Effect Simulation under TOU Price Incentive for Ice Storage Air Conditioning Systems

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Abstract To cope with great peak-valley difference,good technology,feasible price policy and satisfied policy effect are critical elements. Firstly,principles of ice storage air conditioning systems and its operation modes are introduced, main influencing factors which may affect every party participating in demand response(shorted as DR) program are also analyzed. Secondly,every party's expected objective is discussed when an incentive peak-valley time-of-use(shorted as TOU) electricity price is designed,which is specially applied to ice storage air conditioning systems.Meanwhile,various physics and management constraints are also included. Finally, with Matlab platform, branch-and-bound method and ideal point method were used in solving peak-valley TOU price adjustment schemes under multiple scenarios.With simulation, corresponding effect for every price scheme is discussed, which will provide support for promoting ice storage air conditioning systems and also offer reference to other energy storage projects such as battery storage system.

Keywords new power system,ice storage air conditioning systems(ISACS),peak-valley time-of-use electricity price, price incentive,demand response effect

1 Introduction

With the increase of the proportion of renewable energy in the power generation structure,as well the increase of peak-to-valley difference of daily load curve on the consumption-side, to construct new energy storage system becomes essential in power systems[1]. Different from other energy storage, such as battery storage, ice storage air conditioning systems commonly used in summer has its own characteristics, large scale load is available to move from one interval to another flexibly with help of its advanced automation and strong control, so the effect of load shifting is more obvious[2]. However,initial investment of ice storage air conditioning systems is great and the payback period is long, which blocked its application seriously. In this case, what policy is effective to allure consumers to construct in shorter time,what anticipating effect would be produced are concerned by every party of demand response participants[3]. Obviously, only these aspects discussed above are elaborately designed,the problem is likely to be solved. Based on the above analysis, it is urgent to design electricity price for ice storage air conditioning systems and be clear about the price policy

ICPDI 2023, September 01-03, Chongqing, People's Republic of China
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DOI 10.4108/eai.1-9-2023.2338804

implement effect, in order to accelerate development of ice storage air conditioning systems when costumers are guided by price signal.

The price for ice storage air conditioning systems is specially one of peak-valley time-of-use price system, which only exert act onto ice storage air conditioning systems[4]. Usually, this price is adjusted based on the current TOU price. In view of the previous literature,most of research focused on TOU pricing[5]. Four reviews on this issue are found, which appeared in 2006[6], 2008[7],2014[8],2021[9]. In [9], many aspects about TOU price is well summarized, including TOU pricing decision model ,TOU pricing method, TOU interval division method, demand response behaviour analysis influenced by TOU price, as well TOU price implement mode and implement scope at home and abroad, and cost-benefit analysis of DR projects, etc.

Ice storage air conditioning systems were imported into China in 1990, not far away from today, there are not many demonstration projects until today. So few research of TOU pricing specified for ice storage air conditioning systems was reported[10][11], only some information about TOU policy implementation was found[12]. Four TOU price regulation modes are concluded. The first mode is to down electricity price during valley load period. The second mode is to elevate electricity price during peak load period and to drop electricity price during valley load period.The third mode is to keep the proportion of price during peak load period to price during normal load period as well the price during valley load period to be constant, but let the baseline price to increase.The fourth mode is to divide new interval about peak load period and valley load period.

In fact, price policy for ice storage air conditioning systems will influence consumers' investment, power supply company's income,power plant construction,and social economic benefits[13]. For this reason, when pricing for ice storage air conditioning systems,not only these influence factors must be considered, but also the coupling relationship among electricity price system must be considered. Based on above discussion, factors analysis of influencing electricity price of ice storage air conditioning systems is done at first, including the cost and benefit of every party, price response degree from consumers[14][15]. Then the pricing model of ice storage air conditioning system is constructed, in which the multiple scenarios are discussed and complicated constrains from physics system and management requirement are considered. Finally, with case study, response effect from ice storage air conditioning system under every price scheme is discussed and valuable suggestions are proposed.

2 Principle of ice storage air conditioning systems and its operation mode

2.1 Principle

Ice storage air conditioning systems mainly consist of electric refrigeration hosts, ice storage device, cool supplying loop, the schematic structure is shown as figure 1 , heat transfer device is used for heat exchange between two kind of medias[16][17]. Note that, ice storage device is a big tank, its outer wall is made of thermal insulation layer, in order to isolate heat exchange and maintain the tank in low temperature state.

