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OPTIMAL LOAD SCHEDULING OF HOME APPLIANCES CONSIDERING OPERATION CONDITIONS

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Research paper

Abstract: *To reduce energy consumption arising from increasing energy efficiency in response to energy depletion around the world, energy price rises, climate change, and accidents of electric power are cooperating simultaneously. Recognizing the seriousness of the above-mentioned problems, feasible and effective policies for reducing greenhouse gas have been promoted in developed countries since the 2000s. Moreover, industry and academia are actively researching to develop energy-efficient and eco-friendly technologies, respectively. This study proposes an optimal model for scheduling home appliances that minimizes power costs by assuming a smart-home environment with smart metering and advanced metering infrastructure. In addition, a case-study was performed using actual data from South Korea, and sensitivity analysis was performed according to changes in parameters. The experiment considered possible real-life situations, such as an increase and decrease in power cost and a limitation in power usage, and proved that the proposed model was excellent to establish a power schedule for home appliances. This research result seems to serve as a guideline in relation to the control of home appliances to reduce power and smart homes.*

Key words: *Load scheduling, House appliances scheduling, Smart Home, Mixed-integer linear programming (MILP)*

1. Introduction

Nowadays, as the severity of energy resource depletion increases, various studies on energy utilization methods are conducted. In particular, measures to efficiently manage power usage are emerging very quickly. For instance, research related to the construction of next-generation intelligent power networks, called smart grids, not to mention the development of related technologies is becoming an issue. The meaning of smart grids is defined differently depending on each country or institution. Institute of Electrical and Electronics Engineers (IEEE) has defined smart grid as follows. "Smart grids have come to illustrate the next generation of power systems

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represented by the increasing use of communication and information technology in the generation, transmission and consumption of electrical energy." According to Australian Energy Market Operator, Shabanzadeh and Moghaddam (2013) defined smart grid as “Smart Grid creates opportunities for consumers to change their energy consumption at short notice in response to a variety of signals that include price.”

Various discussions around the world regarding the introduction of the smart grid system have been underway since the early 2000s. In North America, the U.S., Canada, and Europe, all member states and Asian regions especially around Japan and China, are focusing on fostering industries and revitalizing early markets, not only at the level of governments, but also private companies to secure the lead in next-generation energy technology competition. In South Korea, a smart grid demonstration complex was established in Jeju Island in 2009, related technologies were commercialized, and export industrialization began. In January 2010, the smart grid national roadmap was announced, and a plan was established to build the smart grid in three stages by 2030. To this end, a total of 27.5 trillion KRW (Korean won) of investment in the smart grid technology will be implemented at the private and public levels, resulting in 230 billion tons reduction in greenhouse gas, 47 trillion KRW reduction in energy income, and 3.2 trillion KRW reduction in new power plant construction costs.

In order for the smart grid system to operate, it is essential to introduce smart metering technology and advanced metering infrastructure (AMI) facilities that exchange real-time power information in both directions using a communication network. Smart metering is the most basic facility technology for smart grids, allowing intelligent measurement, monitoring, and controlling of overall power grids such as user power consumption, distributed energy production, power loss, and power interruption. In the United States, smart metering technology is introduced to restore reliability in the power supply (due to large-scale power outages) and increase people's awareness of energy saving. AMI is an infrastructure facility that actively saves energy through demand response between end consumers and energy suppliers based on smart meters of smart grids. In other words, information and services are provided so that power companies and consumers can use energy efficiently through integrated management of demand-side power resources and efficient operation and distribution thereof. This information is the means for mutual recognition based between power suppliers and receivers and includes functions of various types of distribution power systems and power distribution intelligence systems. It also supports advanced time-based plans such as time-of-usage, critical peak pricing, and real-time pricing, which encourage consumers to participate in active energy savings. If AMI infrastructure and smart metering technology are used, various applications can be used at home; for example, in response to real-time power charges, a schedule of home appliances can be established to save energy, and power consumption patterns and overall energy monitoring can be performed. This study proposes a schedule plan for home appliances in use to minimize power cost in an environment that introduces AMI and smart metering technology. In addition, the sensitivity analysis of major parameters, such as power charge and power usage, was conducted through a case-study using real data in South Korea.

The sections of this study are as follows. In Section 2, existing literature on smart metering, AMI optimization research considering the environment, and scheduling of home appliances are fixed. Section 3 proposes an optimal model for scheduling home appliances. Section 4 verifies the effectiveness of the proposed model by performing model verification and experimental analysis using real data from Korea. Finally, Section 5 presents conclusions and future research contents.

