A Home Power Management System Using Mixed Integer Linear Programming for Scheduling Appliances and Power Resources

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Abstract—In this work, a home power management system is proposed to minimize electricity cost and reduce high peak demand while maintaining user comfort. The system is composed of smart electrical appliances, which are divided into three subclasses as uncontrollable, semi-controllable and controllable, power units (photovoltaic system, grid, battery), communication network and a main controller. At the beginning of each day, the main controller gathers user request and power resource information and solves a mixed integer programming problem formulated with the smart and energy efficient operation constraints defined for appliances and power resources. The solution of this problem provides cost minimizing schedules of controllable appliances and power resources. Simulation results demonstrate that the proposed home power management system significantly reduces the electrical costs and peak demand.

I. INTRODUCTION

Depending on the population growth, the demand for electricity is increasing day by day leading some problems such as environmental pollution and the depletion of fossil sources. For solving these basic energy problems, conventional network structures turns to Smart Grids (SGs). SG is a modernized electricity network including a variety of operational and energy measures for managing electricity demand in a sustainable, reliable and economic manner.

Since an important part of the total electricity consumption occurs in residential, home power management is one of the most important application of SG. Home power management with a central management of residential power consumption provides energy saving, thus electricity cost saving, as well as user comfort.

Residential power consumption varies based on the residential utilization times and daily habits of the residents. When most people consume electricity (e.g. in the evening hours when all household members are in the house), the network overloads and high peak demand takes place. In order to meet this demand, utility companies should make some investments to increase the capacity of their plants. However, it is not always a rational solution to make high cost investments to resolve a problem that is only experienced during a certain period of the day. Since, home power management systems can avoid high peak demand, they contribute to save in electrical infrastructure installation benefiting the utility companies as well as the consumers.

Efficiency of home power management systems is improved by the active participation of end users to a residential Demand Response (DR) program [1], [2]. To accomplish that target, utility companies apply different tariffs in different time periods during the day; such as real-time pricing (RTP), time-of-use (TOU) and critical peak pricing (CPP) tariffs [3]. With TOU, which is considered in this work, electricity prices are lower when the demand is low (off-peak) and higher when the demand is high (on-peak). In the literature, many works have been presented on home power management systems. Most of these works deal with appliance scheduling. For example, in [3] particle swarm optimization method requiring energy usage prediction is used for coordinately scheduling controllable appliances; while in [4] appliances are scheduled due to assigned priorities in order to keep the total power consumption below a predefined limit. In [5], energy consumption is scheduled by using a game theoretic approach for reducing both the total energy cost and high peak demand. Besides, some works present heuristic methods for home energy management, i.e., [6]-[7]. Among these works, in [6] a method using Q-learning approach for learning user behaviour and the corresponding changes in tariff prices is presented, while genetic algorithm is applied for electricity usage scheduling in [8]. In [7], a rule based algorithm is developed for controlling appliances and power resources. Apart from these works, in [9], [10] linear programming and in [11] mixed integer linear programming methods are used to schedule appliances for minimizing the electricity cost.

In this work, a Home Power Management system, namely HPM system, is proposed to minimize electricity cost and reduce high peak demand while maintaining user comfort. The system is composed of smart electrical appliances (e.g., air conditioner, washing machine, dishwasher, refrigerator, TV and lights) which are divided into three subclasses as uncontrollable, semi-controllable and controllable, power units...
(photovoltaic system, grid, battery), communication network and a Main Controller (MC). MC communicates and controls appliances and power units in accordance with the objectives. At the beginning of each day, MC gathers user request and power resource information and solves the mixed integer programming problem formulated with the smart and energy efficient operation constraints defined for appliances and power resources. The solution of this problem provides cost minimizing schedule of controllable appliances and power resources, thus it provides cost minimizing timings of battery charge and discharge, PV usage, grid power usage, power injection to grid processes. Simulation results demonstrate that the proposed HPM system significantly reduces the electrical costs and peak demand.

The paper is organized as follows. In Section II, the proposed HPM system is presented with its distributed power units (Subsection II-A); smart electrical appliances (Subsection II-B) and MC (Subsection II-C). Simulation results are given in Section III. Finally, Section IV concludes the paper and highlights future work.

