Home Energy Management System with Consideration of Consumer Acceptability

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In order to achieve large deployment of renewable energy with variable characteristics of power output, the balancing capability of energy supply and demand of power systems should be ensured. We aim to develop home energy management system (HEMS) that has a function to help to balance the power demand as needed while maintaining comfort and convenience of consumers. We will also conduct research on social mechanisms including tariff systems and consumer acceptabilities in order to promote HEMS.

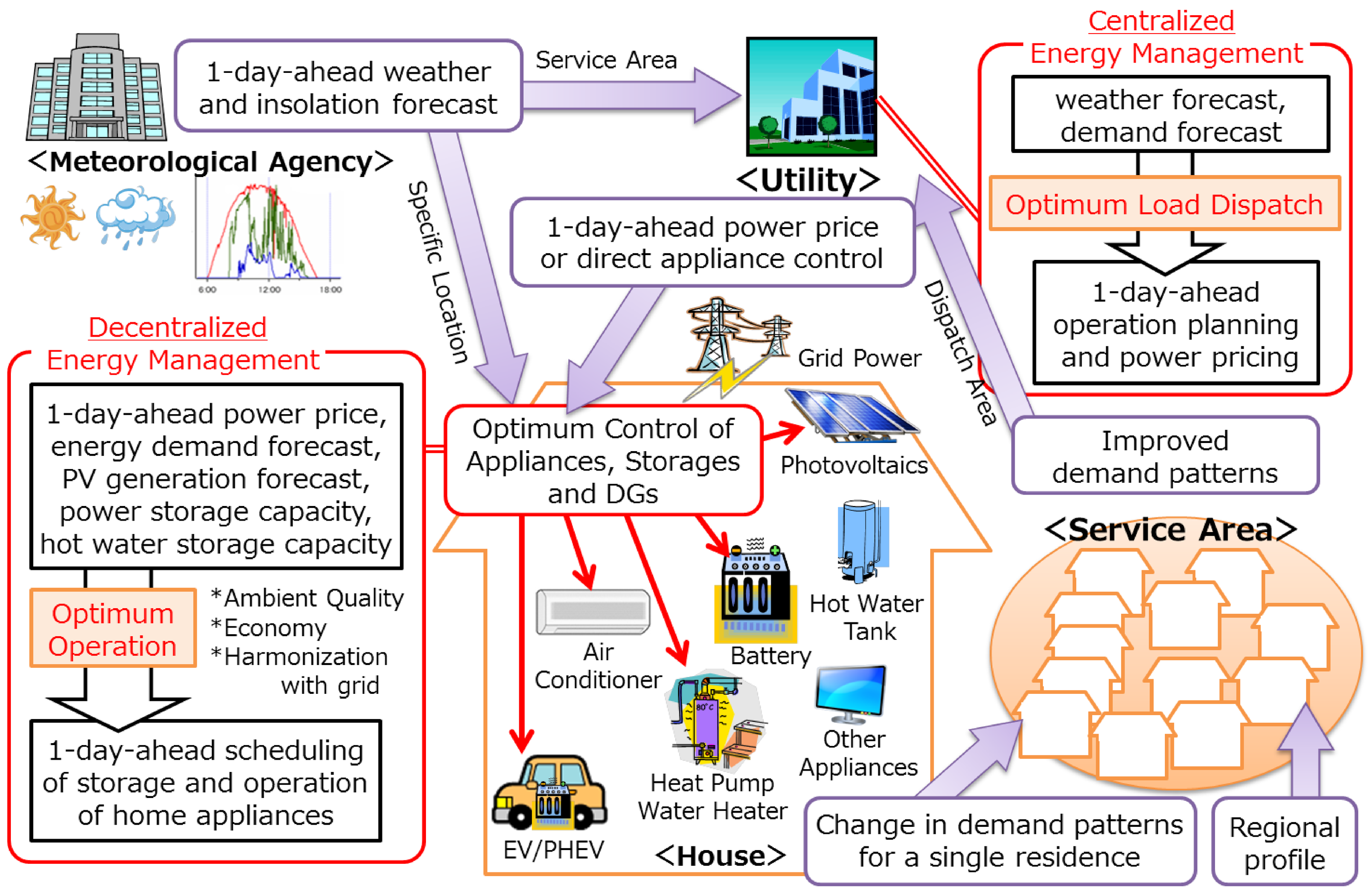

Fig. 1 Cooperative operation of centralized and decentralized energy management systems

Centralized energy management (CEM) treats a whole power system to balance supply and demand, and decentralized energy management such as HEMS treats one building or a community. Under adequate social mechanisms, both energy management operate harmoniously.

