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Power Consumption Control Method Using Pattern Analysis for Load Distribution

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Abstract

In this paper, we propose a method to control an amount of electric power for load distribution of power grid. The proposed method is characteristic which evenly keeps the power consumption through curtailment control. The scheduler of demand/supply management system determines the curtailment state decision and control based on the predicted power demand information and the predicted renewable energy generation information. The dropped appliances are prevented to get the excessive power curtailment and the power grid is obtained the load distribution effect with time domain by the proposed system.

Keywords: Curtailment State Control Method, Load Distribution, Peak Load, HEMS, Smart Grid

1 Introduction

The world has focused renewable energy as a way to meet the growing energy consumption. Renewable energy has the characteristic that the power supply is intermittent by various conditions and the smart grid utilizes the electric power from renewable energy by using the Energy Storage System. In addition, to deal with demand of the home area, various methods have been studied on way how to receive the electric power from the power grid and the renewable energy operator such as photovoltaic. A method of supplying electric power is proposed [1] - [9].

The prediction for PV resource is achieved by using various weather and PV information. Also, dropped appliance is utilized for management of electric supply and demand [10], [11].

However, existing studies didn't achieve efficient load distribution to utilize dropped appliance because these studies was not proposed the appropriate curtailment criteria except the minimum curtailment condition.

In order to solve these problems, an existing study achieved a management method with multi-curtailment method as the minimum curtailment, medium curtailment and maximum curtailment. However, that have a problem, the intensively curtailment amount of the electric power in the maximum state curtailment. So, it needs efficient curtailment method to solve this problem.

Therefore, in this paper, we propose the method to control an amount of electric power for load distribution of power grid. The proposed method is composed of prediction of electric power consumption, prediction of renewable energy generation, and Demand/Supply manager. The proposed method is characteristic which evenly keeps the power consumption through curtailment control for a certain period of time. The method controls dropped and controllable appliances in order to operate home appliance under user preference.

The rest of the paper is organized as follows. In the section II, we discussed how to control curtailment level. The section III describes the proposed demand/supply management system. The performance analysis is implemented in section IV. Finally, we conclude the proposed method in section V.

2 Related Work

The multi-curtailment condition is made based on the KEPCO (Korea Electric Power COperation) progressive tax policy. According to the policy, the power curtailment level is determined by three steps, 0kW ~ 199kW, 200kW ~ 399kW, and over 400kW, which stem from the tax policy [10].

Smart appliances can be composed of must-run, controllable, and dropped appliances. Information on consumed electric power by smart appliances in the past years has been collected in DB server. Information on the consumed electric power is sent the module of power consumption prediction of supply and demand management system for the prediction of the power consumption. The module on power consumption prediction implements clustering of electric power consumption data every time slots based on electric power consumption data in past years [10], [11].

The PV panel is considered as the renewable resource. The PV information such as the weather condition, amount of clouds, the latitude, and the longitude is used to forecast the electric power of the PV panel. The output of the PV panel is decided as a variety of information which is the predicted weather, the peak value of a time during a day, hourly angle, and the air mass respectively. Information on the weather has the value of mean and variance because of the prediction process. The condition of peak value is decided by information which is the peak power of PV panel, the area of PV panel, the latitude, and the longitude [10], [11].

3 Demand and Supply Management System

A. Proposed System Description

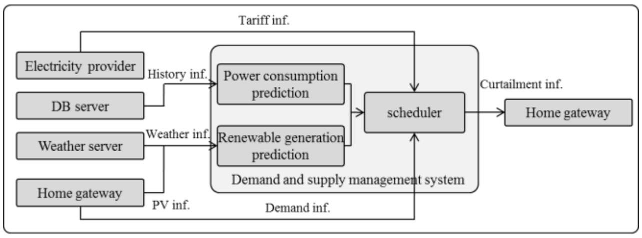

Figure 1. The block diagram about the proposed system architecture

Figure 1 shows a block diagram of proposed demand/supply management system architecture. The demand/supply management system consists of the power consumption prediction module, the renewable energy power generation forecasting module and the scheduler.

The power consumption prediction module analyses the consumption pattern of the electric power based on past electric power information which the smart device consumes. Past information of smart device power consumption is transmitted to the demand/supply management system from the DB server. The prediction module of the electric power generated by the renewable resource predicts the electric power generated by the PV generator in the home area. It collects the weather and specification of PV generator information to affect the power generation.

The scheduler module controls the demand/supply amount for clients to utilize the predicted information of electric power consumption information and renewable energy power generation information. The insufficient electric power by a difference value between the predicted demand power and the renewable power is provided from the power grid.

B. Power Supply of Smart Appliances from power grid

The electric power levels are composed of 6 steps according to the consumption amount based on progressive tax policy of KEPCO for HEMS [10]. The price of the electric power increases according to the consumption amount of the electric power. If the consuming amount of the electric power is included in the step 1 or step 2, curtailment condition (θ_t) is kept as minimum curtailment state ($\theta_{d,t}^{\min}$). If the consuming amount of the electric power is included in the step 3 or step 4 at time slot t, curtailment condition (θ_t) is kept as medium curtailment state ($\theta_{d,t}^{med}$). If the consuming amount of the electric power is included in the step 5 or step 6 at time slot t, curtailment condition (θ_t) is kept as maximum curtailment state ($\theta_{d,t}^{\max}$).

