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COST-BENEFIT ANALYSIS UNDER THE DSM MODEL OF GREEN LIGHTING

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ABSTRACT

Based on the concept of DSM and the requirements of the demonstration project, the DSM model of green lighting was studied, carrying out the cost-benefit analysis. Combining the characteristics of the demonstration area, first of all, the cost-benefit of different interest subjects was analyzed. Secondly, the association rules algorithm was analyzed in detail, and the cost-benefit was analyzed by the association rules algorithm. Finally, the sensitivity analysis of the key factors, affecting the cost and benefit of each interest subject, was done by using the algorithm. And it is concluded that the user subsidy rate and consumer electricity price are the key factors that affect the user's willingness to use green lighting technology and power grid enterprises to implement DSM measures.

Keywords: DSM model, green lighting, electricity saving technology, cost benefit analysis

1. INTRODUCTION

Green lighting is the concept proposed by the national environmental protection agency in the early 90s of the last century. The complete green lighting contains 4 indexes, which are efficient, energy saving, environmental protection, safety and comfort. The implementation of demand side management (DSM) in the electricity side mining terminal electricity saving potential to a large extent, can effectively improve energy utilization efficiency, energy saving and emission reduction [1]. Green lighting energy saving technology as a means of DSM technique, can effectively reduce the peak load and improve the characteristics of power grid, improve power supply reliability. However, the application of the technology in the electric side will increase the purchase cost of energy saving lighting products [2]. The Power Grid Corp will decline due to the sale of electricity and reduce electricity generation enterprise income, also as a result of the implementation of DSM measures and affect the benefits and costs [3]. Therefore, in the current social background of energy saving and emission reduction, it is necessary to analyze the cost benefit of the relevant stakeholders from the economic perspective. In view of this, this paper was based on the cost efficiency method [4]. From the four aspects of the user, the power grid enterprises, power generation enterprises and the whole society on the energy saving technology of green lighting in the electricity are terminating by cost benefit analysis. Moreover, this paper conducted a sensitivity analysis of the key factors that affect the interests of the main costs and benefits, so as to reduce the risk of decision-making departments [5].

2. STATE OF THE ART

The feasibility of evaluating a DSM technology requires cost-benefit analysis. We assume that B is the full benefit of the implementation of a DSM technology, C is the total cost of implementing a DSM technology, ΔB is net income, and p is the cost and return ratio [6]. Obviously, only when the $\Delta B = B - C \geq 0$ *or* $= B/C = 1$, the implementation of a DSM technology is feasible. Whether or not the income is greater than or equal to the cost is the basic judgment basis for evaluating the feasibility of a DSM technology or energy conservation project and the possibility of large-scale popularization and use of the green lighting technology in the electric terminal [7]. Based on the basic principle of cost-benefit analysis in respective to the four aspects of the user, the power grid enterprises, power generation enterprises, and the whole society analyzing the cost and benefit of energy saving technology in the green lighting electricity terminal [8]. And the sensitivity analysis is made to the key factors that affect the cost and benefit of each interest subject [9].

The example analysis results show that it is feasible to carry out the green lighting power saving technology at the power consumption terminal, and the user subsidy rate and the resident consumption price are the key factors to decide the feasibility of the green end lighting technology [10].

3. METHODOLOGY

3.1. User Cost-benefit Analysis

The cost and benefit of the user were analyzed. In user cost analysis, users' participation in green lighting projects needs to pay additional costs for changing incandescent lamps into energy-efficient lighting products. That is, direct cost or increased purchase cost of equipment can be expressed as:

$$Cc = \sum_{j\in J,k\in K}(C_{c(j,k)}n_{(j,k)}N_{(j,k)}). \qquad (1)$$

Among them:

