CHALLENGE FOR COORDINATION CONSUMPTION OF A POOL OF PROSUMER

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ABSTRACT

The residential-scale solar photovoltaic (PV) system prices is dropping in last ten years, a simple household could become an active energy consumers, often called 'prosumers' because they both consume and produce electricity. In one hand, they could dramatically change the electricity system. In other hand, household without PV system could reduce their cost by buying electricity from other prosumer. In order to create this eco-system, the coordination mechanism among prosumer is necessary. This paper focus on a sharing economical model based on the simulation of load shifting. A simple mechanism for shifting two shiftable appliances that applied to a community of ten households in a full year simulation. The results of contracting between household and comparing between non coordination and coordination will be presented.
Keywords: prosumer, coordination, load shifting

INTRODUCTION

Fulfilling to energy demand in community especially household need improvement where the demand are more and more increased. Recently, the energy consumption of the household sector around 30–40% of the total energy use all over the world [1], and the load consumption have to meet with the available energy. Conventional power plant is not able to handle enhancement of energy demand and need to expand the power plant infrastructure, but it will rise the cost of energy. In other side, expanding of power plant infrastructure have disadvantages in some sectors such as geography, financial and environmental issue.

Distributed generation especially PV system is developed to help the grid operator in fulfilment of electricity needs. Moreover, households in some country are encouraged to install their PV system [2]. Household was also encouraged to manage their consumption with some method of energy management. Government in some countries make policies to promote PV system to their people in order to install local PV[2], likely compensation and revenue for household that using and selling of their PV electricity.

IEA PVPS gives the analysis in their report as the self-consumption is legally permitted in each country. The household is given the right to self-consume and connect their PV system to the grid. They also will get revenue and green certificate if they maximize their self-consumption. Meanwhile, in excess PV electricity, net metering and net billing is introduced [3]. The household can save the excess energy in credit form in their account for their future consumption. In other hand, the household can use net billing where they receive compensation for their excess energy from grid.

The investment into PV system also protect the household from unstable electricity price and make them become active players in the energy market who is often called 'prosumers' because they both consume and produce electricity[4]. The rise in the number of prosumers has been facilitated by the fall in the cost of renewable energy technologies, especially solar panels. Therefore, the household as prosumer are expected to maximize their consumption from their PV system. Energy excess can be stored in the battery system for night activity or sold to the neighbors who plan to get the cheapest price for electricity and reduce their consumption from the grid.

DEMAND SIDE MANAGEMENT

Several methods are proposed to maximize self-consumption in the household, such as energy storage and load management [2]. These methods can be used alone or combined. Commonly, Demand Side Management (DSM) is called Demand Response (DR). DR have some contribution in financial and reliability where it is useful for household that need to control the consumption, such as shift the consumption from high peak (with high price) to low peak. So that, minimizing the cost could be realized.

Information and Communication Technology (ICT) is associated with the Generation, Transmission and Distribution system of Power Grid in order to improve the reliability of power system [5]. Commonly, it was called “Smart Grid”, where it enable dual communication (bi-directional) of information and flow of electricity. ICT is also applied in resident sector where Advance

Metering Infrastructure (AMI) along with Home Energy Management System (HEMS) has been installed in each house for managing the consumption demand. Thanks to AMI, Smart meter and HEMS are able to inform the consumption pattern and availability of energy with the price and incentives. [6][7]. Commercial solutions of Energy Management Systems (EMS) have been developed in the field of control system. It gives solution for energy efficiency and cost reduction, especially HEMS for residential consumers. HEMS are also a way to maximize self-consumption in the household. They combine monitoring, logging, controlling, communication, and alarm system to achieve satisfaction of customers [8][9].

Type Load	Flexibilities	
Flexible	Shiftable	Washing Machine, Dish Washer,
	Energy Storage	Water heater, HVAC, Electrical Car
Non-Flexible	Fixed-load	Lamp, Refrigerator, Television, microwave

Table 1. Type of Appliance

The strategies of DR are divided in two parts such as event based and price based [5]. The former are conducted with the support of an operator (an aggregator) that participates in controlling household's appliances. Meanwhile, user can use their power consumption based on prices send by an aggregator or an energy supplier.

Load shifting is a method for DSM that consists in shifting demand from peak period to off peak period typically when price is lower. This method is only used for rescheduling of appliance, so the total energy consumption of household should not be changed [10]. Load shifting cannot be applied to all of appliance, it is only applicable for some appliances that can be reschedule to another period. Therefore, household appliances can be divided in two types, flexible appliance and non-flexible (fixed load), see table 1.