Brief principle of ice storage air conditioning systems is described as follows. The first step is to making ice with refrigeration hosts during lower load demand in power system and to store ice ball in ice storage tank. The second step is to discharge cool during daytime in order to meet greater cool load demand,which is realized by phase change material (shorted as PCM) . Glycol is commonly used, which is is with the characteristic of sensible heat or latent heat.

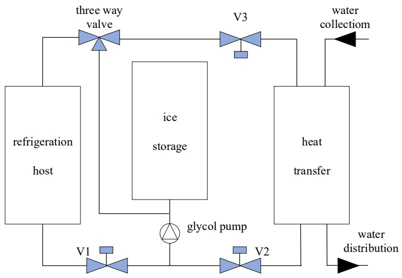


Figure 1. Structure for ice storage air conditioning systems

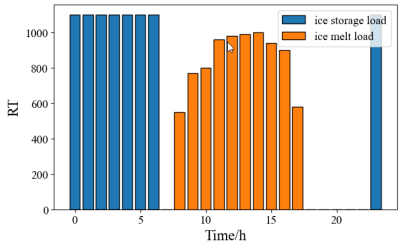


Figure 2. Operation curve with full ice storage mode

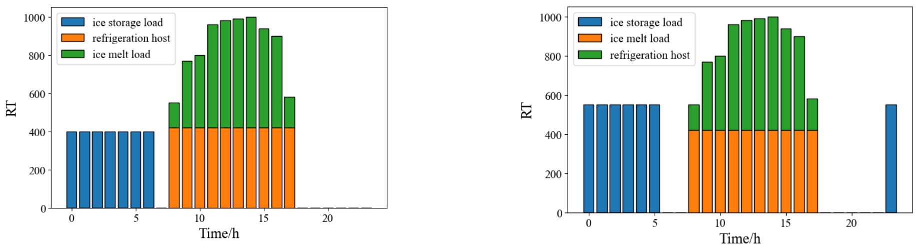
2.2 Operation mode

There are two operation mode for ice storage air conditioning systems,full ice storage and partial ice storage. For the former, all cool load demand during daytime is from the ice stored at lower electricity price period, its daily operation curve is shown as figure 2.

Full ice storage mode is characterized by these aspects, refrigeration hosts do not operate during peak load hours and operation cost becomes lower. But equipment investment of ISACS is higher and equipment occupied area is larger,so it is only suitable for those buildings with greater cool demand in shorter peak load time.

Partial ice storage mode means that the required cooling amount on a typical day is supplied simultaneously by refrigeration hosts and ice storage device.There are two kind of cool supplying ways, i.e. refrigeration host priority and ice discharging priority, Figure 3 shows their daily operation curves.

The advantage of partial ice storage operation mode is with lower capacity of the refrigeration hosts, improved utilization rate and better economy, so this operation mode is widely adopted by consumers.



(a)Refrigeration host priority (b)Ice discharging priority

Figure 3. Daily operation curve with partial ice storage mode

3 Influencing factors on ice storage air conditioning systems participant in demand response

3.1 Cost and benefit of ISACS project

To adjust time-of-use electricity price on consumption side is one of the important means for consumers to adjust their time of electricity use by price signal,which will affects the interests of related parties of ice storage air conditioning project.

3.1.1 Cost and benefit of consumers

For any ice storage air conditioning system, total cost of consumers consists of three parts.Namely,the investment expense,operation & maintenance cost, and subsidy. The last item is offered by government to those users with ice storage air conditioning system which are participant in demand response.The calculation is followed as formula (1).

$$C_{T1} = E_S + M_1 - S \tag{1}$$

Where, C_{T1} is total cost of consumers, E_S is investment cost of ISACS, M_1 is operation & maintenance cost of ISACS, S is subsidy offered by government.

