but the average suppression amount is only 0.26 kWh. For small commercial customers, the overall achievement rate and suppression amount (5.05 kWh)

of customers with energy storage are better than other commercial customers. Furthermore, customer behavior analysis and cost-benefit analysis of representative customer groups show that the power saving of a single customer is not high, and the benefits are insufficient to attract customers to invest. This study recommends that participation can be achieved through existing equipment in the initial stage. In the medium to long term, the electricity industry environment, application scenarios, technology, resources, customer awareness, and other conditions may gradually develop to provide a favorable business environment for developing low-voltage resource aggregation, thereby promoting electricity resource diversity, flexibility, and sustainability.

區域	案例	執行方式		獎勵機制	
美國	Southern California Edison	自動調控智慧恆溫器	自動	電價優惠	獎勵回饋
		自動控制空調	自動	電價優惠	獎勵回饋
		用戶改變行為	傳統式	依節省度數計量	售電形式
	OhmConnect	自動啟動節電模式	自動	獎勵積分	售電形式
		用戶改變行為	傳統式	獎勵積分	售電形式
Sunrun	儲能固定排程放電	半自動	一次性設備回饋金	獎勵回饋	
歐盟	法國 Nice Grid	用戶改變行為	傳統式	電價優惠	獎勵回饋
	法國 Voltalis	自動調控智慧恆溫器	自動	電費折抵	
澳洲	AGL Energy	用戶改變行為	傳統式	有上限的回饋金	獎勵回饋
	Energy Australia	自動調控儲能	自動	固定回饋金	獎勵回饋
	Evergen	自動調控儲能	自動	依照合作電力公司獎勵	
日本	MC零售能源	自動調控儲能、負載	自動	電費折抵	
	九州電力公司	用戶改變行為	傳統式	獎勵積分	售電形式
新加坡	SP Group	用戶改變行為	傳統式	電費折抵	

Source: Compiled by this research

Figure 1. Compilation of Low-Voltage Demand Response Programs

	我國發展現況	國外發展情形
需求反應	<ul style="list-style-type: none"> ✓ 現行方案除了智慧型校園空調外，皆限定高壓以上契約別用戶參與，低壓無法透過聚合參加 ✓ 住商自動需求反應試辦方案，供智慧家電參與試驗 ✓ 隨低壓AMI持續布建，未來所有用戶都將換裝AMI，促進時間電價及需求反應參與潛力 ✓ 淨零關鍵戰略已將低壓需求反應納入推動，為低壓需求反應提供應用場景及確立方向 	<ul style="list-style-type: none"> ✓ 戶數多、容量小、位置分散、組成複雜之特性，且用電調整彈性較低，引入自動控制技術為發展關鍵 ✓ 低壓需求反應仍多屬於零售市場階段，參與批發市場仍有法規及經濟挑戰需克服 ✓ 第三方服務模式逐漸興起，減輕公用售電業於設備維護、用戶管理相關成本 ✓ 漸朝住宅向上需求反應推動，因應再生能源過剩
輔助服務市場	<ul style="list-style-type: none"> ✓ 目前民間合格交易者於資源招募方面以大用戶為主，低壓資源於經濟考量、通訊及表計要求下難以符合成本效益，非短期階段之目標對象 ✓ Enel X與GOGORO合作，聚合全台超過2500電動機車充電站點參與即時備轉 ✓ 隨我國綠電發展與電力交易平台開設，開啟DER參與電力市場之契機，《電力交易平台管理規範及作業程序》允許聚合同類型資源參與，且無契約別之限制，有利於發展VPP 	<ul style="list-style-type: none"> ✓ FERC第2222號命令旨在消除分散式能源面臨的競爭障礙，要求RTO/ISO修改市場規則，包括最小容量要求100kW、跨節點、異質資源聚合等 ✓ 澳洲AEMO開設分散式能源聚合提供輔助服務之示範計畫，並於試驗後修訂市場規則 ✓ 低壓資源參與批發市場方面，2022年Sunrun於ISO-NE批發市場中聚合數千戶家庭太陽能搭配儲能，提供電網靈活性及降低尖峰供電成本，成為美國第一個住宅虛擬電廠成功案例

Source: Compiled by this research

Figure 2. Comparison of Low-Voltage Resource Development Plans

第 1 週 ~ 第 4 週	第 5 週 ~ 第 8 週	第 9 週 ~ 第 12 週
命題一 不同的回饋金算法		
	命題二 排名制度	
		命題三 隨機改變「執行時間」和「提醒時間」

Source: Compiled by this research

Figure 3. Experimental Mechanism and Timeline Planning

用戶	平均達成率	累積回饋金	平均節電率	實際用電度數變化	實際用電度數變化加總	用電度數變化 (僅計算需求反應成功)
商業用戶 -- 婚宴會館01	50 %	\$ 7,620	0.29%	-126.36	-275.21	-661.32 平均: -5.05度/次
商業用戶 -- 婚宴會館02	60 %	\$ 9,200	-19.43%	-125.45		
商業用戶 -- 車體維護中心	48 %	\$ 8,660	-16.05%	-16.76		
商業用戶 -- 超商01	35 %	\$ 3,440	2.31%	-3.16		
商業用戶 -- 超商02	38 %	\$ 3,870	2.34%	-3.48		
商業用戶 -- 超商03	50 %	\$ 3,640	-1.77%	-1.73	+94.92	-408.77 平均: -4.05度/次
商業用戶 -- 超商04	40 %	\$ 4,660	-0.38%	-3.29		
商業用戶 -- 超商05	30 %	\$ 1,410	-8.51%	97.98		
商業用戶 -- 餐飲業者01	38 %	\$ 5,390	-12.41%	+42.42		
商業用戶 -- 餐飲業者02	46 %	\$ 6,580	2.66%	-40.46		
家庭用戶01	56 %	\$ 4,840	-36.56%	-3.31	-18.11	-37.83 平均: -0.26度/次
家庭用戶02	54 %	\$ 4,590	12.49%	-3.15		
家庭用戶03	60 %	\$ 7,550	-3.34%	-7.47		
家庭用戶04	50 %	\$ 3,460	-6.19%	-2.96		
家庭用戶05	42 %	\$ 2,700	-26.85%	-1.22		
所有用戶	49.86 %	\$ 5,174 (平均)	-7.42%	-198.4度	-198.4度	-1107.92度 平均: -2.92度/次

Source: Compiled by this research

Figure 4. Statistical Analysis of Experimental Results