$$C_{c(j,k)} = (P_j - Q_j / Q_b P_b)/(p_b - p_j), \qquad (2)$$

$$N_{(j,k)} = \sum_{j\in J,k\in K} N_0 i_{(j,k)}. \qquad (3)$$

In the formula, *Cc* is the total direct cost of users, yuan /W, *K* is the user category collection that participates in green lighting power saving projects, mainly including residents, shopping malls, hotels and restaurants. *J* is a collection of green lighting products. Currently, more mature and simple measures for lighting and electricity saving are mainly using compact fluorescent lamps (commonly known as energy saving lamps) instead of incandescent lamps or instead of common inductance ballasts for fluorescent lighting. $C_{c\,(j,\,k)}$ is the direct cost of saving 1 W electricity using seventh types of green lighting products for class *k* users, yuan /W; $n_{(j,\,k)}$ uses seventh types of green lighting products to replace the number of original lighting products for class *k* users. $N_{(j\ k)}$ has the intention to replace the original lighting products with seventh types of green lighting products for class *k* users. Respectively, Q_b, Q_j are the average life of the original lighting products and seventh kinds of green lighting products, *h;* p_b, p_j, respectively, the power of the original lighting products and seventh kinds of green lighting products, W; N_0 is the total number of users in a certain area, $i_{(j,\,k)}$ is willing to replace the original lighting products with the *j* class green lighting products for class *k* users. The analysis of the benefit of the user is done. The benefit of users using energy saving lighting products is the energy saving income in the life period of the product. It is accumulated by all kinds of users involved in the project of green lighting saving. The energy saving benefits obtained by users during the life period of green energy saving lighting products are as follows:

$$B_{c(j,k)} = \Delta W_{c(j,k)} P_k. \qquad (4)$$

Among them:

$$\Delta W_{c(j,k)} = (p_b - p_j) Q_j n_{(j,k)} N_{(i,k)} \times 10^{-3}. \qquad (5)$$

In the formula, $B_{c(j,k)}$ is the power saving benefit of class k users using seventh kinds of green lighting products, yuan; $\Delta W_{c(j,k)}$ is used for class k users to use class J green lighting products for energy saving, kW/h; P_k is class *k* user lighting consumption price, yuan / kW/h. In the period of static investment recovery, the static investment recovery period of users using all kinds of energy-saving technology is one of the key factors that affect the willingness of users to participate in this DSM measure. The static investment recovery period for users using green lighting products is as follows:

$$T_j = \frac{P_j - Q_j / Q_b P_b}{P_k h_j (p_b - p_j)\times 10^{-3}} = \frac{C_{c(k,j)}}{P_k h_j \times 10^{-3}}. \qquad (6)$$

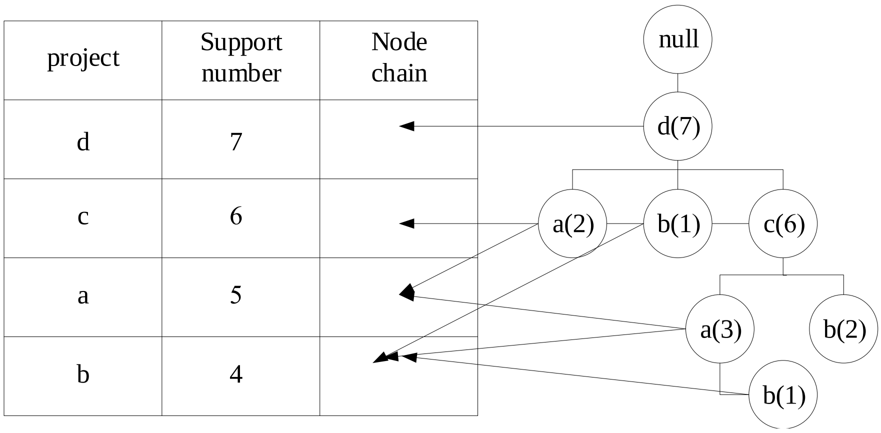

Fig.1. Head table and FP-tree

In the formula, h_j is the lighting time in hours for seventh types of green lighting products per day.