Consumers benefit is come from the savings of electricity payment when ice storage air conditioning system is installed,the calculation is written as equation (2).

$$B_{T1} = F_C - F_S \tag{2}$$

Where, B_{T1} is total benefit of consumers, F_C is daily electricity expense without ISACS, F_S is daily electricity expense with ISACS.

$$F_C = \rho_P \times P_P + \rho_N \times P_N + \rho_V \times P_V \tag{3}$$

$$F_S = \rho_P{}' \times P_P{}' + \rho_N{}' \times P_N{}' + \rho_V{}' \times P_V{}' \tag{4}$$

Where, ρ_P, ρ_N, ρ_V and ρ_P', ρ_N', ρ_V' are electricity price during peak load, normal load,and valley load without ISACS and with ISACS, P_P, P_N, P_V and P_P', P_N', P_V' are electricity consumption during peak load, normal load, and valley load without ISACS and with ISACS.

3.1.2 Cost and benefit of power supply company

Total cost of power supply company consists of two parts, one is the expense of increased electricity consumption as of installing ice storage air conditioning system, another is the added management cost as of promoting ice storage air conditioning system, calculation is seen in equation(5).

$$C_{T2} = C_2 + M_2 \tag{5}$$

Where,C_{T2} is total cost of power supply company, C_2 is expense of increased electricity consumption, M_2 is its management cost.

Total benefit of power supply company is composed of two parts, one is the decreased capacity cost as peak load is shaved when ice storage air conditioning system is installed, another is the change of sell electricity income caused by the change of electricity consumption before and after ice storage air conditioning system is installed,see equation (6).

$$B_{T2} = Cap_2 + (Be_S - Be_C) \tag{6}$$

Where, B_{T2} is total benefit of power supply company,Cap_2 is decreased capacity cost, Be_S and Be_c are selling electricity income of power supply companies before and after ISACS is installed.

3.1.3 Cost and benefit of power generation enterprise

Total cost of power generation enterprise is composed of two parts, one is the increased coal purchasing cost to meet more electricity demand from power supply companies, another is the operation & maintain cost to ensure enough generation output, see equation (7).

$$C_{T3} = C_3 + M_3 \tag{7}$$

Where,C_{T3} is total cost of power generation enterprise,C_3 is increased coal purchasing cost,its calculation see equation (8), M_3 is operation & maintain cost for generators.

$$C_3 = (Q_S^A - Q_C^A) \times \eta \times k \tag{8}$$

Where, Q_S^A and Q_C^A are annual electricity consumption before and after ISACS is installed,η is conversion coefficient form electricity to coal, k is coal price per ton.

Total benefit of power generation company is composed of the decreased generator capacity cost as of peak load shaving and the increased income as of selling more electricity to power supply company,see equation (9).

$$B_{T3} = Cap_3 - Be_3 \tag{9}$$

Where, B_{T3} is total benefit of power generation company, Cap_3 is decreased generator capacity cost, Be_3 is increased income of generation plants.

3.1.4 Cost and benefit of the society

Total social cost includes investment cost of ice storage air conditioning system, increased coal cost of power generation enterprise, as well management cost used in DR activity promotion at consumption-side,see equation(10).

$$C_{T4} = E_S + C_3 + M_4 \tag{10}$$

Where, C_{T4} is total social cost, M_4 is DSM management cost, set as 10% of investment cost in ISACS.

Total social benefit is come from the capacity decrease of power supply company and power generation enterprise as of peak load shaving,which are Cap_2 and Cap_3, see equation (11).

$$B_{T4} = Cap_2 + Cap_3 \tag{11}$$

Where, B_{T4} is total social benefit.

3.2 Price response degree of ISACS users

3.2.1 Price response degree function of ISACS

In common, consumers are concerned with extent of price adjustment, Figure 4 gives the curve of consumer response to price.

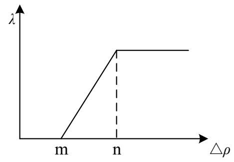


Figure 4. Curve of user response to price

In Figure 4, $\triangle\rho$ is the change in electricity price,and λ is consumer response degree to price.

- When price changes is less($\triangle\rho\leq m$),consumers response to price is weak. This is because that initial investment of ISACS project is huge, human resource cost, operation & maintenance cost is also increasing, these extra expenditure would result in ISACS users will have no will to change electricity consumption behavior, so they almost have no reaction to cope with the change of price.
- In contrast, limited by the capacity of ISACS, even if the change of price is large,($\triangle\rho\geq n$), as of load shifting ability, users will have no response to the change in price.
- Only within certain range($m\leq\triangle\rho\leq n$),it is possible to shift load under price action.