Decentralized energy management decides the most economical operation schedule of domestic electric appliances by using energy demand forecast, PV generation forecasting forecast, and electricity prices sent from the CEM.

Development of Battery HEMS Model

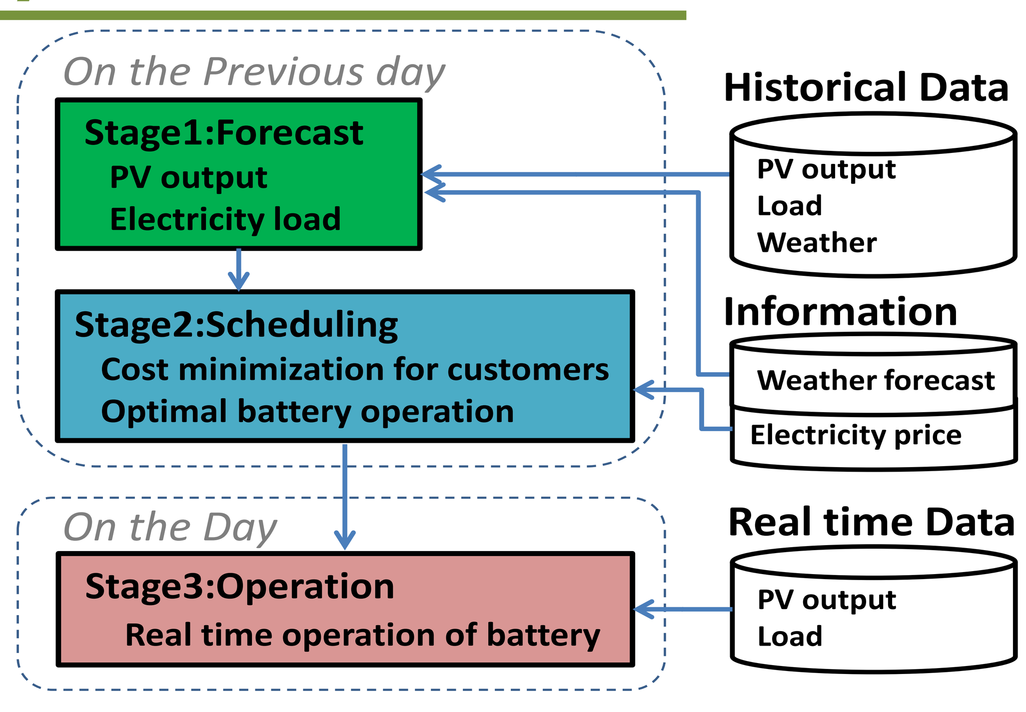

Fig. 2 HEMS Structure

HEMS model that controls a residential battery system connected to a rooftop PV system was developed taking into account of energy load and PV generation forecast errors. Forecast accuracy is verified by real of energy load and PV generation forecast errors. Forecast accuracy is verified by real HEMS data from 160 households; the impact of forecast errors on household economics is examined. Furthermore, the contribution to the entire power system is examined using the model under the dynamic pricing system.