2. Literature Review

In this section, studies using optimization methods were investigated and summarized, focusing on keywords such as application scheduling, smart metering, and demand response. Adika and Wang (2014) conducted clustering analysis related to power consumption patterns and power loads for each device used. Based on the analysis results, a linear programming was developed to save consumers' electricity bills. Zhu et al. (2012) established a mathematical model based on the integer programming method for the purpose of balancing electricity use by time zone. The latter model proposed a power load balancing mechanism that minimizes the maximum power load per hour, and it was argued that it is essential to prepare a plan to induce voluntary participation of consumers as a way to reduce the power peak load. Althaher et al. (2015) designed a model in consideration of the increase in consumer satisfaction while minimizing power cost. Beaudin and Zareipour (2015) designed a model by classifying the characteristics of the device in detail. Heterogeneity, consumer considerations, and uncertainties were considered, and optimization models and heuristic methods were presented to solve the problem. In addition, this study also presented evaluation criteria for Home Energy Management Systems. Samadi et al. (2015) solved problems related to power load scheduling and electric power transaction under a system with a high penetration rate of renewable energy. It is assumed that the excess power produced by the user can be sold to enterprises or other users, and sellers participate in price competition. Besides, a game theory approach is adopted to model interactions between producers, and utilize approximate dynamic programming to represent different types of device operations. Sou et al. (2011) reflected the power consumption by step considering the characteristics of home appliances and proposed a mixed-integer linear programming that aims to minimize power costs. A case-study was conducted by constructing a scenario based on actual data, and the computational complexity and scalability of the research model were discussed. The integer and mixed-integer linear programming methods are efficient methods for deriving an optimal solution within an appropriate time when the problem size is small. However, this process takes a lot of time as the problem size increases. There are also studies that have adopted complex methods to solve these problems. Morales-España et al. (2022) summarized and classified the demand response in detail, focusing on the power system. Furthermore, an optimization model was developed in this study to perform flexible load management.

Research using heuristic methods has been actively conducted to reduce the problem complexity and resolution time of load scheduling. Alham et al. (2016) and Gupta et al. (2016) developed and utilized heuristic methods for optimal power use. Alham et al. (2016) approached the problem with the aim of minimizing energy use cost and carbon emission. To simultaneously consider cost aspects and eco-friendly factors, objective-functions were defined linearly, and branch and bound method and genetic algorithm were used in consideration of the increase in problem complexity as the problem size grew. Gupta et al. (2016) developed a mixed-integer linear programming model with the aim of minimizing consumer power cost. In addition, heuristic methods such as genetic algorithms, are utilized to compensate for the limitations of mixed-integer linear programming methods in which computational time increases exponentially as the size of the problem grows. Bharathi et al. (2017) divided the power peak hours into industrial, commercial, and residential areas, and developed a model that effectively distributes available power in other areas and minimizes power use during the power peak hours. The developed model solved the problem through a genetic algorithm and proved the superiority of the results compared to evolution algorithms. Chakraborty (2013) proposed an intelligent economic operation model that considers wind and solar powers in a smart grid environment. The model was developed based on fuzzy logic and the Quantum inspired evolutionary algorithm was used to solve the problem. The model was verified through case-studies considering multiple heat devices, electric vehicles, thermal and wind power plants. Excellent results were derived to reduce production cost and carbon emission at the same time. Ma et al. (2016) presented a cost-effective, efficiency-based residential power load scheduling framework that increase the economic efficiency of residential power consumption, rather than minimize power charges that have been primarily used for purposes. In addition, the power bidding process and real-time pricing mechanism were reflected to make the smart grid environment more realistic, and a load scheduling algorithm based on the Quadratic optimization program was proposed. Chakraborty et al. (2020) proposed a power load scheduling-based management plan to reduce peak load. It was assumed that the user could set the desired operating time for each home appliance, and a two-dimensional strip problem-based heuristics model was developed to solve the problem.

