ATLANTIS PRESS
Advances in Computer Science Research, volume 70
2nd International Conference on Mechatronics Engineering and Information Technology (ICMEIT 2017)

Optimization Analysis of Demand Response Model for Smart Grid

Yufan Lei[1, a], Guanglin Han[2, b], Yanqun Wang[3, c] and Shengli Wang[4, d]

[1]school of Yufan Lei, Tianjin Normal University. Tianjin 300000, China.

[2]school of Guanglin Han, Tianjin Normal University. Tianjin 300000, China.

[3]school of Yanqun Wang, Tianjin Normal University. Tianjin 300000, China.

[4]school of Shengli Wang, Tianjin Normal University. Tianjin 300000, China.

[a]lyfan1108@163.com,[b]hgltj@163.com,[c]1002890010@qq.com,[d]690591833@qq.com

Keywords: smart grid, demand response model, communication system optimization.

Abstract. This paper analyzed and summarized for the smart grid user demand response, put forward the optimization problem of smart grid communication system in response to demand, and effectively solve the problem of zero user utility of inelastic demand.

1. Introduction

At present, the research of demand response only considers the optimization of supply and demand curve. With the rapid development of smart grid, the optimization of communication system will become an important problem in the demand response. This paper establishes communication system optimization model of real time pricing of utility maximization based on the transformation problem by Lagrange dual decomposition method, with the corresponding electricity supply side end algorithm and the algorithm guarantees that all users of the utility ratio of equity, and analyzed and simulated.

2. Demand Response

Demand response refers to the behavior of power consumer in response to price signals or incentives to change the habit of electricity usage patterns [1]. Demand response measures in accordance with the response of different users can be divided into two types: price-based demand response (PBDR) and incentive-based demand response (IBDR) [2], the specific classification as follows.

1) Price-based demand response (PBDR). The terminal consumers face a variety of price signals and make the arrangement and adjustment of electricity consumption, electricity time and electricity mode. PBDR focuses on the user's active participation, the response behavior comes from the user's internal economic decision-making process and load adjustment.

2) Incentive-based demand response (IBDR).IBDR direct use of compensation or discounts to encourage and guide users to participate in the system needs many kinds of load reduction projects, through direct load control, interruptible load control and capacity/auxiliary service plan, transfer electricity consumption and electricity load to meet the system. Existing IBDR includes incentive based demand response plan and market based incentive demand response project.

3. Communication System Optimization Method based on Demand Response of Smart Grid

This section will study and analysis of price based Demand Side Smart Grid Based on demand response response optimization, the fitting of the utility function is introduced in the objective function of user utility maximization problem, to the larges of the difference between the fit utility of all users and cost of electric energy as the objective function, with all the user's power consumption is less than the electricity supplier provides electric energy for the constrained optimization, realize the real-time pricing method of utility proportional fairness, transformation by Lagrange dual

decomposition method, the corresponding algorithm can use electricity and power supply terminal end algorithm effectively solve all user utility proportional fairness allocation problem.

3.1 Communication System Optimization Model

At present, the demand side of the smart grid is a real-time pricing model based on utility maximization. In order to ensure the fairness of all users' utility ratio, this paper uses utility fair flow control. The proportional fairness of user demand is derived from Optimal Flow Control [3] (OFC), and OFC is used to achieve the purpose of rate control by maximizing the utility of the business. Proportional fairness optimization model based on maximizing the total benefit of all users[4] is defined as the optimization model can meet the total consumption is lower than the total production conditions based on the fitting of utility of all users and the difference between the cost of the maximum power. The model is represented as follows:

$$\max_{\substack{m_i^k \le x_i^k \le M_i^k, \\ L_{\min}^k \le L^k \le L_{\max}^k, \\ i\in N, k\in \vec{K}}} \sum_{k\in\vec{K}} \sum_{i\in \vec{N}_e \cup \vec{N}_{ine}} U\left(x_i^k, w_i^k\right) - C^k\left(L^k\right) \tag{1}$$

$$s.t. \sum_{i\in \vec{N}_e \cup \vec{N}_{ine}} x_i^k \le L^k, \forall k \in \vec{K}$$

Let N denote all user set, using N_e is strictly concave utility function user set, N_{ine} is a set of non-concave utility functions of users, K users consuming time set; x_i^k said users i consumption in the K time slot power; M_i^k and m_i^k represent the user consumption power on the lower limit of i. The electricity produced by K is $L^k \in \left\{L_{\min}^k, L_{\max}^k\right\}$. Cost function using $C^k\left(L^k\right) = a\left(L^k\right) + b\left(L^k\right) + c$, $a,b,c \ge 0$ .In formula (1):

$$U\left(x_i^k, w_i^k\right) = \int_{m_i^k}^{x_i^k} \frac{1}{U\left(t, w_i^k\right)} dt, m_i^k \le x_i^k \le M_i^k \tag{2}$$

$U\left(t, w_i^k\right)$For the user's utility function, w said the change of parameters (temperature, electricity prices, etc.), non-concave utility function users in the form of a logarithmic utility function, concave utility function users using sigmoid function.

Because the formula (1) satisfies the optimization condition:

$$\sum_{i\in \vec{N}_e \cup \vec{N}_{ine}} \frac{\partial U\left(x_i^{k*}, w_i^k\right)}{\partial x_i^k}\left(x_i^k - x_i^{k*}\right) = \sum_{i\in \vec{N}_e \cup \vec{N}_{ine}} \frac{x_i^k - x_i^{k*}}{U\left(x_i^{k*}, w_i^k\right)} \le 0 \tag{3}$$

Therefore, in the optimal solution x_i^{k*}, the utility ratio of all users is realized.