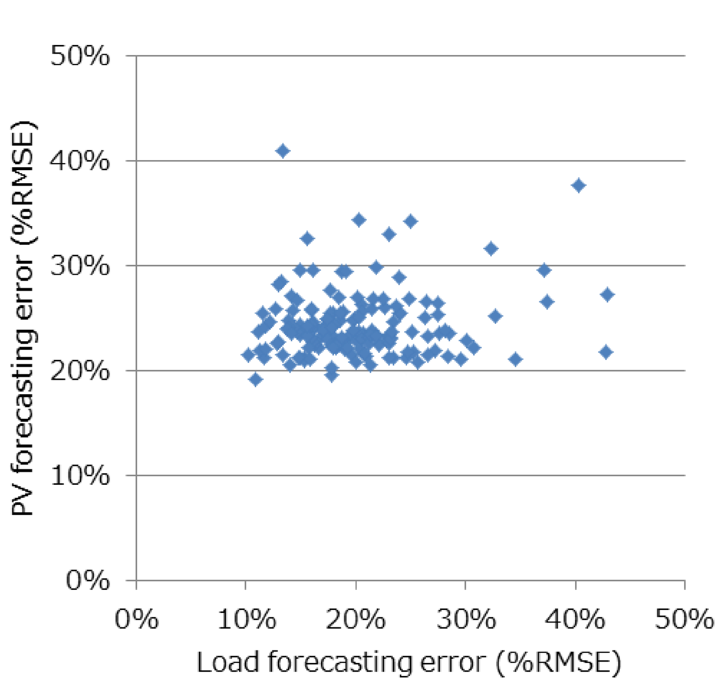

Fig. 3 Day ahead forecast error for load and PV generation in 160 households

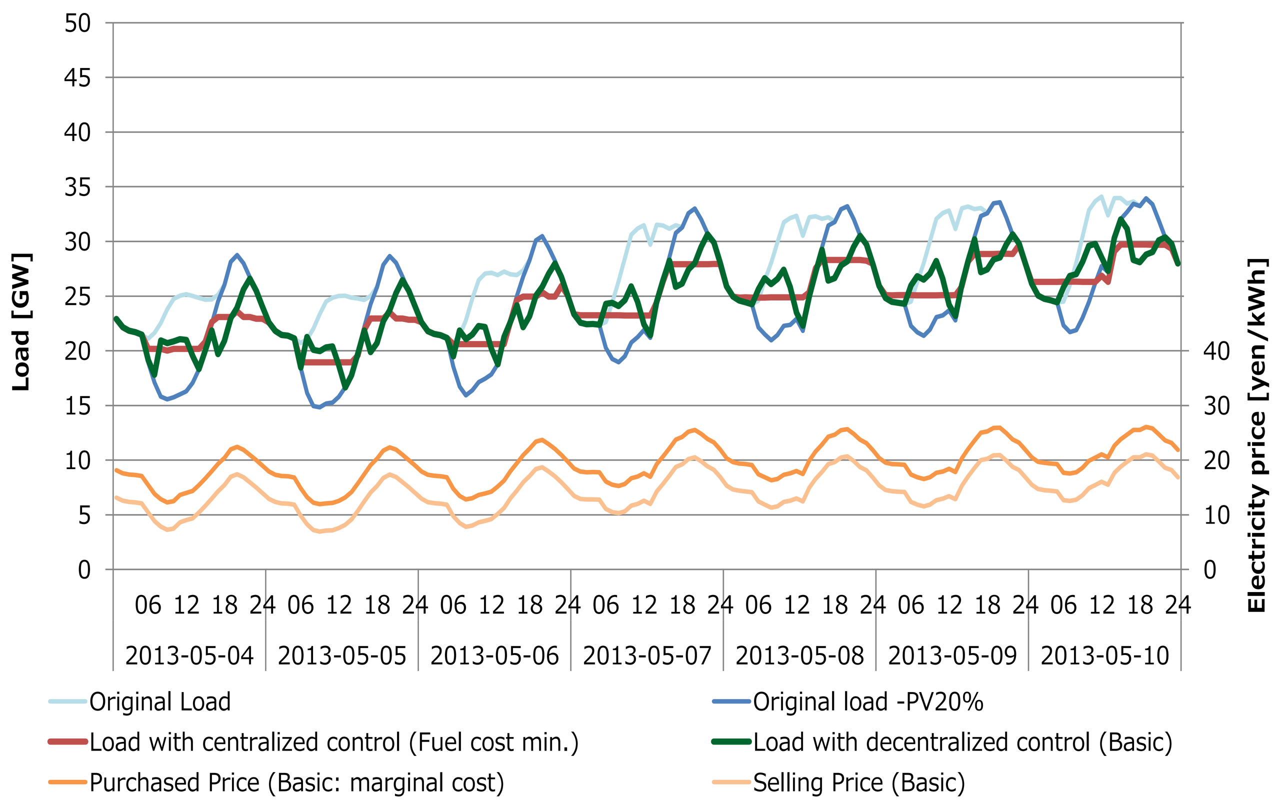

Fig. 4 System load change by the battery operation of an uncoordinated HEMS

Development of Multiple-Customer HEMS Model (Aggregator model)

In order to evaluate total effects of Home Energy Management Systems in a whole power system, Multiple-Customer HEMS Model were developed. Using this model, changes in electricity demand which are activated by charging/discharging controls of a battery (BT) and operating control of a heat pump water heater (HPWH) in each house are calculated, and activated demand in a whole area are also calculated. Therefore the effects of demand side management using HEMSs could be evaluated. We evaluated the effects of HEMSs using day-ahead electricity prices based on marginal fuel costs of thermal power plants (Fig.6) in Kansai region in 2030.