Load scheduling is also being actively conducted in studies related to smart-home or smart-building. Wang et al. (2016) used an optimization method to establish a schedule plan for home appliances that can operate in a smart-home environment. Each home appliance reflected the presence or absence of automation, the possibility of stopping during operation, the use of hot water, and the setting according to the change in the ambient temperature as constraints. The integer programming method was constructed, and the minimization of consumers' electricity bills was defined as an objective function. In addition, as computational complexity increases and decreases, the problem was solved by utilizing particle swarm optimization. Ogunjuyigbe et al. (2017) developed a model that can manage the power load of the home within the budget set by the user. The developed model aims to maximize user convenience while reducing power consumption cost, and the problem is solved through genetic algorithm. In addition, various implications were derived through scenario analysis based on variables such as satisfaction and budget. Nazemi et al. (2021) presented the intensive-based multi-objective nonlinear optimization approach for load scheduling problems in smart-building. This study aims to minimize the total power cost, maximize incentives allocated to each customer, minimize customer inconvenience, and consider electronics, electric vehicles, heating sulfur, and air conditioning systems. Foroozandeh et al. (2021) proposed a multi-objective mixed-binary linear programming to minimize the total energy consumption cost and peak load for residential builds. This model is considered the electric vehicles and battery energy storage system, and the performance of the model was compared and analyzed through scenario analysis. Nezhad et al. (2021) proposed a scheduling problem considering solar photovoltaic power supply and home energy management systems. This study considered the uncertainty of photovoltaic power generation and established it for the optimal schedule plan of home applications based on mixed-intermediate programming to minimize the daily bill. Korkas et al. (2022) proposed a distributed feedback-based optimization method based on principles of approximate dynamic programming for grid-connected builds. This model was considered to be user-convenience. Electric vehicles, energy storage systems, and robustness evaluation were performed through various experimental designs. Foroozandeh et al. (2022) assumed the customers have flexible contract systems in smart-buildings. In this study, a mixed binary optimization problem was proposed considering photovoltaic power generation, electric vehicles, and battery energy storage systems. Scenario analysis was conducted to prove the excellence of the proposed model, and the experimental results showed that the electricity cost was reduced by about 47%.

3. Mathematical Model

3.1. Assumptions

This study aims to establish a schedule for home appliances to minimize total power usage at home. The type and power consumption of home appliances were set based on periodical data published by the Korea Electric Power Exchange (2019). The operating level of the home appliance was composed of three stages, and the conditions that consumers can set are divided into three as follows.

Condition #1: Operate the home appliance at a definite time.

Condition #2: The home appliance is set to a range time and operates in consideration of the power charge. However, it is not necessary to operate continuously.

Condition #3: The home appliance is set to a range time and operates in consideration of the power charge. However, it must be operated continuously.

It is assumed that electricity charges are measured under circumstances in which seasonal and hourly rate systems are applied. This is a plan that induces users to use power at a low cost because the high rate unit price is applied during the time of the day when power demand is high, and the low rate unit price is applied during the day time. Since its introduction in South Korea in 1977, the criteria for seasonal and time-of-day classification have been changed according to changes in conditions, and it is being applied to large-capacity users such as general industrial use nationwide. In addition, the demand power is obtained by dividing the amount of power used within the demand time by the usage time. In South Korea, the demand time is applied as 15 min. Accordingly, this study also assumed that it can be set every 15 min.

3.2. Model Description

The following notation is used to formulate the proposed model. The indices, parameters, and variables used to formulate the model are described below.

<u>Indices</u>

i = index of appliances ($i = 1, \dots , I$)

l = index of appliance levels ($l = 1, \dots , L$)

t = index of time periods ($t = 1, \dots , T$)

Parameters

p_t^{over} = Power charge corresponding to punitive charge (Super user) in period t

l_t^{over} = Amount of electricity used applied to punitive charge (Super user) in period t

p_t = Power charge in period t

s_{ilt}^{fix} = 1 if the consumer sets to the appliance i to level l in period t, zero otherwise

tdc_{il}^{max} = Maximum value of the operation time if the consumer sets the appliance i to condition 2 status and level l

tdc_{il}^{min} = Minimum value of the operation time if the consumer sets the appliance i to condition 2 status and level l

$s_{il}^{var,dc}$ = Operation time if the consumer sets to the appliance i to condition 2 status and level l

tc_{il}^{max} = Maximum value of the operation time if the consumer sets the appliance i to condition 3 status and level l

tc_{il}^{min} = Minimum value of the operation time if the consumer sets to the appliance i to condition 3 status and level l

$s_{il}^{var,c}$ = 1 if the consumer sets the appliance i to condition 3 and level l, zero otherwise

cot_{il} = Continuous operation time if the consumer sets to the appliance i to condition 3 status and level l

ec_{il} = Power consumption operated to the appliance i to level l

Variables

c_{ilt} = Cost of operating appliances i to level l in period t

c_t^{cum} = Cumulative charging to the period t

c_t^{over} = Excess cost of the t period following the introduction of a punitive charge

u_t^{over} = The amount of excess electricity in period t according to the introduction of the electric power peak

x_{ilt} = 1 if appliance *i* is set to condition 1 and level *l* in the period *t*, zero otherwise

y_{ilt}^{dc} = 1 if appliance *i* is set to condition 2 and level *l* in the period *t*, zero otherwise

y_{ilt}^{c} = 1 if appliance *i* is set to condition 3 and level *l* in the period *t*, zero otherwise

y_{ilt}^{cont} = 1 if appliance *i* is set continuously by condition 3 and level *l* in the period *t*, zero otherwise

z_{ilt} = 1 if appliance *i* is set to level *l* in the period *t*, zero otherwise