Therefore, δ, the response degree of ISACS price is defined as the ratio of shifted load to the electricity amount during peak load period by consumers actively, while the total of cool load keeps constant.

Obviously, the transfer amount of cool load in the ISACS project refers to the amount of cool released by the melting ice,which depends on the operation mode of ice storage air conditioning system. In addition, the direction of cool release is transferred from peak and normal load period to valley load period.

λ_P,λ_N and λ_V in Equation (12)- (14) is response function of ISACS price during peak load period, normal load period and valley load period, which is corrected based on the general TOU price response function[15], a_P,a_N and β_V are correcting coefficients.

When carrying out demand response, consumer response degree to ISACS price is different from that of other prices,some correction should be done based on the response function for the price during peak load, price during normal load and price during valley load respectively, and correction method is also given.

$$\begin{cases} \lambda_P = \alpha_P(0.329x_P{}^3 - 1.8315_P{}^2 + 2.5134_P - 0.0111) & x_P = \dfrac{\rho_P'}{\rho_P} > 1 \\ \lambda_N = \alpha_N(0.329x_N{}^3 - 1.8315_N{}^2 + 2.5134_N - 0.0111) & x_N = \dfrac{\rho_N'}{\rho_N} > 1 \\ \lambda_V = \beta(0.4319x_V{}^3 - 0.4794_V{}^2 + 0.4191_V + 1.4666) - 1 & x_V = \dfrac{\rho_V'}{\rho_V} < 1 \end{cases} \tag{12}$$

Where, x_P ,x_N and x_V are the ratio of adjusted price during peak load period,valley load period,normal load period to the price before adjusting. As the price within peak load and normal load period would be up,so x_P and x_N are larger than 1,whereas x_V is less than 1 as the price during valley load would be down.

Based on equation (12), it is seen that:

- Great different exists in different time for price response degree,which is determined by the ratio of price before adjusting to the price after adjusting.
- a_p,a_n and β_v as correction coefficients which are determined by the transfer ratio of cool load for ISACS in day time. Unlike other TOU price-incentive projects, the amount of cool transfer available is influenced by its physics characteristics,such as capacity of ISACS, the ice-melt rate of ISACS.

Considering that the amount of transferred cool during peak load is influenced by the increase of electricity price during peak load period and the decrease of electricity price during valley load period, the total amount of cool transfer degree from peak period to valley period is the result of price response in these two periods, which is the sum of response degree in peak period and response degree in valley period,see equation(13).

$$\lambda_{PV} = \lambda_P + \lambda_V \tag{13}$$

Similarly, the total price response from normal load period to valley load period is equal to the sum of price response degree during normal load plus price response degree during valley load,see equation (14).

$$\lambda_{NV} = \lambda_N + \lambda_V \tag{14}$$

For refrigeration hosts of air conditioning system, let L_P represents cool load during peak period, L_N represents cool load during normal period and L_V represents cool load during valley period. For refrigeration hosts of ISACS system, L_P', L_N'and L_V' represent the cool load in corresponding periods.

$$\begin{cases} L_P' = (1 - \lambda_{PV})L_P & (peak\quad load) \\ L_N' = (1 - \lambda_{NV})L_N & (normal\quad load) \\ L_V' = \lambda_{PV}L_P + \lambda_{NV}L_N & (valley\quad load) \end{cases} \tag{15}$$

For refrigeration hosts of ISACS, they make cool in daytime,they also make ice at night, and energy efficiency coefficient for these two conditions is different. Denote Cop_{cold} as energy efficiency coefficient in cool making condition, Cop_{ice} as energy efficiency coefficient in ice melt condition,then electric load in distinct period is calculated as following equations.

$$\begin{cases} P_P' = L_P' / Cop_{cold} & \text{(peak load)} \\ P_N' = L_N' / Cop_{cold} & \text{(normal load)} \\ P_V' = L_V' / Cop_{ice} & \text{(valley load)} \end{cases} \tag{16}$$

3.2.2 Correction coefficient

Considering that price response degree of peak load is different from that of normal load as well as valley load, based on consumer psychology theory, consumers is more sensitive to price rise than that to price cut, then the price response degrees among peak load, normal load and valley load satisfy the following inequality (17).

$$\lambda_P > \lambda_N > \lambda_V \tag{17}$$

As transferred cool load during day time should be less than the maximal cool amount L_{max} at night,then equation (18) is satisfied.

$$L_P(\lambda_P + \lambda_V) + L_N(\lambda_N + \lambda_V) \le L_{max} \tag{18}$$

The scenario that equation is to be equality means the transferred cool load in daytime is exactly equal to the maximal cool produced at night, and the price response degree is the highest.