II. HOME POWER MANAGEMENT SYSTEM

The proposed HPM system is composed of smart electrical appliances, communication network and MC. In this scheme, MC controls the home power demand and the usage of power resources for efficient use of energy, thus minimizing the electricity cost. In the following, the appliances and power resources with the proposed operation constraints will be presented and then the optimization problem for the control of these components will be given. Note that, in this work, one day is discretized into a prescribed number $T$ of uniform time slots, i.e., $t \in T = \{1, 2, ..., T\}$, so that the total number of time slots in a day is $T = 24/\Delta_t$ where $\Delta_t$ represents the length of each time slot.

A. Power Units

In the proposed HPM system, power units providing the home power demand are the grid, PV system and the storage battery.

Power demand of home consists of battery charge power and power consumed by load (appliances) which are provided by PV system, battery discharge power and grid. The relationship between the power demand of the home $P_L(t)$, PV power $P_{PV}(t)$, battery charge power $P_{Bc}(t)$, battery discharge power $P_{Bd}(t)$, power drawn from the grid $P_G(t)$ and power injected to grid $P_S(t)$ at any time $t \in T$ is given as:

$$P_G(t) + P_{PV}(t) + P_{Bd}(t) = P_L(t) + P_{Bc}(t) + P_S(t), \forall t \in T$$

Here, right side of equation corresponds to power resources as inputs and left side of equation corresponds to power consumptions.

1) Grid: Grid is the fundamental power unit providing power demand of the home. In order to avoid high peak demand, the maximum power that can be drawn from the grid $P_{lim}^G(t)$ is specified:

$$P_G(t) \leq P_{lim}^G(t), \forall t \in T$$

It is possible to inject power to the grid as well as to purchase power from the grid within a limit, $P_{lim}^S(t)$:

$$P_S(t) \leq P_{lim}^S(t), \forall t \in T$$

Note that, injecting and purchasing from the grid can not be performed at the same time:

$$x^S(t) + x^G(t) \leq 1, \forall t \in T$$

where $x^S(t) \in \{0, 1\}$ and $x^G(t) \in \{0, 1\}$ are binary decision variables indicating whether power is injected to the grid and power is provided from the grid at time $t$, respectively. Thus, $x^S(t) = 1$ if and only if power is injected to the grid, similarly $x^G(t) = 1$ if and only if power is provided from the grid at time $t$.

2) Battery: Battery is used to store energy which is used to reduce power purchased from the grid especially when the tariff is expensive.

For batteries, one of the most important parameter is State-Of-Charge (SOC). SOC of a battery at time slot $t$, i.e., $SOC(t)$, is defined as the ratio of its current energy capacity $E_B(t)$ to the nominal energy capacity $E_{cap}(t)$, i.e., $SOC(t) = E_B(t)/E_{cap}(t)$. SOC of the battery can be calculated by:

$$SOC(t) = SOC(t-1) + \frac{P_{Bc}(t)\eta_c \Delta t}{E_{cap}(t)} - \frac{P_{Bd}(t)\Delta t}{E_{cap}(t)\eta_{dc}}$$

Here, $\eta_c$ and $\eta_{dc}$ represent the charge and discharge efficiency, respectively.

The simplest and most obvious way of getting the maximum life of a battery is to ensure that it always works within its designed operating limits:

$$SOC_{min} \leq SOC(t) \leq SOC_{max}, \forall t \in T$$

where, $SOC_{min}$ and $SOC_{max}$ are the minimum and maximum $SOC$ limitations for battery operation.

In order to provide efficient and well-balanced battery usage, the power taken from the battery at any time $t \in T$ is desired to be below the maximum discharge rate of the battery, i.e., $P_{max}^B$. That is,

$$P_{Bd}(t) \leq P_{max}^B, \forall t \in T$$

Similarly, a certain limit is also considered for battery charging:

$$P_{Bc}(t) \leq P_{max}^B, \forall t \in T$$

Note that, battery charging and discharging can not be performed at the same time. Hence, the following condition must also be satisfied:

$$x_{Bc}(t) + x_{Bd}(t) \leq 1, \forall t \in T$$

where $x_{Bc}(t) \in \{0, 1\}$ and $x_{Bd}(t) \in \{0, 1\}$ are binary decision variables indicating whether battery is charging and
discharging at time $t$, respectively. $x^{Bc}(t) = 1$ if and only if the battery is charging, similarly $x^{Bd}(t) = 1$ if and only if battery is discharging.

3) PV System: In order to reduce the power drawn from the grid and the electricity cost, it is an important factor to integrate PV system into the home architecture.

