Research on the Software of Planning Assisted Decision of Park Integrated Energy System

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Abstract. According to the characteristics of multi-demand of integrated energy customers, multi-faceted projects and complex technology categories, a decision-making software for integrated energy system planning is proposed. By constructing the investment income model of the energy system in the park, the software realize the accurate planning of the capacity of the integrated energy system and the accurate evaluation of the investment income of the energy system, which provides the auxiliary decision support for the energy end users, the energy service providers and so on. The software realizes the intelligent optimization of the planning scheme through the optimization algorithm, and realizes the optimal planning capacity and investment income of the integrated energy system in the park. The software enriches the means of energy system planning and design, and improves the efficiency of planning.

1. Introduction
At present, China's energy consumption supply, energy structure transformation, energy system form presents a new development trend [1, 2]. The integrated energy system integrates many types of energy and promotes the clean and efficient supply of renewable energy through multi-energy complementary synergy and energy cascade utilization [3]. With the acceleration of Internet information technology, renewable energy technology and electric power reform, the development of integrated energy services has become an important development direction to improve energy efficiency, reduce energy cost, and promote competition and cooperation[4]. The park is not only a consumer of energy, but also a producer of energy, which involves the production, conversion, storage and use of many kinds of energy, such as electricity / heat / gas / cold, and is a typical application scenario of multi-energy complementary and integrated energy. With high energy price, high energy demand and abundant energy use, the integrated energy system service has become the main business direction of many energy service providers including State Grid Corporation of China, China Southern Power Grid Company Limited. Because the integrated energy service has the characteristics of many customers' demand, wide project points, complex technology analogy and diversified service mode, the analysis of investment income of integrated energy system becomes complicated, which seriously affects the development of integrated energy service business[5, 6, 7].

In view of the above problems, this paper develops the park integrated energy system planning auxiliary decision software, taking the park integrated energy system life cycle net present value(NPV),
internal rate of return (IRR), payback period and other key indicators as the evaluation planning basis, providing comprehensive energy efficiency assessment, clean energy assessment, electric vehicle construction station evaluation, multi-energy supply planning services for the park integrated energy system project screening, preliminary planning, auxiliary design, precision investment analysis to provide auxiliary decision support.

2. Investment Return Model

The planning assistant decision-making software of park integrated energy system is to optimize the capacity of energy system on the basis of satisfying the demand of electricity, heat and cold load of the energy end users in the park. An important basis for optimal allocation is the investment income of the project. The comprehensive energy project investment income analysis mainly carries on the analysis to the project profitability, the main measure index includes the net present value, the internal rate of return, the investment payback period and so on [8, 9].

2.1. Net Present Value (NPV)

NPV is a dynamic evaluation index of the profitability of a project throughout its life cycle. The sum of net cash flows during the project period is calculated by a certain discount rate:

$$NPV = \sum_{t=1}^{n} \frac{(CI_t - CO_t)}{(1 + i)^t}$$  \hspace{1cm} (1)

Where: NPV project net present value; n is the project life, including the project construction period and operation period; $CI_t$ is the net cash inflow of the project in year t; $CO_t$ is the net cash outflow of the project in year t; $i$ is the project discount rate.

$CI_t$ including: electricity sales revenue, sales revenue, sales revenue, charging services, electricity subsidies, construction subsidies, etc. $CO_t$ including: equipment purchase costs, annual electricity purchase costs, gas purchase costs, annual operating and maintenance costs, taxes and fees, as well as loan interest.

The calculated NPV greater than or equal to zero indicates that the planning scheme is financially acceptable.

2.2. Internal Rate of Return (IRR)

IRR refers to the discount rate at which the cumulative net cash flow during the project cycle equals zero:

$$\sum_{t=1}^{n} \frac{(CI_t - CO_t)}{(1 + IRR)^t} = 0$$  \hspace{1cm} (2)

An evaluation of an integrated energy system project indicates that the project programme is financially acceptable when the calculated internal interest rate IRR greater than or equal to the benchmark rate of return set by the user.

2.3. Payback Period ($P_p$)

Payback period $P_p$ refers to the time required to recover the project investment from the net income of the project, generally in years. The investment payback period is calculated by means of the project investment cash flow statement, the cumulative net cash flow in the project investment cash flow from negative value to zero point, is the project investment payback period.
The shorter the investment payback period, the faster the investment recovery of the project, indicating that the project's ability to resist risks is stronger.

3. Planning Assisted Decision Software Architecture

3.1. Overall Functional Architecture

The park integrated energy system planning auxiliary decision software includes: integrated energy efficiency assessment, clean energy assessment, EV charging station construction Assessment, multi-energy planning and design 4 business function modules, 1 model library, 1 user center, 1 system management module. The overall functional architecture of the software is shown in figure 1.

