2015 JST-NSF-DFG-RCN Workshop
On Distributed Energy Management Systems

Group Optimization for Conserving In-Vehicle Batteries Shared in Apartment Buildings

Akihiko Kawashima, Nagoya University (A member of Suzuki Team, JST CREST)

Utilized In-Vehicle Batteries: Vehicle-to-X (V2X)

Energy Management Systems (EMSs)

- Control and balance demand and supply of energy.
- EMSs are important component in Smart Grid.

Power Storages

- Work as buffers for balancing of energy.
  e.g. stationary batteries for electricity

Huge and Expensive!

In-vehicle batteries installed in EVs and PHEVs

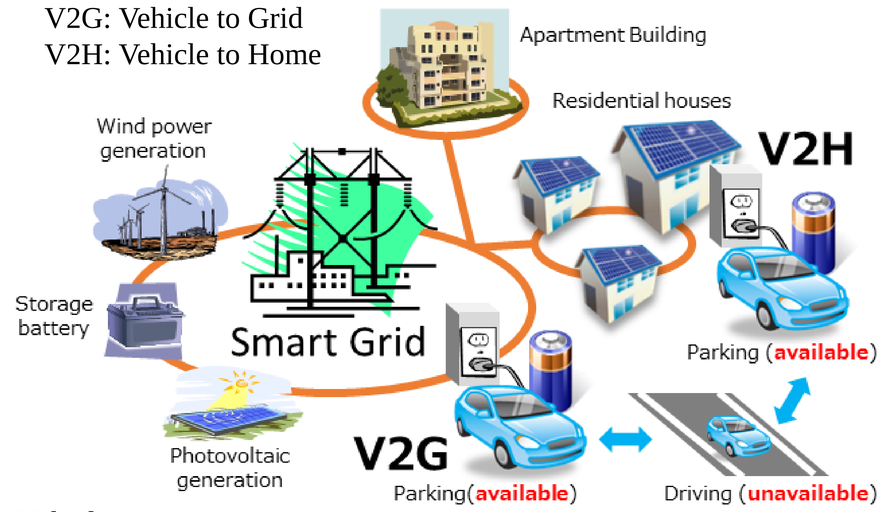
Utilization!

- Reduce the number of stationary batteries and its installation cost.
- Add value to EVs and PHEVs providing services (e.g. ancillary services).
- Be available as movable electricity resources at the time of disaster.

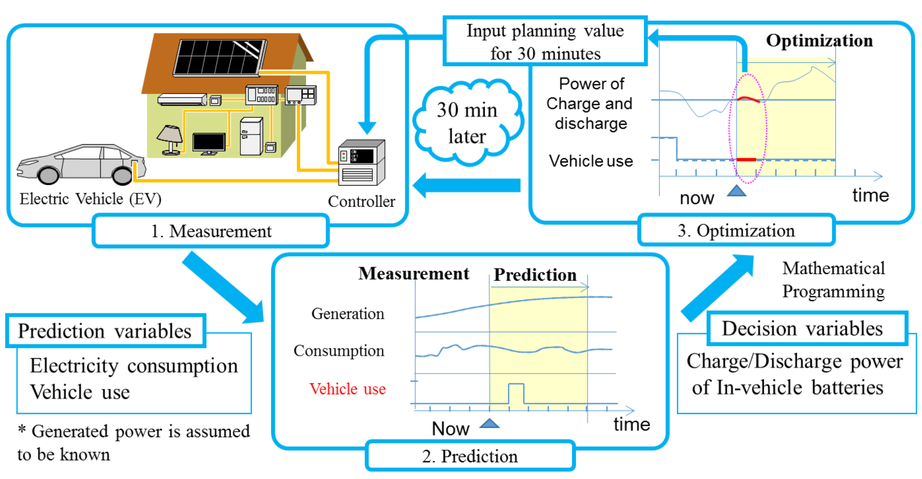
EV: Electric Vehicle
PHEV: Plug-in Hybrid Electric Vehicle

W. Kempton, J. Tomic: Vehicle-to-Grid power fundamentals, calculating capacity and net revenue, Journal of Power Sources, 2005.

V2G: Vehicle to Grid
V2H: Vehicle to Home



Overview of Smart Grid with V2X



Model Predictive Energy Management System

Model Predictive Home EMS with V2H using Mathematical Programming

- Optimize the charging/discharging schedule of in-vehicle batteries considering the vehicle use.
- Minimize the electricity fee for 24 hours in a house.

The model predictive HEMS with V2H can reduce electricity cost in its house.

T. Yamaguchi, et al.: Model Predictive Control of Car Storage Battery in HEMS Considered Car Traveling, SICE AC, 2013.

Model predictive EMS

Actual Services and Business Model in Japan

* Mansion: Apartment Building

- Started aggregator services of Mansion* Energy Management System and supported from 2013.
- Make a basic profit from the reduction of electricity price by the collective power receiving service.
- Manage totally electricity of common and individual spaces with PV, batteries and others.