3.2. Cost-benefit Analysis of Power Grid Enterprises

For user subsidies, whether residents, shopping malls or hotels, or restaurants, the basic premise for users to adopt green lighting power saving technology is to recover more cost from electricity saving than to conventional technology. Even a shorter period of static investment recovery is required. Otherwise, users generally do not use this technology unless the power company grants users until the user feels profitable. The amount of the power company's subsidy to the user is related to the user's ideal static investment recovery period (T_{id}). If the user's ideal static investment recovery period only needs to meet the lifespan days of lighting technology (Q_j/h_j), then the power grid enterprises do not need to subsidize users, that is, the subsidy amount is Cs=0. If the user hopes that the ideal static investment recovery period is shorter than the T_j, the power grid enterprises need to subsidize the users. The number of subsidies per 1W is:

$$C_s = \begin{cases} 0 & T_j \le T_{id} \le Q_j / h_j \\ \dfrac{P_j - Q_j / Q_b P_b}{p_b - p_j} - P_k h_j T_{id} \times 10^{-3} & T_{id} \le T_j \end{cases}. \quad (7)$$

In addition, the rate of user subsidy can be defined as

$$\eta = C_s / C_{c(j,k)} \quad \eta \in [0,1]. \quad (8)$$

For management costs, the power company takes on the cost of each phase of the feasibility study, design, implementation and supervision of the DSM measures, which mainly has administrative management, design, evaluation, technical support and other costs, collectively known as the cost of management, expressed in C_m, usually accounting for 10 %~20 % of the cost of compensation. For the loss of electricity sales, the reduction of electricity consumption due to the use of energy-efficient lighting products is equal to the loss of electricity sold by the power company due to the implementation of the DSM measures. The corresponding losses of the sale of electricity are as follows:

$$\Delta I_{loss} = \sum_{k \in K} [(\sum_{k,j} \Delta W_{c(j,k)}) P_k]. \quad (9)$$

For the benefit analysis of power grid enterprises, the first is to avoid the cost of electricity purchase. The cost of avoiding electricity purchase is mainly reflected by the reduction of the power supply of the peak load on the power supply side, which is caused by the use of energy saving lighting products. Then the cost of power purchase is reduced, so the cost of electricity purchase can be avoided.

$$\Delta M_b = (\sum_{k \in K, j \in J} \Delta W_{c(j,k)}) P_B / [(1-l)(1-m)] \quad (10)$$

In the formula, P_B is the unit purchase cost of power grid enterprises, yuan / (kW h); l is the terminal distribution loss coefficient, and l is the transmission loss coefficient of the power grid. The cost of electricity can be avoided. As the terminal load of power supply line is reduced, the loss of supply and distribution power supply will be reduced. The economic benefit caused by the loss of transmission and distribution loss can be seen as the avoidable electricity cost of the power grid enterprise, that is:

$$\Delta M_l = P_k f \sum_{k,j} \Delta W_{c(j,k)}. \qquad (11)$$

Among them:

$$f = 1/[(1-l)(1-m)] - 1. \qquad (12)$$

In the formula, f is the loss coefficient of the transmission and distribution.

3.3. Association Rule Algorithm

Apriority algorithm is based on continuously constructed set, screening item sets mining the frequent item sets, and each screening needs to scan all the original data. So, the original data needs to be repeatedly scanned, when the original data quantity is large, efficiency is relatively low. So, ways should be proposed to reduce the number of scanning the original data, simplify the frequent item sets mining strategy, simplify the calculation, and shorten the time. In order to avoid the defects of the Apriority algorithm, J. Han et al. proposed the FP-Growth algorithm. This algorithm does not produce candidate frequent item sets, which only needs to scan the original data two times and compress the original data through the FP-tree data structure, having high efficiency. Therefore, for a large amount of data under the condition of mining frequent item sets, FP-Growth algorithm is a more efficient algorithm.