Based on the notation described, the model for the load scheduling of home appliances is formulated as follows:

<u>objective function</u>

$$Minimize\ c_{t=T}^{cum} \tag{1}$$

<u>subject to</u>

$$\sum_{l=1}^{L} z_{ilt} = 1 \quad \forall i,t \tag{2}$$

$$s_{ilt}^{fix} \leq x_{ilt} \quad \forall i,l,t \tag{3}$$

$$\sum_{tdc_{il}^{min} \leq t \leq tdc_{il}^{max}}^{L} y_{ilt}^{dc} \leq s_{il}^{var,dc} \quad \forall i,l \tag{4}$$

$$\sum_{tc_{il}^{min} \leq t \leq tc_{il}^{max}}^{L} y_{ilt}^{c} \leq s_{il}^{var,c} \quad \forall i,l \tag{5}$$

$$cot_{il} y_{ilt}^{c} \leq \sum_{t' \leq t}^{t+cot_{il}-1} y_{ilt'}^{cont} \quad \forall i,l,t\,(t \leq T - cot_{il} + 1) \tag{6}$$

$$\frac{x_{ilt} + y_{ilt}^{dc} + y_{ilt}^{cont}}{3} \leq z_{ilt} \quad \forall i,l,t \tag{7}$$

$$\sum_{i=1}^{I} \sum_{l=1}^{L} ec_{il} z_{ilt} \leq l_t^{over} + u_t^{over} \quad \forall t \tag{8}$$

$$c_{ilt} = ec_{il} p_l z_{ilt} \quad \forall i,l,t \tag{9}$$

$$c_t^{over} = p_t^{over} u_t^{over} \quad \forall t \tag{10}$$

$$c_t^{cum} = \sum_{i=1}^{I}\sum_{l=1}^{L} c_{ilt} + c_t^{over} \quad \forall t \tag{11-1}$$

$$c_t^{cum} = c_{t-1}^{cum} + \sum_{i=1}^{I}\sum_{l=1}^{L} c_{ilt} + c_t^{over} \quad \forall t \tag{11-2}$$

$$x_{ilt}, y_{ilt}^{dc}, y_{ilt}^{c}, y_{ilt}^{cont}, z_{ilt} = \{0,1\} \tag{12}$$

$$c_{ilt}, c_t^{cum}, c_t^{over}, u_t^{over} \geq 0 \tag{13}$$

Equation (1) is an objective function, and aims to minimize the total power cost incurred in all periods. Constraint equation (2) means that all home appliances can only set one operation per hour. Constraint equation (3) is an equation for a definitive operation setting of a home appliance. That is, when the home appliance, the operating level, and the operating time are set, x_{ilt} is calculated accordingly. Constraints (4) and (5) are indicating that the home appliance is set as a range time. Constraint equation (4) is a case where discontinuity is allowed, and constraint equation (5) is a case where continuous operation is required. Constraint equation (6) means that when the home appliance is set to the range time, it must be operated for a set time based on the operation start time. Constraint equation (7) means that only one of the definitive setting, range setting (continuous and discontinuous) is possible. Constraint equation (8) is a restriction for determining whether the power usage corresponds to an excessive power consumption layer (super consumers). Constraints (9) and (10) represent the costs for power consumption. Constraint equation (9) refers to the cost of general power consumption thatis calculated by multiplying the power consumption of the home appliance, the power charge of the corresponding time, and whether it is operational or not. Constraint equation (10) is a formula for calculating the amount of power used when corresponding to superuser. Constraint equations (11-1) and (11-2) calculate the accumulated power usage amount in period t. Constraint (12) represents the binary variables, and constraint (13) indicates the non-negative variables.