3.2. Sub-function module description

3.2.1. Integrated energy efficiency assessment. Through Energy conservation assessment and response capacity assessment, to realize the energy efficiency diagnosis of the buildings in the park, to provide the basis for the subsequent energy-saving renovation of the buildings.

Energy conservation assessment: taking the annual energy consumption per unit area of buildings in the park (unit kWh) as the evaluation index, the annual energy consumption per unit area (unit kWh) of electric power, gas, heating and refrigeration in the park is unified and converted to calculate the annual energy consumption per unit area (unit kWh), and compared with the constraint value and guidance value of energy consumption per unit area stipulated by the state. The calculated value is less than the guide value of energy consumption, and the energy consumption is good. The calculated value is greater than the constraint value, and the energy consumption is not up to the standard. The calculated value is between the constraint value and the guide value, and has the potential of energy saving.

Response capacity assessment: according to the local demand response incentive policy, the main energy consumption equipment such as HVAC system, lighting system and power system of public buildings in the park are analyzed, and the load adjustable range is analyzed.
3.2.2. **Clean energy assessment.** To realize the evaluation of the construction of distributed clean power station, it is mainly to evaluate the distributed PV power station, including PV investment assessment and electricity sale price analysis.

   **PV investment assessment:** the user enters available area, inclination Angle, subsidy amount and years, unit investment cost, peak and flat electricity price and time period of the grid, and the mode of access. Software output PV installed capacity, cumulative power generation, investment amount, investment payback period, internal rate of return, etc.

   Sale price analysis: If the Internet mode is for self-use and spare power is used for Internet, then on the basis of investment evaluation, users are supported to adjust the payback period and internal rate of return as constraints, and the software reversely calculates the price discount of electricity sold.

3.2.3. **EV charging station construction Assessment.** To realize the preliminary evaluation of the construction of electric vehicle charging station, including charging station investment assessment and charging service fee analysis, and to realize the preliminary evaluation of the investment income of comprehensive energy projects of charging station.

   Charging station investment assessment: Investment evaluation of station construction can be divided into two business scenarios: urban charging stations and special bus charging stations. The user enters the number of EVs, the number of charging posts that can be installed, the type of vehicle, charging service fee, unit investment cost, loan proportion, loan interest rate, loan term and repayment method. The software automatically calculates the output number and specification of charging piles, accumulated charging amount, investment payback period, internal rate of return, etc.

   Charging service fee analysis: based on the investment evaluation, the software reversely calculates the minimum charging service fee that meets the user's investment income requirement by adjusting the payback period and internal rate of return as constraints.

3.2.4. **Multi-energy planning and design.** For construction of buildings, parks and industrial users, for electricity, gas, cold, hot multi-energy system such as planning and design, with the optimal net present value as the goal, project planning scheme is realized by using scientific and practical optimization algorithm of intelligent optimization, to provide users with load calculation, capacity optimization, operation simulation, technology by the analysis of the preliminary planning function, the comprehensive energy system prior to the construction of the project to provide auxiliary decision making support for the user. The design process is as follows:

   1) **Project Scenario Selection:** The user enters the basic project information and selects PV, battery energy storage (BES), Combined Cooling Heating and Power (CCHP), ground source heat pump (GSHP), air source heat pump (ASHP), Direct-fired Machine (DFM), Gas boiler (GB), Water Storage (WS) and other equipment to define the type of equipment.

   2) **Load Calculation:** The user enters basic load information such as electrical load, heating and cooling load, and the software automatically calculates the annual hourly load based on the geographic location of the project.

   3) **Parameter Setting:** Users set parameters such as energy supply equipment, energy prices, financial calculations, energy conservation and environmental protection, etc., which are used for planning basic data.

   4) **Capacity Optimization:** The software calculates the capacity of the energy supply equipment for the multi-energy system through an intelligent algorithm and automatically optimizes it. The software outputs the optimal configuration scheme of the multi-energy system.

   5) **Operation Analysis:** According to the optimal configuration scheme of the multi-energy system, the software displays the typical daily output strategy, energy consumption and production capacity of each energy supply equipment.

   6) **Financial Analysis:** Calculate the key financial indicators such as static payback period and internal rate of return, and output financial statements such as total investment estimate and liquidity estimate for users to quantify the investment income of the project.
7) Sensitivity Analysis: The user sets sensitivity analysis parameters such as load, energy purchase and sale price, and the software re-finances the financial analysis of the configuration plan to quantitatively analyze the fluctuation of financial indicators caused by changes in the sensitivity factors.

8) Report generation: The software generates the planning report according to the template from the load data, energy supply equipment parameters, energy price parameters entered by the user, as well as the configuration plan, operation plan, financial analysis, and sensitivity analysis output by the system, which is convenient for users to view and share.

3.2.5. User center. Used for users to manage and view personalized data such as project information, planning schemes, exclusive equipment, and energy prices.