Let λ_P:λ_N:λ_V = 3:2:1, put it into equation(19).

$$L_P \times \frac{4}{3}\lambda_P + L_N \times \lambda_N = L_{max} \tag{19}$$

So the maximal price response degree λ_{Pmax} in peak period is gotten. Put λ_{Pmax} into equation (12),the correction coefficient a_P of price response degree in peak load period is also gotten. Similarly, the correction coefficient a_N of price response degree in normal load period and the correction coefficient β_V of price response degree in valley load period are also gotten.

4 Time-of-use pricing model for ISACS

4.1 Objective function

4.1.1 Operation of ISACS refrigeration hosts

To reduce frequent start and stop of the refrigeration hosts as minimal as possible is the objective pursued by ISACS users, the reason is because operation curve will become smooth, its life cycle will be extend, operation cost will be decreased. So the objective function is to let the variance of the number of start refrigeration hosts in every hour during the daytime to be minimized, sometimes the variance is called as instability,see equation (20).

$$\min Z_1 = \sum_{t=1}^{T_D} (n_t - \overline{n})^2 \tag{20}$$

Where, n_t is number of refrigeration hosts in starting operation condition at t interval, $\overline{n}$ is the average of start refrigeration hosts per hour within daytime,calculated as equation (21), T_D is operation hours for refrigeration host in daytime,for example, T_D=16h.

$$\overline{n} = \frac{L_P + L_N + L_V - L_V'}{D \times T_D} \tag{21}$$

Where,D is the produced cool per hour for one refrigeration host(assuming all refrigeration hosts with the same model), the molecular item represents the daytime cooling capacity required by the ice storage system,molecular item in the fraction represents the daytime required cooling amount.

4.1.2 Electricity expense for ISACS users

ISACS users seek to save electricity expense,their expected goal is to minimize daily electricity expenditure of ISACS under time-of-use tariff.

$$\min Z_2 = \rho_P' \times P_P' + \rho_N' \times P_N' + \rho_V' \times P_V' \tag{22}$$

4.1.3 Social average of annual benefit

For whole society, its objective is to maximize average of annual social benefit ,see equation (23).

$$\max Z_3 = (Cap_2 + Cap_3 - E_S - C_3 - M_4) / T_{life} \tag{23}$$

Where, $T_{\rm life}$ represents the life cycle of ISACS,for example, $T_{\rm life}$ = 15 year.

4.2 Constraints

4.2.1 Operation constrains for ISACS refrigeration hosts

Three constrains are from the requirements of ISACS:

- Constraint of cool demand. At $t^{\rm th}$ interval,cool amount supplied by refrigeration hosts as well as melted ice must meet consumers cool demand, positive bias or negative bias between them is less than 5%.

$$0.95L_t \le L_{HI,t}' \le 1.05L_t \tag{24}$$

Where, $L_{HI,t}$'is cool amount supplied, L_t is cool demand.

- Constrain of ice storage capacity.The sum of cooling amount hourly discharged by ice storage system during daytime is not large than the stored ice which is produced by refrigeration hosts at night.The cool amount is better to be used up, the surplus is no more than 5%,see equation (25).

$$0.95L_{IM}' \le \sum_{t=1}^{T_m} q_t \le L_{IM}' \tag{25}$$

Where, q_t is cooling amount discharged in one hour,or called as cool releasing rate.T_m means ice melt hours.

- Constrain of cool releasing rate. When ice is melt,cool release rate is not allowed to exceed the its maximum, for example, set as 10-15% of maximal ice-making ability,see equation (26).

$$q_t \le 0.15L_{IM}' \tag{26}$$

Where, L_{IM}' is maximal ice-making ability.

