OPTIMAL MANAGEMENT OF HOUSEHOLD ELECTRCITY DEMAND IN A MICRO-GRID: GAME THEORY APPROACH

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Overview

The growing trend of Microgrid (MG), through collective self-consumption, will be at the heart of the revolution in the future power system. Collective self-consumption has the advantage of being less carbonaceous by optimizing local green electricity produced locally. Currently, microgrid is experimented in some cities through pilot projects such as Brooklyn Microgrid (New York), IssyGrid (Issy-Les-Moulineaux / France) or Lyon Smart Community (Lyon / France). This trend is due to the increasing penetration of Distributed Energy Resources (DERs).

In that shed light, the present paper aims to study the optimal power consumption behavior of consumers through a islanded MG at the scale of a building. We suppose that the MG is composed with a group of households living in a same single building. Each users acquires electical power from the on-site power generation and storage system to satisfy their demand. The DER device is owned by all users and consists of Photovoltaic (PV) solar panel installation and energy storage system (battery). Which means that all consumers in the MG owns the DERs in commons. The MG is a king of Community on-site PV generation and Communty Energy Storage (CES) system owned by all users. Consequently, each homogenous user interiacts noncooperatively with the others by sharing an amount of power generated by the PV solar panel and stored in the dedicated Energy Storage System (ESS).

Methods

The objective of each user is to maximize his own power consumption under economic and technical constraints related to the MG. These constraints are based on the capacity of the PV panel and the available power generated, the battery state of charge, and individual smart meter capacity power allowed.

We model the users's preference function in form based on concepts from microeconomics. This function models how much users values the consumption of amount of energy. Accordingly, we use a non-cooperative game theory approach to analyse the optimisation problem of each consumer embedded in a MG. Without loss of generality, we assume a theoretical model frameworks which consider two homogeneous users (players) denoted by $i = 1,2$ and two time periods $t = 1,2$. The power demand of each user is the sum of the energy directed load from the PV installation and the indirect load getting from the battery. Each user can adopt one of this two kind of strategies: a "*responsible strategy*" denoted by e_{DSM} and a *"selfish strategy"* denoted by e_{EGO}.

The numerical analysis is built by using the software Gams (General Algebraic Modeling System, https://www.gams.com/). We use the average load curve for a typical January day of a French household to build simulations analysis. The kilowatt hour (kWh) is considered as the measure power consumption unit.

Results

the model based on autonomous microgrid building shows that the unique Nash equilibrium profile depends on the level of the parameters and an optimal battery sizing is found.

Table 1: Nash equilibrium of users power consupmtion

Parameters	**State of charge of the battery**	**Static Game**	**Repeated Game**
$\beta > c'(.)$	High level : $c'(.) < 0$	$(e^2_{1,EGO} e^2_{1,EGO})$	$\left((e^1_{1,EGO}, e^2_{1,EGO}), (e^1_{2,EGO}, e^2_{2,EGO})\right)$
	Low level : $c'(.) > 0$		
$\beta < c'(.)$	High level : $c'(.) < 0$	$(e^2_{1,EGO} e^2_{1,EGO})$	$\left((e^1_{1,EGO}, e^2_{1,EGO}), (e^1_{2,EGO}, e^2_{2,EGO})\right)$
	Low level : $c'(.) > 0$	$(\boldsymbol{e^2_{1,DSM} e^2_{1,DSM}})$	$\left((\boldsymbol{e^1_{1,DSM}, e^2_{1,DSM}}), (\boldsymbol{e^1_{2,DSM}, e^2_{2,DSM}})\right)$