Amount of power drawn from the PV system (shortly, PV power) at any time slot $t \in T$, i.e., $P^{PV}(t)$ can be used for battery charging which is represented by $P_{Bc}^{PV}(t)$, for power injection to grid which is represented by $P_{S}^{PV}(t)$ and for supporting to meet the power demand of appliances which is represented by $P_{E}^{PV}(t)$. Hence,

$$P^{PV}(t) = P_{Bc}^{PV}(t) + P_{S}^{PV}(t) + P_{E}^{PV}(t), \quad \forall t \in T$$  \hspace{1cm} (10)

Battery is charged only by the PV power:

$$P_{Bc}^{PV}(t) = P^{BC}(t), \quad \forall t \in T$$  \hspace{1cm} (11)

Similarly, power injected to the grid is only provided by the PV power. Hence,

$$P_{S}^{PV}(t) = P^{S}(t), \quad \forall t \in T$$  \hspace{1cm} (12)

PV power of the considered day is calculated by using the historically measured PV power:

$$P^{PV} = P_{hist}^{PV}(t) \frac{G(t)}{G_r(t)} [1 - \hat{\beta}_p (T_C(t) - T_r(t))], \quad \forall t \in T$$  \hspace{1cm} (13)

Here, $P_{hist}^{PV}(t)$, for which data generated by PVGIS of European Commission Joint Research Center’s Institute for Energy and Transport is used, $T_r(t)$ and $G_r(t)$ are the historically measured PV power, panel temperature and solar irradiance at time slot $t$ respectively; $\hat{\beta}_p$ is the temperature coefficient for efficiency of PV panels; $T_C(t)$ is the measured panel temperature and $G(t)$ is the measured solar irradiance at time slot $t$, which are assumed to be constant during $T_i$.

B. Appliances

In the proposed HPM system, smart electrical appliances (shortly, appliances) are proposed. Clearly, an appliance operates if the user request exists, otherwise it is turned off. Besides, four program modes are assigned to each appliance $a \in \mathcal{L}$, where $\mathcal{L}$ represents the set of appliances in home. Program modes offer different functionality and features, such as operation duration, energy consumptions and more. These program modes are allocated by manufacturers to fulfill these functions and features.

The sets of program modes are represented $S_p = \{1, 2, 3, 4\}$, respectively. The status of an appliance $a \in \mathcal{L}$ operating in a program mode $i \in M_p$ at time slot $t \in T$ is represented by the status vector which is defined as $X^a(t) \in \{0, 1\}^{T \times 4}$. Here, $X^a(t) \in \{0, 1\} \times |S_p|$ is the program mode vector at time slot $t$ in which $i^{th}$ element of the vector, $X^a_{i}(t)$, is 1 others are zero when the $i^{th}$ program mode is active. For example, the status vector of an appliance $a$ operating in program mode 2 at time slot $t$ is $X^a(t) = [0 1 0 0]$, while its status vector is $X^a(t) = [0 0 0 0]$ when it is not operating.

Power consumption of an appliance $a$ operating at a program mode $i \in S_p$ is given by the discretized power profile vector:

$$P_i^a (i) = \begin{cases} p_i^a(i), & \text{if } i \in [0, T^a_i], \\ 0, & \text{otherwise} \end{cases}$$  \hspace{1cm} (14)

where $i$ represents the internal time slot of appliances, $(\Delta_i = \Delta_1)$, $p_i^a(i)$ represents the average power consumption of the program mode $i$ of the appliance $a$ at $i^{th}$ internal time slot and $T^a_i$ is the operation duration of that program mode. Hence, the total power consumption of appliances at time slot $t$ is calculated by:

$$P^E(t) = \sum_{a \in \mathcal{L}} \sum_{i \in T} P_i^a(t - t^a_i) X_i^a(t)$$  \hspace{1cm} (15)

where $t^a_i$ is the starting time of the appliance $a$. Appliances are divided into three subclasses; namely uncontrollable, semi-controllable and controllable. The set of appliances is represented by $\mathcal{L} = \mathcal{L}_{UC} \cup \mathcal{L}_{SC} \cup \mathcal{L}_{C}$ where $\mathcal{L}_{UC}$, $\mathcal{L}_{SC}$, $\mathcal{L}_{C}$ are the sets of uncontrollable, semi-controllable and controllable appliances, respectively. Classification of appliances is made based on user comfort and appliance’s features. These classes and their properties will be explained in the following.