The so-called FP-Growth is the frequent pattern of growth. The idea of this algorithm is to construct a frequent pattern tree (FP-tree) with frequent item sets on the premise of preserving the information of the item set by the first scan. Then the frequent pattern tree is differentiating into several conditions of library, these conditions database mining. FP-Growth algorithm is divided into two steps: construct and recursive FP-tree mining FP-tree construction. By two data scanning, will compress the original data in the transaction to a FP-tree. The FP-tree is similar to the path prefix tree, and the same prefix can be shared, so as to achieve the purpose of compressing data. Then, through the FP-tree, to find the conditional pattern base and conditions of each project FP-tree, FP-tree mining conditions recursively get all frequent item sets. Similarly, the main steps of FP-Growth algorithm are introduced for example given earlier.

First, the construction of FP-tree, scanning the entire database of a single item of frequent item sets and their support are $\{a\}:5, \{b\}:4, \{c\}:6, \{d\}:7, \{e\}:1$, respectively. The minimum support number is 1 and the result set in descending order is A= $\{\{d\},\{c\},\{a\},\{b\}\}$. Then we can construct FP-tree. First, build an empty root node, and then scan the database second times, creating branches for each order according to the previous degree of support. For example, there are a, b, d, e in order 1. The support ranking is three branches, d (7) – a (5), empty nodes connect to *d*, *d* is connected to *a*; the branch node of order 2 is *d* (7) -b (4). At the same time and so on, create a header table, and the recording project support and node, convenient behind mining convenient traversal. The frequent pattern tree and the head table are shown in Fig.1.

Then the FP-tree is excavated recursively. Starting from the last item of the item table (the lowest support), the condition pattern base for each project is built. Calculate all the paths that project contain, and the prefix path of the project is the conditional pattern base. For example, the paths that include the b project are d-b, c-a-b, c-b, d-c-b. Among them, the prefix path of b is d, d-c-a, c, d-c, which is the conditional pattern base of the *b* project. Then, under the constraint of minimum support, the condition tree of the project is constructed by the set of conditional pattern base of the project. The condition tree of b is presented in Fig.2.

The minimum support number is 1 for all the combinations of frequent item sets generated on the basis of a conditional tree. For *b*, the frequent item sets are {*b, d*} {*b, c*}, these frequent item sets support are respectively 2 and 3. The results obtained with the Apriority algorithm is the same. But the FP-Growth algorithm also has its fatal flaw. Because the algorithm is recursive condition database and conditional frequent pattern tree, so the lar-

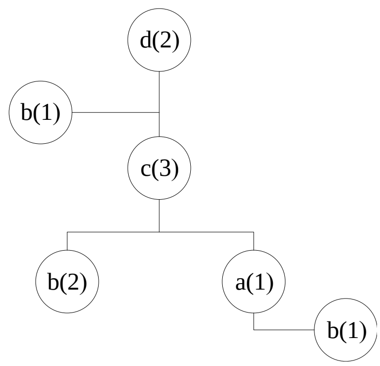

Fig.2. *b* – conditional mode

Table 1. Values of Relevant Parameters

Parameter	Company	Value (using experience value)	Parameter	Company	Value (using experience value)
Tid	a	1.0	l		0.04
k	%	15.0	m		0.07
θ		0.7	δ		0.05
γ		1.2			

Note: k is the cost ratio of the management cost.

ger memory, this is the main problem of this algorithm lies. The recommendation based on association rules is that it is simple and intuitive to mimic real shopping scenes and do not need knowledge about goods. At the same time, it can also discover the potential interest points of the user and stimulate the purchase. However, computational complexity is a significant disadvantage of association rule mining. With the increase of the size of frequent item sets, especially in the case of large data sets, the cost of mining will be higher and higher. However, for the same set of data, in the same degree of a given minimum support, confidence limit conditions, association rules by Apriori algorithm and FP-Growth algorithm are the same. The only difference is that whether the candidate frequent item sets mining process of association rules, mining efficiency is different, different memory operations.