4. Experiment Results and Discussion

4.1. Input Data

In order to conduct the experiment of the mathematical model proposed in Sections 3-2, actual data operated by Jeju island of South Korea was used. Jeju Island uses seasonal and hourly rate systems (Korea Electric Power Corporation (2021), Basic Terms of Supply Enforcement Detailed Rules) to induce users to use low-rate power by applying high rates during high power demand times of the day or low rates during low power times. That is, power charges vary by season and time, and detailed data are presented in Table 1. In addition, if the monthly power consumption exceeds 1000 kWh in summer (from June 1 to August 31) and winter (from November 1 to the end of February of the following year), it will be classified as a super user, and the unit price of 704.5 KRW per kWh will be applied to the excess usage. In addition, household appliances and power consumption in regular publications published by the Korea Electric Power Exchange (2019) were used, and data on household appliances are presented in Table 2. The power usage according to the level of home appliances was set based on the second stage, and it was assumed that the first stage decreases by 20% whereas the third stage increases by 20%. IBM ILOG CPLEX 22.1, a commercial optimization package conducted on a PC (AMD Ryzen 5600x, CPU 3.7 GHz), was used to conduct experiments on the optimization model.

Table 1. Energy charge for seasonal and hourly in Jeju Island

Basic rate (KRW/kW)	Energy charge (KRW/kWh)		
	A time zone	Spring, fall	Summer, winter
4310	Light-load (22:00–08:00)	99.0	111.9
	Heavy-load (08:00–16:00)	127.0	157.9
	Overload (16:00–22:00)	145.6	193.7

Table 2. Data and experimental settings for appliances

Appliance	Number of level	Power rating (kW)	Operation setting			
			Condition setting	Operating time (min)	Minimum start time	Maximum start time
TV	3	0.1515	#1	420	17:00	22:00
Refrigerator	3	0.0422	#1	1440	00:00	24:00
Washing machine	3	0.9043	#3	120	07:00	22:00
Air conditioner	3	1.5	#2	300	12:00	20:00
Vacuum cleaner	2	1.2	#3	30	07:00	22:00
Microwave	2	1.1615	#2	30	06:00	07:00
Water purifier	2	0.5775	#1	1440	00:00	24:00
Induction heating cooking heater	2	1.3745	#3	30	18:00	20:00
Toaster	2	0.9157	#3	30	05:00	07:00
Blender	2	0.7276	#3	30	05:00	07:00
Air purifier	1	0.0491	#2	120	18:00	24:00
Computer	1	0.3119	#1	360	18:00	24:00
Stereo	1	0.1015	#1	300	18:00	23:00
Dryer	1	1.5061	#2	15	06:00	07:00
Iron	1	1.3748	#3	30	17:00	22:00

4.2. Experimental Results

The results of the experiment are shown in Figure 1. The experimental results showed that a flexible operation was set during light and heavy-load times when power charges were low by avoiding the maximum load time, except for the appliance set to condition 1. In addition, as shown in Figure 2, it can be seen that the cost in the heavy-load time period has increased rapidly due to the power usage transfer to the heavy-load time period in the overload time period.