1) Uncontrollable Appliances: Appliances whose on-off status (operation time) and program modes effect user comfort directly are classified as uncontrollable appliances, e.g., TV and lights. In order not to deteriorate user comfort, not only operation time but also program modes of these appliances are strictly selected only by the user.

These appliances are turned on when the user requests, thus operation time is selected strictly by the user. Program modes of lights are specified due to the level of illumination, that is no energy saving mode (100% illumination), minimum energy saving mode (60% illumination), medium energy saving mode (30% illumination) and high energy saving mode (10% illumination); while the program modes of TV are specified due to the level of brightness, that is no energy saving mode (100% brightness), minimum energy saving mode (60% brightness), medium energy saving mode (30% brightness) and high energy saving mode (10% brightness). Since these program modes effect user comfort, the active program mode is selected according to the user preferences.

2) Semicontrollable Appliances: Appliances whose operation time effect user comfort directly are classified as semi-controllable appliances. Thermostat controlled appliances (i.e. water heater, fan heater, air conditioner, refrigerator and etc.) are in this type. Hence, operation time of these type of appliances are strictly selected by the user, while their program modes can be switched to the least power consuming one by their local controller due to the current tariff rate.

For example, a refrigerator operates if user request exists (normally, all day long). Its program modes are specified according to the compressor speed, i.e., low speed, moderate speed, high speed and defrost. Program mode of the refrigerator is firstly selected according to cabin temperature and then adjusted according to the tariff rate by its local controller.
Similarly, AC operates if user request exists. Its program mode, which can be cooler-normal, cooler-economic, heater normal and heater-economic, is firstly selected by the user, but can be adjusted by its local controller during its operation according to the tariff rate.

The common property of uncontrollable and semi-controllable appliances is that operation time of uncontrollable and semi-controllable appliances are strictly selected by the user. This is stated with the following constraint:

$$\sum_{t=t^a_i}^{t^f_j} X^a_i(t) = t^a_i - t^a_j + 1, \quad \forall a \in L_{UC} \cup L_{SC}$$  (16)

where $t^a_i$ represents the starting time and $t^f_j$ represents the finishing time of appliance $a$.

3) **Controllable Appliances:** Appliances whose program modes effect user comfort directly are classified as controllable appliances (e.g., washing machine, dishwasher). Program modes of these appliances are selected only by the user and can not be changed by any other way.

For example, washing machine operates if the user request exists. Since the program modes of washing machine is suitable for particular type of materials (namely express, regular, long and special) the convenient one should be selected by the user. Dishwasher also works in a similar way.

A kind of freedom is available for operation duration of controllable appliances, that is, for controllable appliances user can define an operation time interval instead of operation time, such as [$T^a_{x,i}$ $T^a_{f,i}$], where $T^a_{x,i}$ and $T^a_{f,i}$ represent the user defined earliest start time and the latest finish time, respectively. In this way, the starting time of a controllable appliance can be shifted through the operation time interval by considering the latest finish time. The operation time of a controllable appliance $a \in L_C$ at program mode $i \in S_p$ is stated with the following constraint:

$$\sum_{t=T^a_{x,i}}^{T^a_{f,i}} X^i_a(t) = T^a_i$$  (17)

where $T^a_i$ is the duration of the program mode $i$ of appliance $a$.

In this work, un-interruptible operation is assigned to all appliances. Hence, the following series of constraints are defined for each program mode $i \in S_p$ of all appliance $a \in L$:

$$X^a_i(t) \leq 1 - u^a_i(t), \quad \forall t$$  (a)

$$X^a_i(t - 1) - X^a_i(t) \leq u^a_i(t), \quad t > 1$$  (b)

$$u^a_i(t - 1) \leq u^a_i(t), \quad t > 1$$  (c)  (18)

Due to 18(a), $u^a_i(t) = 1$ indicates that operation of program mode of appliance $a$ has already finished by time slot $t$, thus $X^a_i(t) = 0$ while $X^a_i(t - 1) = 1$. Equation 18(b) stands for switching $u^a_i(t)$ from 0 to 1 if $X^a_i(t)$ switches from 1 to 0. Henceforth $u^a_i(t)$ should have the value of one as imposed in 18(c) [11].

**C. Main Controller**

MC, thus the brain of the system, communicates and controls appliances and power units for minimizing the electricity cost. At the beginning of each day, MC gathers user request and power resource information.