3.2 Real-Time Electricity Price Algorithm Based on Dual Decomposition

The Lagrange function of formula (1) based on the user's total benefit maximization problem is as follows:

$$L\left(x_i^k, L^k, \lambda^k\right) = \sum_{i\in \vec{N}_e} \int_{m_i^k}^{x_i^k} \frac{1}{U_e\left(t, w_i^k\right)} dt + \sum_{i\in \vec{N}_{ine}} \int_{m_i^k}^{x_i^k} \frac{1}{U_{ine}\left(t, w_i^k\right)} dt - C^k\left(L^k\right) - \lambda^k\left(\sum_{i\in \vec{N}_e \cup \vec{N}_{ine}} x_i^k - L^k\right) \tag{4}$$

Its dual problem is expressed as:

$$\min_{\lambda^k > 0} D\left(\lambda^k\right) \tag{5}$$

The objective function (5) of the dual problem is processed by the gradient projection method, and the real-time update price λ_{t+1}^k is obtained:

$$\lambda_{t+1}^k = \left[\lambda_t^k + \gamma\left(\sum_{i\in \vec{N}_e \cup \vec{N}_{ine}} x_i^{k*}\left(\lambda_t^k\right) - L^{k*}\left(\lambda_t^k\right)\right)\right]^+ \tag{6}$$

The γ said the iterative step, $x_i^{k*}\left(\lambda_i^k\right)$says the user demand (local optimal solution), $L^{k*}\left(\lambda_i^k\right)$ said the power supply end of electricity production (local optimal solution), $L^{k*}\left(\lambda_i^k\right)$solution of the dual problem of λ^{k*} in economics refers to the shadow price, said the price of power supply and demand balance in the competitive market.

3.3 Simulation Results

This paper mainly through the MATLAB simulation platform to verify the algorithm proposed in this paper. Firstly, according to the optimization toolbox provided by MATLAB, the global optimal solution is obtained by solving the optimization problem. Then, using the MATLAB based distributed algorithm to solve the optimization problem in this paper, compared with the global optimal solution of the centralized performance analysis, and the performance of optimization algorithm is analyzed. The user parameter is set to a random number of 1~2.5, the simulation figure as shown in figure 1. Figure 2 is the real time electricity price and supply and demand trend of the 50 users within 1 hours.

In Figure 1, non-concave utility function is marked as "ine", when the non-concave utility function by the user power consumption optimization model and the proportion of consumption equity is lower than the critical value, the result is the users get zero utility, it is unfair for the non-concave utility function of the user, when a non-concave utility the utility function of the user proportional fairness optimization model, the user gets a higher utility. The analysis results show that the utility fairness optimization model makes the utility of all users fairly optimized.

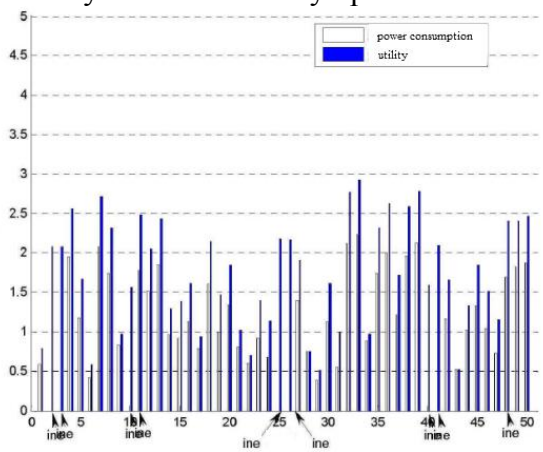

Fig 1. Comparison of utility of 50Users in the two models of proportional Fairness and utility proportional fairness

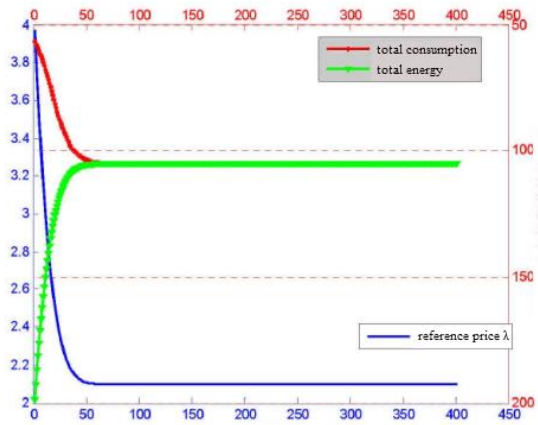

Fig 2. Real-time electricity price of achieve utility proportional fairness and supply and demand trends (50 users)

4. Summary

In this paper, the optimization problem of the communication system in the demand response of the smart grid is analyzed and explained, and the MATLAB simulation platform is used to verify the analysis: In this paper, the load scheduling model based on real-time electricity price can be used to distribute the proportion of all users' utility, which can effectively solve the problem of user's zero utility.

References

[1]. Han Weiji. Study on analysis method of demand response characteristics [D]. Shangdong University, 2012.
[2]. US Department Of Energy. Benefits of demand response in electricity markets and recommendations for achieving them [EB/OL]. (2006-01-01).
[3]. Wang W H.Palaniswami M,Low S H. Application-oriented flow control fundamentals algorithms and fairness[J].IEEE/ACM Transactions on Networking,2006,14(6):1282-1291.
[4].]Pedarm Samadi, Amir-Hamed Mohrenian-Rad, Robert Schober, Vincent W.S. Wong and Juri Jatskvich. Optimal Real-time Pricing Algorithm Based on Utility Maximization for Smart Grid[C]. IEEE Smart Grid Communications Conference.2010:415-420.