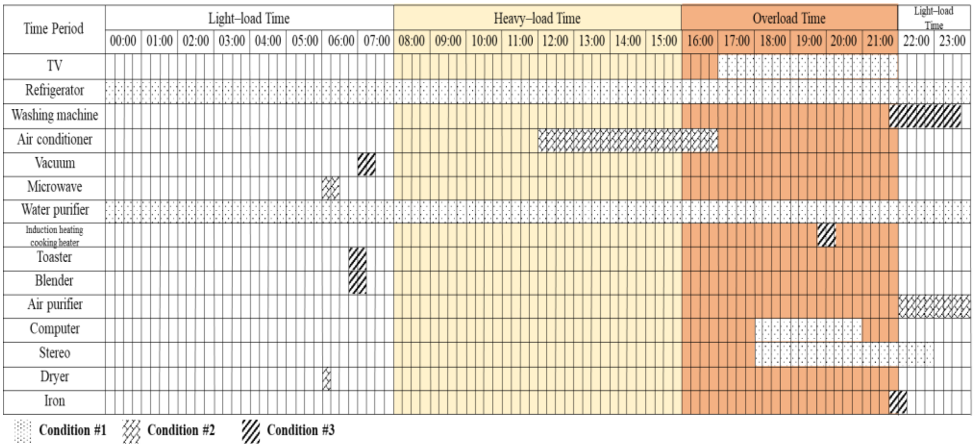

Figure 1. Experimental results by conditions

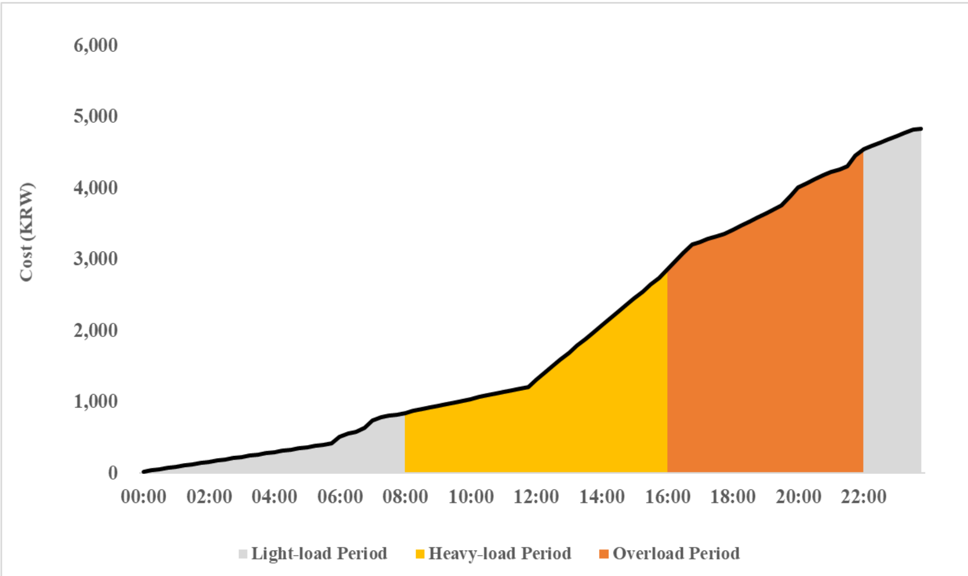

Figure 2. Cumulative cost according to time period

4.3. Additional Experimental Design and Results

In this study, sensitivity analysis was conducted to analyze the change in the result value according to the change in the input data value. The new light-load power rate and overload power charge were calculated using the power charges and weight factors in the light-load, heavy-load, and overload times presented in Table 1. Weight factors were taken to be 0.5, 0.8, 1.0, 1.2 1.5, respectively. The experimental results are as illustrated in Figure 3, and it is confirmed that reducing the difference in power charge according to load increases the power usage cost during light load time, whereas increasing the difference in power charge increases the power usage cost during overload time.

New light-load power charge = Heavy-load power charge - (Heavy-load power charge - Light-load power charge) · Weight factor

New overloaded power charge = Heavy-load power charge + (Overload power charge - Heavy-load power charge) · Weight factor

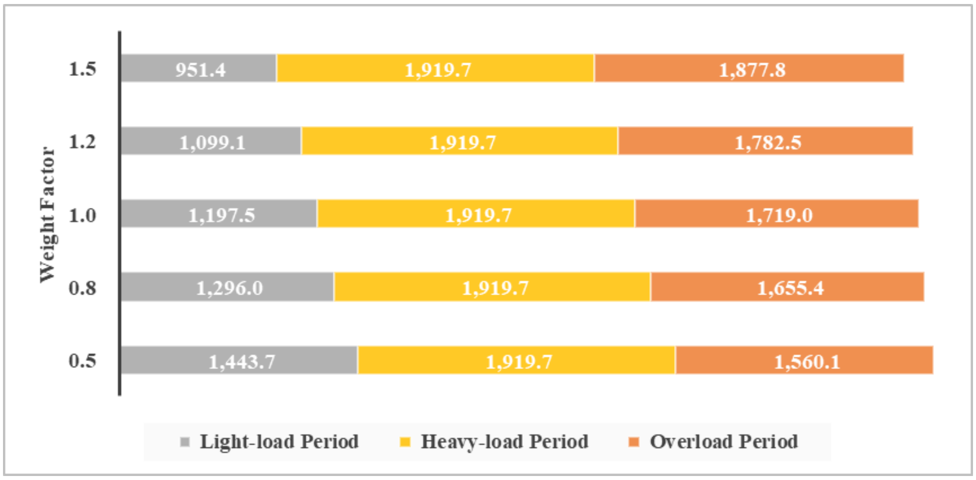

Figure 3. Total costs based on power rate weight factor and time zone by rate

In the second experiment, we added constraints on the instantaneous maximum used amount. In South Korea, when power consumption is high, such as in summer or winter, instantaneous power consumption cannot exceed contract demand. Therefore, the following constraint formula (14) was added in consideration of this situation, and the experiment was conducted assuming that the power use limitations were 2.6, 3.0, and 3.4 kw/h, respectively.

$$\sum_{i=1}^{I}\sum_{l=1}^{L} ec_{il} z_{ilt} \leq ce \quad \forall t \tag{14}$$

Figure 4 shows the rate of change in power cost compared to the basic experimental result value for each light-load, heavy-load, and overload time zone. The experimental results show that, when the instantaneous power use limit is 3.4 kW, the same cost is incurred as in the basic experiment. At 3.0 kW, the power use cost increased in heavy-load time, and in the case of limitation to 2.6 kW, the power usage cost increased in overload time. It can be seen that as the restriction on instantaneous power use became stronger, the schedule plan of home appliances was moved to a section where costs gradually increased.