Table. 1 Case Setting of Penetration Rate and PV Capacity

	Base Case 1	Base Case 2	Case 1	Case 2
BT	0%	0%	5% of detached house	10% of detached house
HPWH	0%	0%	20% of detached housings & 10% of collective housings	40% of detached housings & 20% of collective housings
PV	8.9 GW	17.8 GW	8.9 GW	17.8 GW

BT i/o capacity: 2 kW, BT storage capacity: 6 kWh, HPWH thermal output: 3 kW in each house
All BTs and a half of HPWHs are controlled under the HEMSs

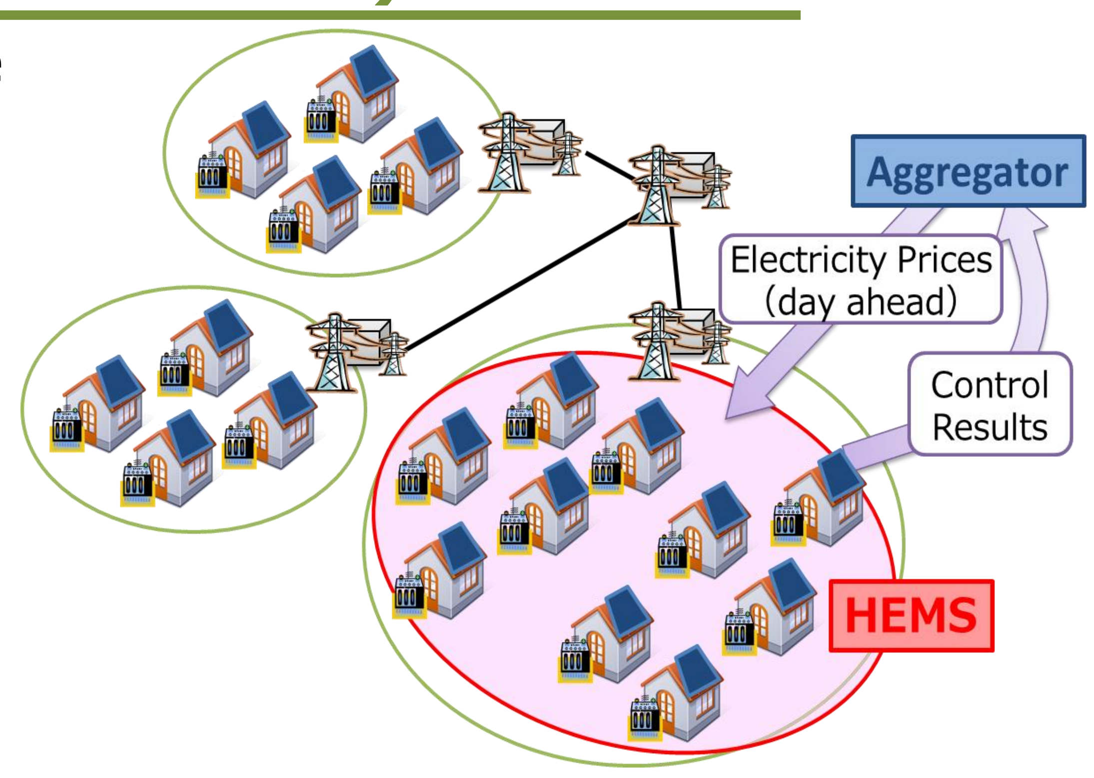

Fig. 5 Evaluation of Total Effects of HEMS in a whole power system

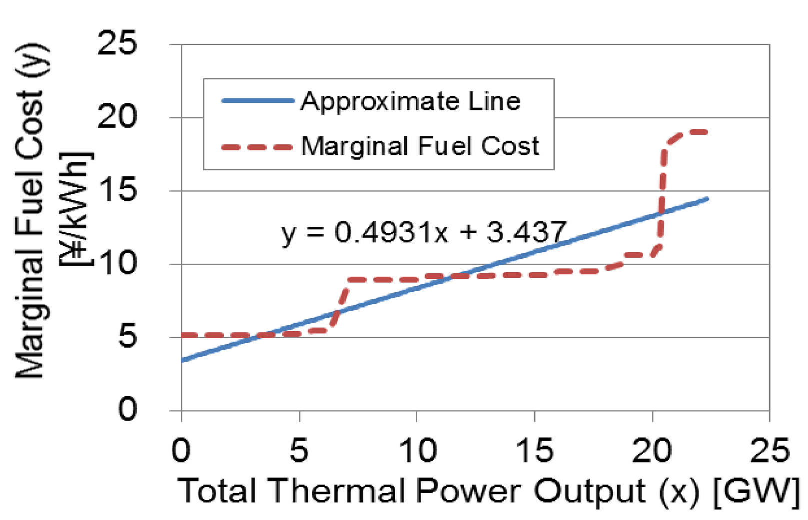

Fig. 6 Marginal Fuel Cost Model in Kansai Region

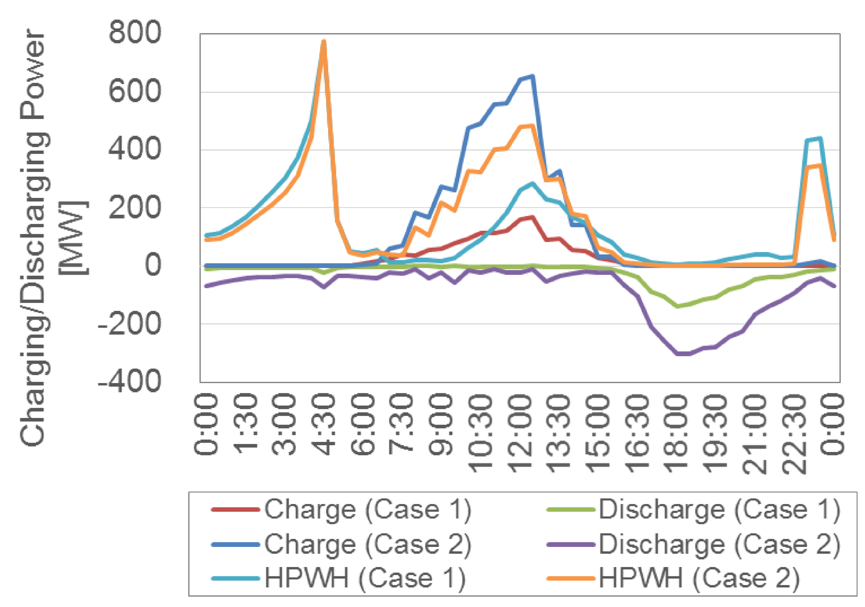

Fig. 7 Annual Average of Activated Demand

Study for Consumer Acceptance of HEMS