Formulation of the EMS

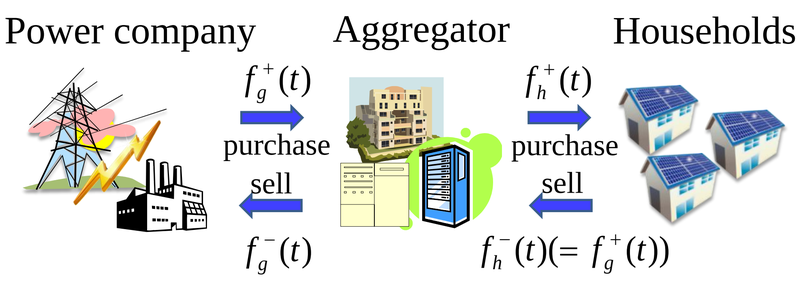
Given: predicted profiles for 24 hours of
1. electricity consumption,
2. electricity generation,
3. vehicle use

in addition,
- initial levels of in-vehicle batteries
- electricity price for 24 hours

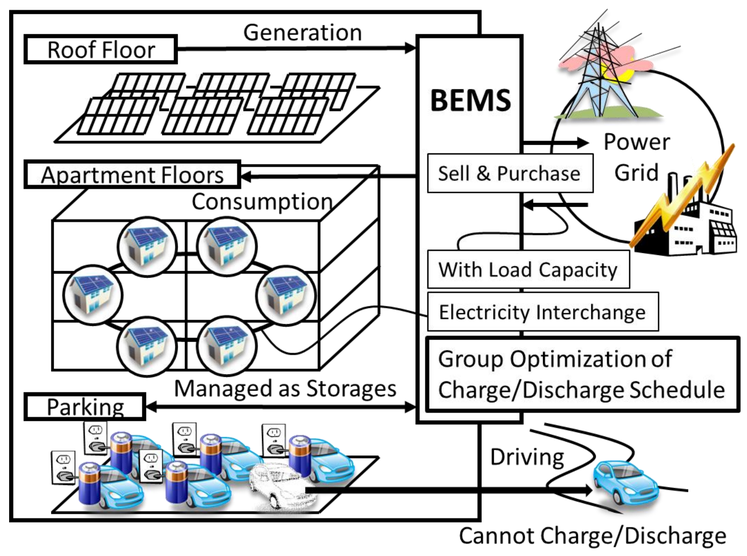
Find: charging/discharging power of in-vehicle batteries for 24 hours
Minimize: electricity fee for 24 hours
Subject to:
- equality of load and consumption
- load limits (contract demand)
- ranges of input/output power
- prevention of reverse power flow
- availability for in-vehicle batteries

Extension of the Home EMS for Apartment Buildings Sharing In-Vehicle Batteries

- Reverse power flow is permitted only for discharging power of in-vehicle batteries as electricity interchange in the building.
- Even if an EV is away from the building, the other EVs are able to charge/discharge for apartments and the building.
- All the charge/discharge schedules of in-vehicle batteries are optimized every 30 min. simultaneously in group optimization.



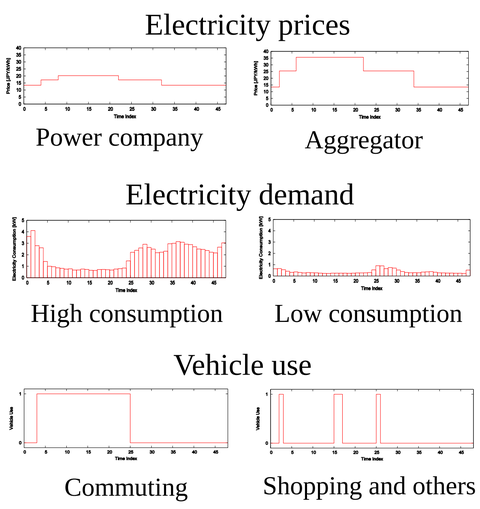
Electricity trade between the three agent layers



An EMS for Apartment Buildings

Example of Computational Experiment

- 40 households (10 households for each setting)
- An EV for each household Capacity: 24 kWh, Output/Input: -3 to 3 kW
- Collective power receiving service
- All quantity buyback program for PV energy with Feed-in-Tariff Scheme (32 JPY/kWh)
- Two patterns of electricity demand:
  1. high consumption
  2. low consumption
- Two patterns of vehicle use:
  1. commuting
  2. shopping, picking up and dropping off



The EMS for apartment buildings can make a profit by electricity interchange.

Kawashima, et al.: Apartment Building Energy Management System in Group Optimization with Electricity Interchange Using In-Vehicle Batteries, SICE JCMSI, 2015.

[JPY/day]

	Limit of power load (contract)			
	No limit (191kW)	150 kW	100 kW	75 kW
Total fee of aggregator	17222	17222	17683	18483
Total fee of households	19513	19513	22638	24914
Profits of aggregator *	12453	12453	15118	16594

High ← **Base price for the electricity contract** → **Low**

* Include a profit **10163** JPY/day by all quantity buyback for PV generation with FIT.

- The apartment building EMS as an aggregator makes a profit.
- The profit is increasing as the limit of power load is decreasing.
- The EMS can reduce the limit of power load by group optimization.