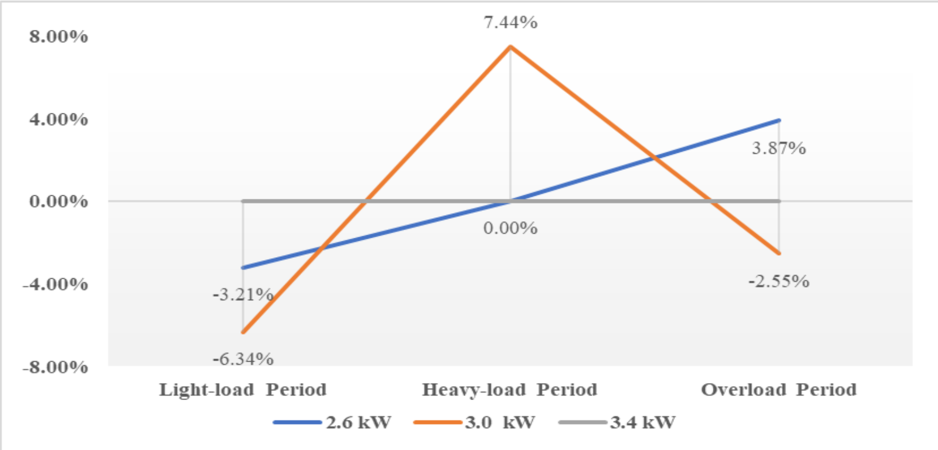

Figure 4. Amount of change in total power cost for instantaneous power usage

5. Conclusion

This study proposed a mathematical model for optimal scheduling for home appliances to minimize electricity charges assuming an environment to introduce smart metering, which is rapidly being promoted in the power market. This study also proved the superiority of the model using actual data in Jeju Island of South Korea.

In addition, sensitivity analysis was conducted to find the change in decision variables and objective function as the parameter values were changed, and as a result, it was confirmed that the decision-making was made by changing the load time to lower the total power charge. Furthermore, two sensitivity analyses were conducted to find out the changes in decision variables and objective functions according to the changes in parameters. The first sensitivity analysis compared and analyzed the case where the difference in power prices according to the light-load period, the heavy-load period, and the overload period increased or decreased, the second sensitivity analysis was performed by considering the instantaneous maximum usage so that instantaneous power consumption cannot exceed the contract demand when the power consumption is high, such as in summer or winter. Looking at the results of the two sensitivity analyses, it was found that the decision was made by reducing the total power cost and varying the load time to satisfy the additional constraints and circumstances. This study result could help establish schedule plans for home appliances to save power and serve as a guideline for development and operation related to smart homes.

The limitations of this study and future research directions are as follows. The electricity rate system applied not only to each region of South Korea but also to each country is different. In this study, input data was prepared using actual data from Jeju Island located in South Korea, but the latter can be changed according to country, timing, policy, and situation. Therefore, in future studies, it will be necessary to analyze power rate systems in various countries and establish a mathematical model for scheduling accordingly. Other limitations of this study include considering only commonly used home appliances, not considering detailed operations such as step conversion, and emergency stop setting of home appliances. and assuming weight factors to increase and decrease changes in power price depending on the light-load period, heavy-load period, and overload period. In future research, it is necessary to develop a detailed and expanded model reflecting the realistic situation. Moreover, the proposed model is developed based on mixed-integer linear programming. This programming has limitations in that the calculation time increases exponentially as the size of the problem increases. Therefore, in future studies, it is necessary to develop a suitable heuristic model.

References

Adika, C. O., & Wang, L. (2014). Smart charging and appliance scheduling approaches to demand side management. International Journal of Electrical Power & Energy Systems, 57, 232-240. https://doi.org/10.1016/j.ijepes.2013.12.004

Alham, M., Elshahed, M., Ibrahim, D. K., & El Zahab, E. E. D. A. (2016). A dynamic economic emission dispatch considering wind power uncertainty incorporating energy storage system and demand side management. Renewable Energy, 96, 800-811. https://doi.org/10.1016/j.renene.2016.05.012

Althaher, S., Mancarella, P., & Mutale, J. (2015). Automated demand response from home energy management system under dynamic pricing and power and comfort constraints. IEEE Transactions on Smart Grid, 6(4), 1874-1883. https://doi.org/10.1109/TSG.2014.2388357

Beaudin, M., & Zareipour, H. (2015). Home energy management systems: A review of modelling and complexity. Renewable and sustainable energy reviews, 45, 318-335. https://doi.org/10.1016/j.rser.2015.01.046