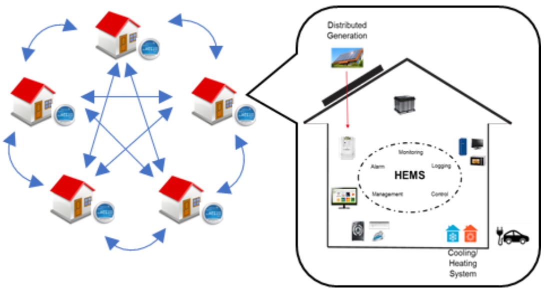

Figure 1. Coordinated Prosumer with HEMS included

Coordination energy management could be a solution for controlling the appliances usage without degradation of the user satisfaction (Quality of Life)[5],[11],[12],[14].

The authors in [11] explain that coordination energy is used to allow each household to be a prosumer and obtain their satisfaction related to consumption profile and energy production. It also allows the households to create a community and participate in electricity market. The challenge in this coordination management system is not only to coordinate a particular household's loads to reach the best Quality of Life but also to seek the benefit for their community as a whole.

CASE STUDY

In this paper, we propose a case study about coordination consumption based on simulation of 10 households with different criteria as object to know and obtain load data. The household type is taken based in software Load Control Generator[14] , such as

1. Couple with both work (CBW)
2. Family Two Children with One Work (FTCOW)
3. Family One Child with One Work (FOCOW)
4. Family Two Children with Both Work (FTCBW)
5. Family One Child with Both Work (FOCBW)
6. Retired Couple without work (RCNW)
7. Single Woman with One Child and work (SWOCW)
8. Single Man with One Child and work (SMOCW)
9. Single Woman with work (SWW), and
10. Single Man with work (SMW)

Prosumer	PV Size (kW)	Storage (kWh)
CBW	8	4
FTCOW	8	0
FTCBW	8	0
FOCBW	7	4
SMOCW	7	0

Table 2. Classification prosumer

The household's load consumption profile is created for one year without shifted appliance and it will be made as input for simulations whose objective to find the efficient time for activating the appliance. Load profile is the accumulation power of the appliance such as kitchen appliances, lamps, bathroom and other, except the washing machine and dishwasher. We propose a classification of households in three classes where two households have PV system with storage system, three equipped PV system only and five normal consumers without PV system and storage. The size of PV and storage in prosumer are detailed in table 2.

In the load shifting section, we also apply washing machine and dish washer as shiftable load with specification Bosh WAE 28143 2300W and use water amount 5 liters per minutes for 2 hour 13 minutes. While the dishwasher used in this simulation has specification NEFF SD6P1F with 2110W in power and 30 liters per minutes for water consumption. Dishwasher will run approximately 2 hour 35 minutes per day.

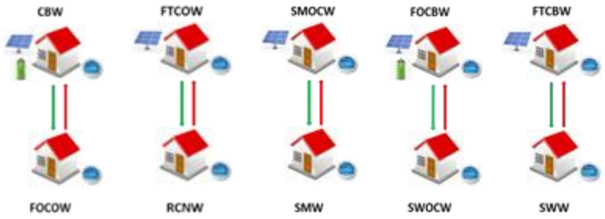

Figure 2. Contract between household

For the financial parameter, we use fix tariff that are applied in France, 15 c€/kWh and distribution line cost 3c€/kWh. We also prepare five bilateral contract between household as shown in figure 3, where they make energy transaction to obtain cheap price. The price of PV production will be made in 10 c€/kWh with considering the distribution line cost, in order to find the different profile of revenue and cost for the household. When a household energy excess still remains after they share with contract partner, it is sold - if possible - to the grid with PV production that is determined by Grid operator or local government policies.

$$Reward = \sum_{1}^{365} E_{ex}.(C_p - C_d)$$

$$Consumer\ cost = \sum_{1}^{365} E_a.C_p$$

Where,
E_{ex} = Excess energy produced by prosumer
E_a = Energy shared with local consumers
C_p = Production cost
C_d = Distribution line cost

	Time	
Household	Washing Machine	Dishwasher
CBW	18:00	21:00
FTCOW	11:00	20:00
FOCOW	09:00	20:30
FTCBW	18:30	20:00
FOCBW	19:00	21:00
RCNW	10:00	19:00
SWOCW	18:00	20:00
SMOCW	19:30	20:30
SWW	20:30	21:30
SMW	20:00	22:30

Table 3. Original activating time of flexible appliances

We prepare two scenario to compare (i) independent household behaviour and, (ii) coordinated behaviour between two households (figure 2). Differences are analysed through rewards and costs received/payed by households. In the first scenario, local energy management is applied in each household when the household activates their flexible appliances referred by their behaviour. Daily activating time for dishwasher and washing machine are given in table 3. In the second scenario, we prepare contract coordination between households as showed in figure 2. Load shifting is applied in all households, where the consumers shift their appliance near peak production of solar energy, and the prosumer activate their shiftable appliances in 13:30 for washing machine and 11:30 for dishwasher.