4.2.2 Constrains from ISACS investment

Investment payback cycle is an important index which is used in judging if ISACS project is worth investing. Based on investigation,users expected investment payback cycle is no more than 7 years.

$$0 \le T \le 7 \tag{27}$$

Where, T is investment payback cycle,which depends on net investment as well as benefit of ISACS.The former is the difference by investment cost and subside, the latter is the saving of electricity expenditure which is difference between electricity expenditure when ISACS is not installed and electricity cost when ISACS is installed,see equation(28).

$$T = \frac{E_S - S}{F_C^A - F_S^A} \tag{28}$$

Where, F_c^A and F_S^A is annual electricity expenditure when ISACS is not installed and is installed respectively.

Calculation of investment cost is written as equation (29),and calculation of subside is written as (30).

$$E_S = \Delta Q \times v \tag{29}$$

$$S = \Delta Q \times u \tag{30}$$

Where,v is coefficient of unit investment,which is calculated by electric power system construction cost per 1kW peak load shaved, for example,let v=3000￥/kW. u is reward coefficient as of ISACS is put into DR program ,which is determined by local DR incentive policy, calculated by shaved 1kW peak load,for example, u=500￥/kW.ΔQ is the shaved peak load per hour as equation (31) shown.

$$\Delta Q = \frac{(L_P - L_P')/T_P}{Cop_{cold}} \tag{31}$$

Where,T_p is the hours during peak load,for example, let T_p=8h.

5 Effect simulation under TOU price incentive for ISACS

5.1 Data and simulation setting

An air condition system without ice storage is selected as our discussion, its daily cool demand at 100% load level is listed in table 1.

Table 1. Cool demand at 100% load level

Interval	0	1	2	3	4	5	6	7	8	9	10	11
Cool Load /kW	0	0	0	0	0	0	0	0	11170	14395	17662	18397
Interval	12	13	14	15	16	17	18	19	20	21	22	23
Cool Load /kW	19382	19136	19189	19101	18978	19818	20008	20040	18739	16460	12732	0

The maximal cool demand is 20040kW. For typical bi-condition refrigeration hosts, its maximal cool is 3869kW/h. Considering that there is only 10 day operating at 100% load level ,see table 2. 4 bi-condition refrigeration hosts are installed and the insufficient cool is offered by melt ice. In addition, the energy coefficient of air conditioning system without ice storage is set as COP_{cold}=4.55.

Table 2. Annual cool load distribution

Operation Mode	100%	75%	50%	25%
Operating days/day	10	35	75	30

Select industrial and commercial electricity price for 1-10kV level as adjustment baseline(denoted as scheme 0),price during peak load is set as ρ_{P}=1.3782￥/kWh,price during general load is set as ρ_{N}=0.8595￥/kWh,price during valley load is set as ρ_{V}=0.3658￥/kWh. The optimal pricing model constructed above is solved with software Lingo [18], in which branch and bound method is used in solving refrigeration hosts start-stop problem,the idea point method[19] is used in solving multiple objective optimization.

5.2 Effect for TOU pricing when single objective function is optimized

When single objective is optimized, three TOU pricing schemes are gotten, and corresponding participant implement effect also will be understood.

- Scheme 1 is corresponding to the situation that refrigeration hosts operation are optimal.
- Scheme 2 is corresponding to the situation that consumers' electricity expenditure is minimal.
- Scheme 3 is corresponding to the situation that average of social annual benefit is maximal.

The simulation result of electricity price adjustment is listed in table 3. In addition,the price implement effect[20]after price adjustment is also listed in table 3,which includes instability for objective 1,daily electricity payment for objective 2,and average of social annual benefit for objective 3 and shifted rate of daytime cool load(denoted as δ), investment payback period(denoted as T) etc.

Table 3 .Effect when single objective function is optimized

Scheme No.	Tariff/￥/kWh			Effects index				
	Peak	normal	valley	Z_1/unit^2	Z_2/￥	Z_3/10^4￥	δ/%	T/year
#0	1.3782	0.8595	0.3658	2.40	59544	60.37	17.84	2.95
#1	1.5938	0.9321	0.2651	2.93	58878	94.64	28.52	3.87
#2	1.4182	0.8595	0.2704	5.73	55957	79.38	24.14	2.82
#3	1.7842	0.9446	0.2592	13.73	60987	110.15	31.44	5.06

Some results can be seen in table 3.