4. RESULT ANALYSIS AND DISCUSSION

4.1. Basic Data and Parameter Hypothesis

The use of energy saving lamps instead of incandescent lamps for residents is taken as an example. Suppose that there are 1 million families in a city, and 30 % of families are willing to take part in the green lighting energy-saving measures under the call of DSM for electricity saving and environmental protection. The incandescent lamps used by users have 15, 25, 40, 60, and 75,100 W. The power of the weighted average incandescent lamp is based on 40 W. The 40 W incandescent lamp can be changed by the 9W energy saving lamp, the energy of the energy-saving lamp is based on the 9W. It is assumed that the cost of the incandescent lamp is 1 yuan per only, the life span is 1000 h, the price of the energy-saving lamp is 30 yuan, and the life of the lamp is at 3000 h. The number of incandescent lamps in each household is 2. The electricity price of the residents in this area is 0.50 yuan / (kW. h), and the lighting time is 4 h/d. The cost of unit capacity is 0.25 yuan / (kW. h), and the unit capacity cost is 7000 yuan /kW. The electricity price of the power generation enterprise is 045 yuan / (kW h), the peak electricity price is 0.2 yuan / (kW h), and the standard coal consumption of power generation is 320 gce/ (kW h). Among them, the relevant parameters involved in the calculation are assumed to be shown in Table 1.

4.2. Calculation Results

According to the above formula, it can be calculated separately. The costs and benefits of green lighting projects are implemented by users, power grid enterprises and the different interests of the whole society. As a result, see Table 2. It can be seen from the table that the cost efficiency is more than 1 as compared with ρ . Therefore, it has good economic benefits for users, power grid enterprises, power generation enterprises and the whole society to implement green electricity saving lighting technology on the electric side.

It is feasible to implement green electricity saving lighting technology on the electric side. Among them, the cost benefit ratio of the power generation enterprises and the whole society is relatively large. The reason is that the power generation side is saved by the electricity side, which avoids the capacity investment cost of the new generating units. Thus, better economic benefits have been produced.

4.3. Sensitivity Analysis

The user subsidy rate η and the consumer electricity price P are two important factors that affect the net income of each stakeholder, ΔB, especially

Table 2 Cost-benefit Analysis Results of Different Beneficial Bodies

Different interests subject	Benefit project	Benefit/10000 yuan	Cost project	Cost/million yuan	Cost benefit ratio/%
User	Electricity saving benefit	2790.0	Direct cost	1620.0	
Total	User subsidy	262.2		1620.0	1.88
Power grid enterprise		3052.2		262.2	
	Avoid electricity purchase cost	2812.3	User subsidy	39.3	
	Avoidable electricity cost	334.8	Management cost	2790.0	
			Loss of electricity	3091.5	1.02
Total		3147.1		2963.0	
Power generation enterprise	Avoid capacity cost	1644.7	Loss of sale of electricity		
	Avoid peak load capacity cost	15363.3			
	Avoidable electricity cost	1106.2		2963.0	6.11
Total		18114.2		1620.0	
	Avoidable electricity cost	1644.7	Direct cost	39.3	
	Avoid capacity cost	15363.3	Management cost		
	Avoid peak load capacity cost	1106.2			
	Carbon emission reduction benefit	397.1			
Total		18511.3		1659.3	11.15

Note: the direct cost is the increase of the purchase cost of the product.

for the power grid enterprises as the main body of DSM implementation. The relationship between the net benefit ΔB of different stakeholders, the rate of user subsidy and the consumption price of residents is analyzed as follows.

The rate of user subsidy is η and the fixed resident consumption price P is calculated. According to equation (5) and combined with the cost benefit formula, users and grid enterprise net income ΔB at subsidy rate η were identified with the user. The relationship is shown in Fig. 3. It is shown that: in the case of P value under the ΔB users and power grid enterprises respectively, into positive and negative correlation. Because the user subsidy cost occurs between the user and the power grid enterprise, it does not affect the ΔB of the power generation enterprise and the whole society is also negatively related to ΔB. For the power grid enterprises, when η ≧0.18, power grid enterprises will increase subsidies for the cost of the loss, so the grid enterprises should implement DSM measures to obtain certain economic benefits, requiring the user to formulate reasonable subsidy policy.