SIMULATION RESULT

Ten households model is developed in MATLAB® Simulink. Differents simulations such as household without coordination and load shifting, and propose coordinated household and load shifting are done.

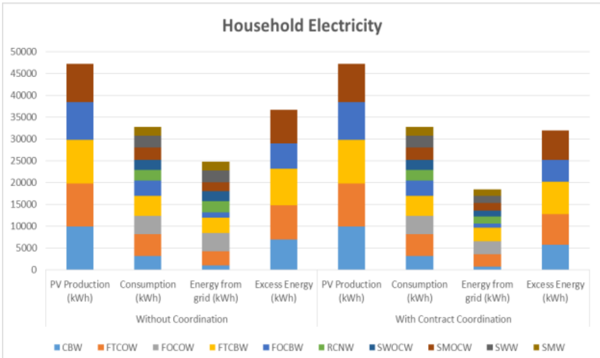

Figure 3. Result of Household No Coordination and Using Coordination

In figure 3, the energy from grid in household without coordination is higher than coordinated households. For example, CBW as Prosumer only uses 737 kWh for one year when applying load shifting whereas they use 1076 kWh when they do not apply it. In consumer side, with coordination, their energy covered by excess energy from prosumer. Meanwhile, the consumers without contract rely heavily on electricity from grid. Prosumer without coordination only sell their energy excess to grid. But in bilateral contract senario, prosumers is able to share their energy production excess before selling to the grid.

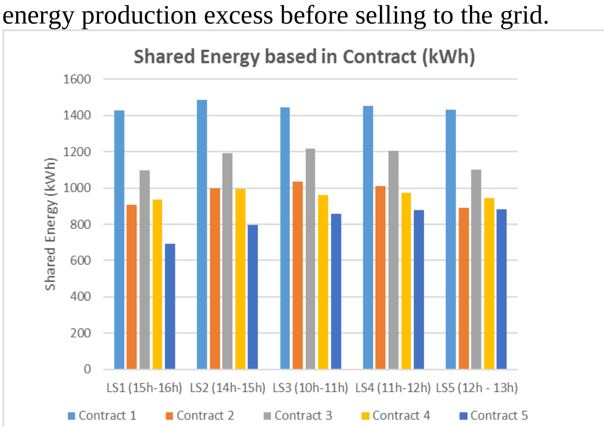

Figure 4. Shared Energy based Contract and LS

Figure 4 shows the comparison of shared energy based on contract and load shifting. The highest values is shared energy in the contract 1. The consumer needs more energy to meet their electricity usage. When the load shifting is applied, the shared energy's value in the contract 1 is almost similar. However, the highest shared energy is occurred when the consumer activate flexible appliance in 14:00 and 15:00. The peak of shared energy in the contract 4 is also taken place in 14:00 and 15:00, while the contract 2 and 3 in 10:00 and 11:00 and the contract 5 in 12:00 and 13:00. With bilateral contract and load shifting, the household can reduce their cost. It can be seen in figure 5 that all households reduce their cost for energy from grid. Prosumer CBW is able to save up to 31.5% of his budget, and consumer SWOCW can reach 23.44% saving.

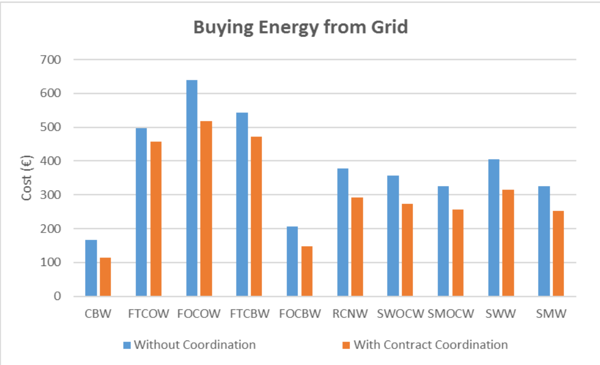

Figure 5. Comparison of electricity between non coordination and coordination scheme

CONCLUSIONS

This paper focus on a sharing economical model based on the simulation of load shifting. A simple mechanism for shifting two shiftable appliances that applied to a community of ten households in a full year simulation, where consumer did not buy energy from grid when the excess energy from prosumers are still available. Consumer also reduce their cost for electricity from grid when they participate in this program. Prosumer also get benefit from this coordination, in one hand their consumption meet with the electricity and store energy for off peak period. In another hand, they also receive income from consumer and grid.

In future work, in order to anticipate reduced feed in tariff from operator, the policies with price decreasing will be taken into account. Optimization and extension the coordination mechanism to a community of consumers will be analysed.

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