Bharathi, C., Rekha, D., & Vijayakumar, V. (2017). Genetic algorithm based demand side management for smart grid. Wireless personal communications, 93(2), 481-502. https://doi.org/10.1007/s11277-017-3959-z

Chakraborty, N., Mondal, A., & Mondal, S. (2020). Efficient load control based demand side management schemes towards a smart energy grid system. Sustainable Cities and Society, 59, 102175. https://doi.org/10.1016/j.scs.2020.102175

Chakraborty, S., Ito, T., Senjyu, T., & Saber, A. Y. (2013). Intelligent economic operation of smart-grid facilitating fuzzy advanced quantum evolutionary method. IEEE Transactions on Sustainable Energy, 4(4), 905-916. https://doi.org/10.1109/TSTE.2013.2256377

Foroozandeh, Z., Ramos, S., Soares, J., & Vale, Z. (2021). Energy management in smart building by a multi-objective optimization model and pascoletti-serafini scalarization approach. Processes, 9(2), 257. https://doi.org/10.3390/pr9020257

Foroozandeh, Z., Ramos, S., Soares, J., Vale, Z., & Dias, M. (2022). Single contract power optimization: A novel business model for smart buildings using intelligent energy management. International Journal of Electrical Power & Energy Systems, 135, 107534. https://doi.org/10.1016/j.ijepes.2021.107534

Gupta, A., Singh, B. P., & Kumar, R. (2016). Optimal provision for enhanced consumer satisfaction and energy savings by an intelligent household energy management system. Paper presented at the 2016 IEEE 6th International Conference on Power Systems (ICPS).

Korea Electric Power Corporation (2021). Basic Terms of Supply Enforcement Detailed Rules.

Korea Power Exchange (2020). Investigation report on the supply status of home appliances in 2019.

Korkas, C. D., Terzopoulos, M., Tsaknakis, C., & Kosmatopoulos, E. B. (2022). Nearly optimal demand side management for energy, thermal, EV and storage loads: An Approximate Dynamic Programming approach for smarter buildings. Energy and Buildings, 255, 111676. https://doi.org/10.1016/j.enbuild.2021.111676

Ma, K., Yao, T., Yang, J., & Guan, X. (2016). Residential power scheduling for demand response in smart grid. International Journal of Electrical Power & Energy Systems, 78, 320-325. https://doi.org/10.1016/j.ijepes.2015.11.099

Morales-España, G., Martínez-Gordón, R., & Sijm, J. (2022). Classifying and modelling demand response in power systems. Energy, *242*, 122544. https://doi.org/10.1016/j.energy.2021.122544

Nazemi, S. D., Jafari, M. A., & Zaidan, E. (2021). An incentive-based optimization approach for load scheduling problem in smart building communities. Buildings, 11(6), 237. https://doi.org/10.3390/buildings11060237

Nezhad, A. E., Rahimnejad, A., & Gadsden, S. A. (2021). Home energy management system for smart buildings with inverter-based air conditioning system. International Journal of Electrical Power & Energy Systems, 133, 107230. https://doi.org/10.1016/j.ijepes.2021.107230

Ogunjuyigbe, A., Ayodele, T., & Akinola, O. (2017). User satisfaction-induced demand side load management in residential buildings with user budget constraint. Applied Energy, 187, 352-366. https://doi.org/10.1016/j.apenergy.2016.11.071

Samadi, P., Wong, V. W., & Schober, R. (2015). Load scheduling and power trading in systems with high penetration of renewable energy resources. IEEE Transactions on Smart Grid, 7(4), 1802-1812. https://doi.org/10.1109/TSG.2015.2435708

Shabanzadeh, M., & Moghaddam, M. P. (2013). What is the smart grid? Definitions, perspectives, and ultimate goals. Paper presented at the 28th International Power System Conference (PSC).

Sou, K. C., Weimer, J., Sandberg, H., & Johansson, K. H. (2011). Scheduling smart home appliances using mixed integer linear programming. Paper presented at the 2011 50th IEEE conference on decision and control and European control conference.

Wang, J., Li, Y., & Zhou, Y. (2016). Interval number optimization for household load scheduling with uncertainty. Energy and Buildings, 130, 613-624. https://doi.org/10.1016/j.enbuild.2016.08.082

Zhu, Z., Tang, J., Lambotharan, S., Chin, W. H., & Fan, Z. (2012). An integer linear programming based optimization for home demand-side management in smart grid. Paper presented at the 2012 IEEE PES innovative smart grid technologies (ISGT).