Quantitative and qualitative consumer research using depth interviews and web-based survey were conducted to investigate consumer acceptance of HEMS. 39 interviews had been performed and after that 10,188 answers were collected with the questionnaire survey conducted using the results of the interview. Factor analysis was performed to confirm the scale of explanatory variable for intention to install HEMS and Covariance Structure Analysis was conducted to examine the causal relationship between the scales. As a result, the following causalities become apparent: Individuals who are likely to accept HEMS have higher intention regarding energy saving, higher intention to improve their living environment, and desire to keep high indoor comfortability.

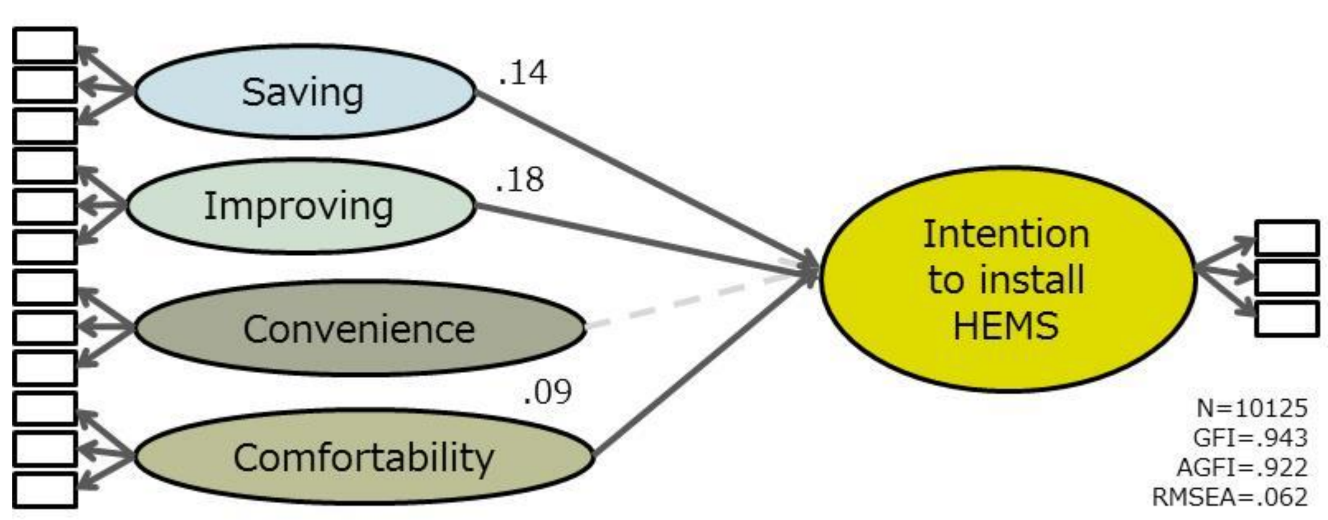

Fig.8 Covariance Structure Analysis for HEMS installing Intention