- Three price adjustment schemes are different based on three single optimal objective function. Among them, scheme 3 is with maximal adjustment amplitude and its price ratio of peak period to valley period reaches to 6.9:1, advanced to nearly1 times compared to previous 3.76:1. In term of adjustment amplitude,the next is scheme 1, the last is scheme 2.

- Each scheme is only optimal for its own objective function and is not optimal for others, due to the different optimization goal of ISACS. Taking scheme 1 as example, the best is 2,93 for objective function 1.In addition,scheme 3 is with best load shift rate, exceeded 30% above. The investment payback period of three schemes are within 5 years.
- Scheme 3 is with The best peak load shifting effect which means it is better to design incentive price from the perspective of society when developing demand response activity. Scheme 2 is with shortest investment payback period, which is more favorable for users.

5.3 Effect for TOU pricing when Multiple objective function is optimized

It's difficult to balance the objective among multiple parties when single goal optimization is adopted,but multiple goal optimization technique is able to solve this problem. Three schemes are designed, denoted as 4,5,6.

- Scheme 4 is combination of goal 1 and goal 2.
- Scheme 5 is combination of goal 1 and goal 3.
- Scheme 6 is combination of goal 1 , goal 2 and goal 3.

Equal weight is adopt by scheme 4, scheme 5 and scheme 6 , unequal weight is adopt by scheme 6',in which the weight of three goals is respectively for 0.8,0.1,0.1.Table 4 shows the simulation results when multiple objective optimization for time-of -use pricing is employed.

Table 4 Effect when multiple objective function is optimized

Scheme No.	Tariff/￥/kWh			Effect index				
	Peak	normal	valley	Z_1/unit^2	Z_2/￥	Z_3/10^4￥	δ/%	T/year
#0	1.3782	0.8595	0.3658	2.4	59544	60.37	17.84	2.95
#4	1.4182	0.8595	0.2704	3.73	55957	79.38	24.14	2.82
#5	1.7483	0.8595	0.2704	2.93	60505	102.65	28.52	4.58
#6	1.6492	0.9321	0.2561	2.93	59881	102.40	29.98	4.44
#6'	1.5636	0.8598	0.2704	5.60	58482	87.14	25.60	3.03

From table 4,some findings are obtained.

- The characteristic of Scheme 4 is with the least for consumers' electricity bill and with the shortest for investment payback period which is help for encouraging consumers to participant in construction of ISACS and is suitable for the initial promotion stage of this technology.

- Scheme 5 embodies these features, consumers' electricity expenditure in typical day is highest, but social benefit is maximal,consumers' daytime shifted load amount is most, this price adjustment scheme is suitable for the mature stage of this technology.
- Scheme 6 is a trade-off price adjustment scheme when the weight of multiple objectives is equal. This is because the price after adjustment is close to the previous compared to scheme 5. So this scheme is easily to be accepted by consumers,and is with satisfied social benefit,suitable for mid-term stage of ISACS technology application.
- Among 4 pricing schemes, scheme 6 is with best peak load shifting effect and scheme 4 is with shortest investment payback period, these parameters are help for making price decision.

6 Conclusions

Based on above research, main conclusions are summarized as follows.

- The necessity that developing effect research of TOU incentive price for ISACS is proposed. When shaving peak load and filling valley load in new power systems, the role of ISACS is not to be neglected. TOU policy is helpful for solving the dilemma of advance technique and difficult application, but developing scientific price design and analyzing implement effect of price adjustment are prerequisite.
- Influencing factors on TOU price for ISACS is discussed and pricing model is constructed. Aimed to use powerful pricing tool to promotion ISACS, cost&benefit of every party and price response degree of consumer are considered as main influencing factors on pricing. When designing TOU price for ISACS, the expected goal of every party is given, and various constrains from ISACS operation and management system are listed.
- Effect of TOU pricing incentive for ISACS are simulated. Based on TOU pricing model, multiple scenarios are set, which is corresponding to find the optimum whether single objective function or combined objective function is discussed. Meanwhile, with help of a set of economical or technical parameters, the anticipated effect under every price adjustment scheme is also analyzed and compared.

Acknowledges. This work was financially supported by the Research Project of State Grid Jibei Electric Power Co.Ltd(2022,52018F220004)

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