3.2.6. Model Library. The system model library realizes the establishment and management of meteorological models, energy supply equipment models and technical and economic models.

3.2.7. System Management. System management realizes user account management, and the management and setting of default parameters of the system.

4. Case Study
Take a park in Beijing for a case study of multi-energy planning. The park is located in the northwest of Beijing, covering an area of about 22,000 square meters, with a building area of about 18,000 square meters. At present, the maximum electrical load of the park is 499kW, the maximum cooling load is 1048kW, and the maximum heat load is 850kW. As the number of residents in the park increases year by year and the power supply and heating equipment is aging, the energy system of the park needs to be reformed.

Use the park integrated energy system planning auxiliary decision software to plan the energy system of this park. Consider the resource resources (light, groundwater flow), electricity purchase price and gas price in the area where the park is located, and make full use of clean energy such as PV, GSHP, and CCHP. The user selects through three scenarios, and the software outputs three sets of energy system configuration schemes as shown in Table 1.

| Parameter          | Planning Scheme 1 | Planning Scheme 2 | Planning Scheme 3 |
|--------------------|-------------------|-------------------|-------------------|
| CCHP (kW)          | 284               | 321               | --                |
| GSHP (kW)          | 0                 | 0                 | 442/407           |
| ASHP (kW)          | 0                 | 628/503           | 434/348           |
| DFM (kW)           | 1000/819          | --                | --                |
| BES (kWh)          | 0                 | 0                 | 1292              |
| WS (m³)            | 0                 | 302               | 534               |
| Grid (kVA)         | 1260              | 1260              | 1260              |
| PV (kWp)           | 160               | 160               | 160               |
| The total investment (Ten thousand yuan) | 765.4 | 899.22 | 922.8 |
| Average annual net income (Ten thousand yuan) | 118.28 | 116.5 | 83.7 |
| NPV (Ten thousand yuan) | 185   | 52.34  | -208.85 |

Planning Scheme 1: Users choose CCHP, GSHP, ASHP, DFM, BES, WS, Grid, PV equipment combination. After the software is optimized, CCHP, DFM, Grid and PV are selected. The operating characteristics of the system are shown in Figure 2.
Planning 1 Analysis: 1) Beijing has low gas price, high electricity price, high economic benefit of CCHP, DFM; Abundant light, high economic benefit of PV; 2) CCHP + DFM 284kW CCHP and 1000/819kW DFM, can meet the requirements of annual cooling and heating load; 3) CCHP can guarantee the operation time of 16 hours a day all year round, with good economic benefits; 4) PV and CCHP are given priority in daytime peak and peacetime section, and Grid is given priority in night valley power, and System configuration and operation are reasonable.

Planning Scheme 2: Users choose CCHP, GSHP, ASHP, DFM, BES, WS, Grid, PV equipment combination, do not choose DFM. After the software is optimized, CCHP, ASHP, Grid, WS and PV are selected. The operating characteristics of the system are shown in Figure 3.

Planning 2 Analysis: 1) DFM is forced to be excluded, CCHP capacity is increased by about 37kW, and the cooling and heating deficiency is provided by 628/503KW ASHP and 302 m³ WS. The investment in optimization results has increased, and NPV has decreased obviously, but it still has certain economic benefits; 2) Priority is given to PV and CCHP in the daytime and Grid at night. The priority of cold and heat utilization is CCHP, WS and ASHP, and System configuration and operation are reasonable.

Planning Scheme 3: Users choose CCHP, GSHP, ASHP, DFM, BES, WS, Grid, PV equipment combination, do not choose CCHP, DFM. After the software is optimized, BES, GSHP, ASHP, Grid, WS and PV are selected. The operating characteristics of the system are shown in Figure 4.
Planning 3 Analysis: 1) DFM, CCHP is forced to be excluded, the heat and cold are provided by 442/407kW GSHP, 434/348kW ASHP and 534m3 WS, and the installed capacity of HP and WS increases. Due to the high cost of electric refrigeration and heat, the NPV of the final optimization result is negative; 2)1292kWh BES, two charges and two discharges, basically zero power purchase in the transitional peak period and less power purchase in the winter peak period, making full use of the price difference between peak and valley, and System configuration and operation are reasonable.

5. Conclusion
This paper constructed the park investment income model of integrated energy system, developed the park integrated energy system planning auxiliary decision software, in the realization of integrated energy system capacity, on the basis of accurate planning, project investment operating income for the quantitative evaluation, for screening for integrated energy system planning and design, project provides the auxiliary decision making support, and An empirical case is given based on multi-energy planning function in a park in Beijing.

The software realizes intelligent optimization of planning scheme through scientific and practical optimization algorithm, ensures scientific planning capacity and optimal investment return of energy system, enriches planning and design means of energy system, and improves planning efficiency.

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