For the user request information, MC is informed about the requested operation time and program mode of uncontrollable appliances; requested operation time of semi-controllable appliances; operation time interval and selected program mode of controllable appliances.

For the status of power resources information, MC is informed about the status of the battery, tariff rate along the day are taken.

By taking these information, MC solves the following Mixed Integer Linear Programming (MILP) problem where $C^0(t)$ represents the electricity tariff for power drawing from the grid (€/kWh) and $C^S(t)$ represents electric power tariff for power injected to the grid (€/kWh):

$$\min \sum_{t=1}^{T} (P^G(t)C^G(t) - P^S(t)C^S(t))\Delta t$$  (19)

subject to constraints (2) - (17):

$$P^a_i(t) \in \mathbb{R}, \quad \forall i \in S_p, \quad \forall a \in L, \quad i \in [0, T_i^a]$$

$$x^S(t) \in \{0, 1\}, \quad \forall t \in T$$

$$x^B(t) \in \{0, 1\}, \quad \forall t \in T$$

$$x^{bd}(t) \in \{0, 1\}, \quad \forall t \in T$$

$$a^s(t) \in \{0, 1\}, \quad \forall a \in L, \quad \forall t \in T$$

$$X^a_i(t) \in \{0, 1\}, \quad \forall i \in S_p, \quad \forall a \in L, \quad \forall t \in T$$

This MILP problem is solved by CPLEX solver in GAMS software. The solution provides the best operation time of controllable appliances in the user requested time interval and the best timing of battery charge and discharge process, PV usage, grid power usage, power injection to grid operations.

**III. CASE STUDY**

This section presents the results of simulations carried out to express the effect of the proposed HPM system.

In the simulations, a 60 m$^2$ home with three occupants is considered. Appliances in the home are 2 lamps 26 W each, 116 cm LED TV, AC with 6.74 kW cooling capacity and 7.03 kW heating capacity, 510 lt no-frost refrigerator, 7 kg front-load WM, 60 cm free standing DW.

Power consumption of appliances are measured by using Yokowaga WT210 power analyzer with the time slot duration of 1 minute, thus $\Delta t = 1$ min yielding 1440 number of time slots in a day.

Integrated PV system capacity and battery capacity are specified as 2 kWp and 6 kV Ah, respectively. The charging and discharging efficiency of the battery and the efficiency of inverter are assumed 95%. In the simulations, battery energy levels are chosen as: $SOC_{min} = 10\%$, $SOC_{max} = 90\%$ and $SOC_{initial} = 50\%$. PV power is calculated based on the
historical PV data which is generated by using monthly PV data of Eskisehir (Turkey) in PVGIS database. Fig. 1 shows PV power profile used in simulations for any day of July and for any day of January.

![Graph of the PV power profile for July and January](image)

In Table I, TOU periods and prices set by Turkish Electricity Distributor Company (TEDAS) [12] and the grid limits are given. Note that, limit on the power drawn from the grid and the limit on the power injected to grid are chosen as equal.

**TABLE I: TOU PERIODS, RATES AND GRID LIMITS**

<table>
<thead>
<tr>
<th>Duration</th>
<th>Cost(€/kWh)</th>
<th>Sold(€/kWh)</th>
<th>Modes</th>
<th>$P_{e_lim}(t)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6am-5pm</td>
<td>0.01</td>
<td>0.006</td>
<td>Moderate</td>
<td>2200</td>
</tr>
<tr>
<td>5pm-10pm</td>
<td>0.015</td>
<td>0.012</td>
<td>Expensive</td>
<td>4500</td>
</tr>
<tr>
<td>10pm-6am</td>
<td>0.006</td>
<td>0.003</td>
<td>Cheap</td>
<td>3460</td>
</tr>
</tbody>
</table>

In order to see the effectiveness of the proposed HPM system on the electricity cost and the power drawn from the grid, many scenarios were created and simulated. Scenarios are created by choosing different seasons, i.e., summer or winter, different occupancy conditions, different operating time intervals and operating times for appliances. Results of simulated scenarios are compared for three cases: Case 1, which stands for the situation that neither power units nor appliances are controlled and the battery is used only when the electricity cut off; Case 2, which stands for the situation that the operation time and program modes of appliances are selected by the user (neither local controller nor MC can change the program mode or status of appliances) while power units are scheduled due to the constraints defined in the HPM system; Case 3, which stands for the situation that the HPM system integrated to the home completely (both appliances and power units are scheduled according to HPM system).