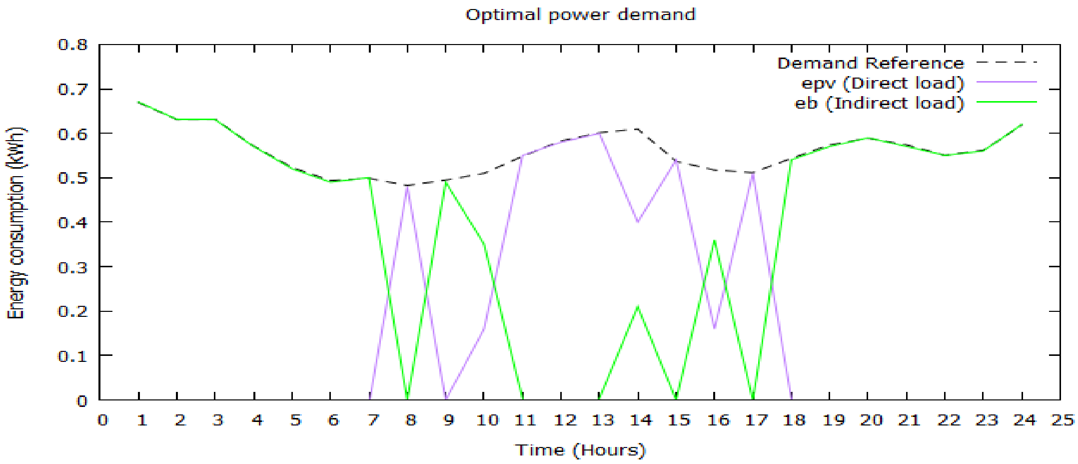

Figure 1: Effect of low β on household behavior

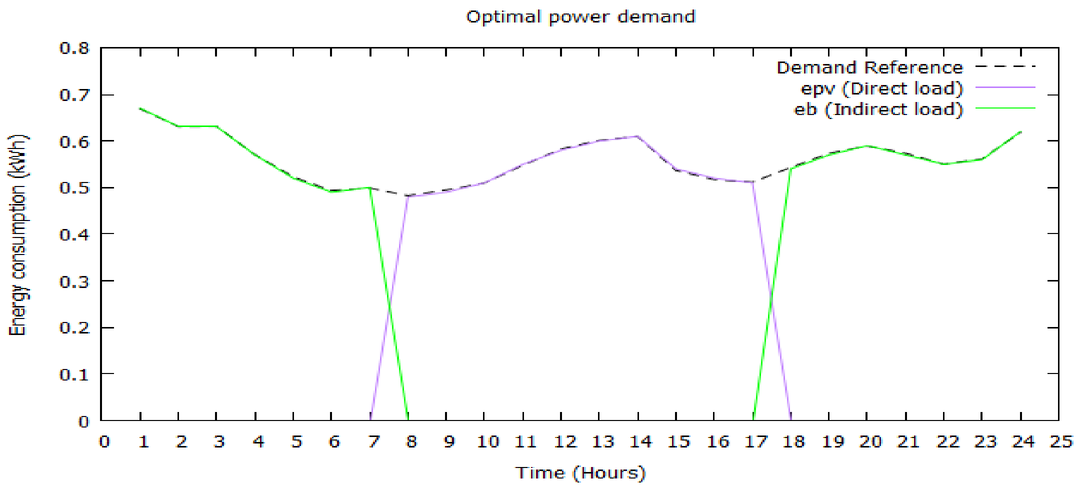

Figure 2: Effect of high β on household behavior

Conclusions

As shown in Table 1 the unique equilibrium profile indicates that the "*responsible strategy"* is played if the user's tolerance toward energy consumption reduction is less than the marginal cost, and the battery sizing is low, unless the "*selfish action*" is played.The implication of this result show that possible DSM as shifting load program can be implemented in the MGB. Since there is some case in which the equilibruim of the game is to play "*responsible strategy"*. Which means that a cooperative action can be adopted if their perceved value toward power consumption are the same. Accordingly, this facilitates the emergence of local energy initiatives such as Integreted Community Energy System (ICES) or Peer to Peer (P2P) energy exchange within a microgrid residential sector.

The results in figure 1 and Figure 2 show how the mains parameters of our model play a key role on user's power consumption behavior.

References

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