For the level of consumer electricity price, the fixed user subsidy rate is η, and the effect of P changes on net benefit ΔB is analyzed, as shown in Fig. 2. It is shown that: the value of certain circumstances, the user's ΔB and were associated with the power grid enterprises positively and negatively correlated. Among them, the ΔB of the whole so-

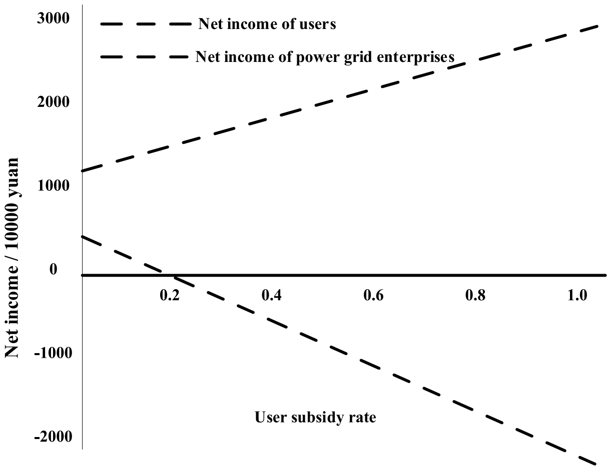

Fig.3. Relationship of net benefit and user subsidy rate under fixed price

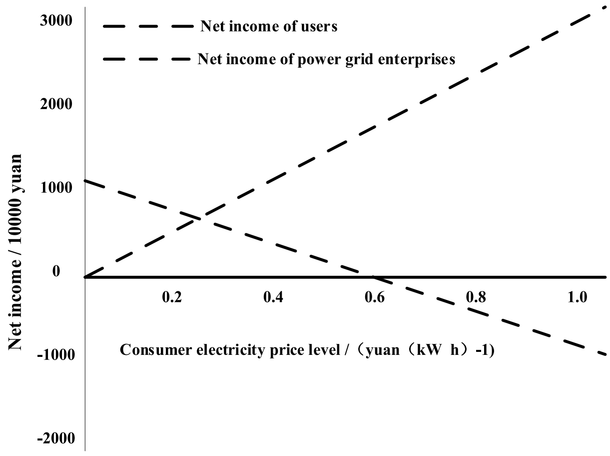

Fig.4. Relationship of net benefit and tariff under fixed subsidy rate consumer

ciety is also positively related to the corpse. If the consumer electricity price level is higher than 0.53 yuan / (kW h) according to the subsidy level of this article η=0.16, the power grid enterprises will lose because of less electricity. When electricity prices are below that level, power grid companies will gain revenue.

If the power grid companies do not want to subsidize the users, the consumer electricity price should be reduced to 0.43 yuan / (kW h). In this way, it can make up for the loss caused by the sale of electricity and not make a loss. That is, under the premise of no loss, the lower the willingness of the power grid enterprises to subsidize the users, the level of consumer electricity price must be reduced accordingly (Fig. 3). However, because the change of consumer electricity price is affected by many factors, the power grid enterprises must determine the rate of user subsidy according to the actual situation.

5. CONCLUSION

As a technical means of power demand side management (DSM), efficient lighting power saving technology can reduce peak load, improve load characteristics and improve power supply reliability. Based on this, the cost efficiency of implementing green lighting was analyzed, saving technology from the user, the power grid enterprise and the society. At the same time, the theoretical basis and technical guidance were provided for the implementation of green lighting project in the region. The result of the case analysis shows that the cost-benefit analysis is one of the effective methods to evaluate the DSM technology. It is also found that user subsidy rate and resident consumption price were two key factors that affected users' willingness to adopt green lighting power saving technology and grid enterprises to implement this DSM measure. At the same time, the feasibility of popularizing green lighting saving technology with electric side was also determined to a great extent. The cost benefit analysis method can also be applied to other DSM measures. It is worth a large-scale application to evaluate the feasibility of a DSM measure by quantitative study of cost benefit.

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