The dropped appliance of smart appliances is curtailed of the electric power supplied from the power grid according to the curtailment condition. The three cases is derived from mean ($d_{n,t}^{a}$) and variation ($V_{n,t}^{a}$) of the required electric power and mean ($S_{n,t}^{sol}$) of renewable resource.

The average power consumption ($\overline{d^{a}}$) is can described as following equation (1)

$$\overline{d^{a}} = \frac{\sum_{d=1}^{m}\sum_{t=1}^{n} d_{n,t}^{a}}{m \cdot n} \tag{1}$$

$d_{n,t}^{a}$ means the power consumption of smart appliances during a month ($d = 1, 2, ..., m$) and every time ($t = 1, 2, ..., n$).

The curtailment volume is decided from the power grid during a month and every time according to predicted electric power requirement. Mean of the curtailment volume to consider the electric power supplied from the power grid during a month and every time is can described as following equation (2)

$$\overline{\theta} = \frac{\sum_{d=1}^{m}\sum_{t=1}^{n} \theta_{d,t}^{\min} + \sum_{d=1}^{m}\sum_{t=1}^{n} \theta_{d,t}^{med} + \sum_{d=1}^{m}\sum_{t=1}^{n} \theta_{d,t}^{\max}}{m \cdot n} \tag{2}$$

The electric power from the power grid consists of six cases is can described as following equation.

$$S_{grid,t} = \begin{cases} d_{n,t}^{a} + |V_{n,t}^{a}| - S_{n,t}^{sol} - \overline{\theta}, & when\, \theta = \theta_{\min}\ and\ d_{a,t} - S_{sol,t} \geq \overline{d_{a}} \\ d_{n,t}^{a} + |V_{n,t}^{a}| - S_{n,t}^{sol}, & when\, \theta = \theta_{\min}\ and\ d_{a,t} - S_{sol,t} < \overline{d_{a}} \\ d_{n,t}^{a} + \frac{|V_{n,t}^{a}|}{2} - S_{n,t}^{sol}, & when\, \theta = \theta_{med}\ and\ d_{a,t} - S_{sol,t} \geq \overline{d_{a}} \\ d_{n,t}^{a} + |V_{n,t}^{a}| - S_{n,t}^{sol} - \overline{\theta}, & when\, \theta = \theta_{med}\ and\ d_{a,t} - S_{sol,t} < \overline{d_{a}} \\ d_{n,t}^{a} - S_{n,t}^{sol}, & when\, \theta = \theta_{\max}\ and\ d_{a,t} - S_{sol,t} \geq \overline{d_{a}} \\ d_{n,t}^{a} + |V_{n,t}^{a}| - S_{n,t}^{sol} - \overline{\theta}, & when\, \theta = \theta_{\max}\ and\ d_{a,t} - S_{sol,t} < \overline{d_{a}} \end{cases} \tag{3}$$

Scheduler uses the values of user preference (α) for reduction of peak load. If the requirement exceeds user preference, the requirement ($d_{n,t}^{a}$) decreases to the value of difference between the requirement and user preference ($d_{n,t}^{a} - \alpha$).

4 Performance Analysis

We analyse the two methods of the proposed method and existing method to compare the state of the consumed electric power during a month. Smart appliance is composed of three groups as a group of must-run appliance, controllable appliance, and dropped appliance.

Fig. 2 shows the comparison of the electric power consumed about the proposed method and existing method during a month. The duration from day 1 to day 12, day 13 to 24, and day 25 to 31 equal to case 1, case 2, and case 3 respectively because of the minimum, medium, and maximum curtailment policy. Also, the amount of electric power of the proposed method is under user preference (blue line).

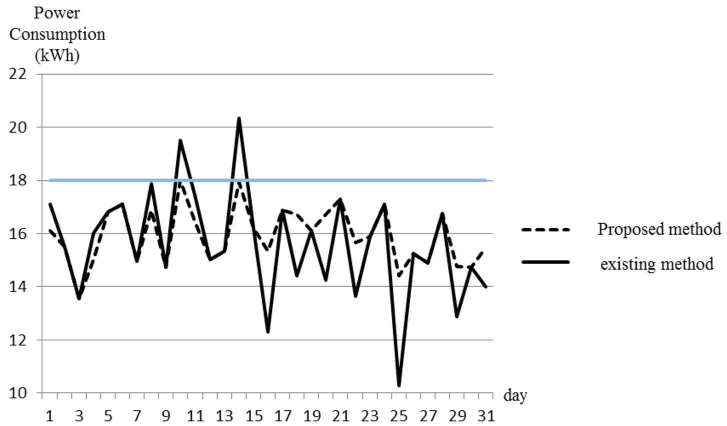

Figure 2. Comparison of existing method and proposed method about power consumption during one month

5 Conclusion

We proposed the method to control an amount of electric power for load distribution. The scheduler of demand/supply management system determined the uniform power curtailment level based on predicted power demand information renewable energy. A dropped appliance prevented excessive power curtailment and obtains the uniform curtailment effect with time domain by the proposed system. The result of performance analysis shows that the proposed method is a regular curtailment condition and the proposed method get the affect load shaving in the time domain. We have a further study from the proposed method. A study extends the proposed method from the home area to the community area.

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