Let us inspect one of the studied scenarios in detail: In the scenario, the home is occupied throughout a day in July. The user sets WM to run in the time interval [02:00 PM - 04:00 PM] at the normal program mode (60 min), and DW to run in the time interval [09:00 PM - 11:59 PM] at the normal program mode (80 min). AC and REF runs all day long. TV and lamps are strictly selected time by the user, such that the user turns on TV [09:00 PM - 11:59 PM] at the high energy saving mode and turns on two lamps [08:00 PM - 11:59 PM] at the medium energy saving modes.

In Case 1 and Case 2, WM and DW start with the user defined earliest start time, i.e., 2:00 PM and 9:00 PM, and finish at 3:00 PM and 10:20 PM, respectively. AC and REF are operated at cooler-normal mode and moderate speed mode, respectively during the whole day. In Case 3, the operation time of WM is shifted for 5 min and its operation starts at 2:05 PM. The operation time of DW is shifted for 29 min and its operation is started at 9:29 PM. According to the time duration of normal program mode of WM and DW, their operation finish at 3:05 PM and 10:49 PM, respectively. Program modes of AC and REF are switched to cooler economic mode and low speed mode when the tariff pass to expensive period. For uncontrollable appliances the aforementioned conditions are valid for all three cases.

In Table II, total power consumption, grid power and cost values of the scenario are given. As it is clear from the table, the cost of the scenario would be 1.92 € when no control is applied to the system (Case-1). If the power units of the system are scheduled due to the HPM system in a home equipped with traditional appliances without control, the cost would be 0.92 € with 52% reduction (Case-2). By integrating the HPM system completely to the home (Case-3), the cost is realized as 0.76 €, with an improvement of 17% with respect to Case-2 and with an improvement of 60 % with respect to Case-1.

In Figures 2, 3 and 4 graphs of power demand and power drawn from the grid are given for Case-1, Case-2 and Case-3, respectively. While sudden increases are observed in the power taken from the grid in Case-1 and Case-2, the power taken from the grid in Case-3 remains below the predefined grid limits and high peak demand with the reduced high peak demand.

![Graph of the power demand/grid power/grid limit for Case 1](image)

**TABLE II: RESULTS OF THE SCENARIO FOR THE CONSIDERED CASES**

<table>
<thead>
<tr>
<th>Cases</th>
<th>Cost(€/kWh)</th>
<th>$P_{e}(t)$</th>
<th>$P_{g}(t)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>1.92</td>
<td>20.03</td>
<td>27.75</td>
</tr>
<tr>
<td>Case 2</td>
<td>0.92</td>
<td>12.56</td>
<td>27.75</td>
</tr>
<tr>
<td>Case 3</td>
<td>0.76</td>
<td>11.27</td>
<td>26.46</td>
</tr>
</tbody>
</table>
was reported as 47%. Simulations of plenty of scenarios demonstrate that the proposed HPM system improves this result. That is, HPM system provides 45%-65% reduction in the electricity cost with respect to the uncontrolled case (neither power units nor appliances are controlled and the battery is used only when the electricity cut off).

Future work related to this paper includes reducing total and peak power demand of the neighborhood by applying the proposed HPM system to a neighborhood homes simultaneously.

ACKNOWLEDGMENT

This work was supported by Anadolu University through Research Project 1508F597.

REFERENCES


IV. CONCLUSION

In this work, a home power management system, namely HPM system, is proposed to minimize electricity cost and reduce high peak demand while maintaining user comfort. The system is composed of smart electrical appliances, power units, communication network and MC. In the system, appliances are divided into three subclasses as uncontrollable, semi-controllable and controllable due to user comfort and appliance’s features. Power resources providing the power demand of home are grid, PV system and the battery. Smart and energy efficient operation constraints are defined and used for appliances and power resources. MC is the brain of the system and controls the home power demand and the usage of power resources for efficient use of energy, thus minimizing the electricity cost. At the beginning of each day, MC gathers user request and power resource information and solves the MILP problem formulated with the aforementioned constraints of appliances and power resources. The solution of this problem provides cost minimizing schedule of controllable appliances and power resources, thus it provides cost minimizing timings of battery charge and discharge, PV usage, grid power usage, power injection to grid processes.

A MILP based method was already used for scheduling appliances. In that work, the provided electricity cost reduction...