RESEARCH ON KEY TECHNOLOGIES OF REGIONAL INTEGRATED ENERGY MANAGEMENT SYSTEM

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ABSTRACT

Regional Integrated Energy Management System(IEMS) can integrate cold, heat, electricity, gas and other energy synergy into account, and can be used to achieve renewable energy local absorption on a large scale and improve energy comprehensive utilization efficiency. This paper proposed the system architecture and design thought of IEMS, and described the key technologies, including the enterprise self-optimizing control, the park Energy Risk Assessment, and the Park Integrated Energy Coordination and Optimization Dispatch. The IEMS was supported by the National Key R&D Program of China (2016YFB0901300) named "R & D and demonstration of electricity distribution system for multi-energy interaction in the industrial park ". Through this system, the multiple types of energy within the demonstration park can complement each other, the peak load and the external power purchased of the park can be curtailed.

INTRODUCTION

In recent years, the construction and development of industrial parks promoted the growth of local economy and caused serious resource waste and environmental pollution. How to make the coordinated development of energy, economy and environment in the construction of industrial parks has become an urgent problem to be solved[1]. Construction demonstration project for integrated energy and intelligent distribution system, which can friendly interact with the big power grid, will make contributiveness for industrial resources agglomeration, efficiency optimization, and lifting efficiency. And it has the benefit of driving industrial innovation and enterprise to improve management efficiency by energy supply effect and is helpful to promote energy-park-industry for ascension.

“R & D and demonstration of electricity distribution system for multi-energy interaction in the industrial park" project make a demonstration pilot in an industrial park. The IEMS is developed and it integrates cold, heat, electricity, gas and other energy synergy into account, explore the response potential of each participant in the park, make them better interaction with the grid and better serve the needs of the user, reduce multi-energy costs and improve multi-energy using efficiency.

SYSTEM ARCHITECTURE

The IEMS is divided into two layers as shown in Fig.1. On the bottom layer, the autonomous control terminals are expanded in each enterprise, and the park energy coordination and optimization dispatch system is located on the top layer.

Base on the multi-agent technology, the bottom layer autonomous terminals and the top layer optimization dispatch system are designed as relatively independent autonomous agent. Each agent has its own relatively independent goal which is also able to coordinate with and server other agents. In this way, the whole system always runs at its best.

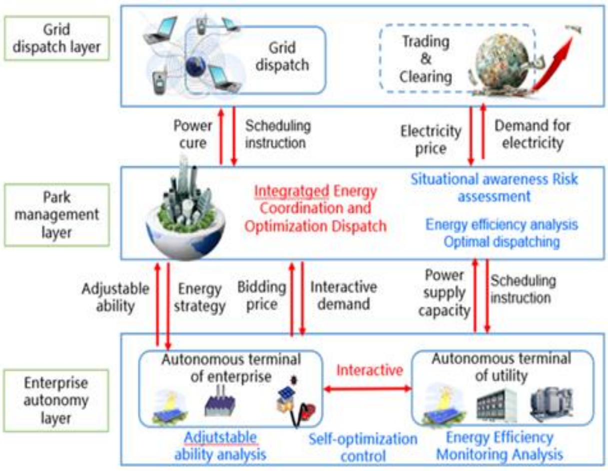

Fig.1 System Architecture

The park energy coordination and optimization dispatching system

The energy coordination and optimization dispatch system is responsible for coordinating and dispatching the energy production and consumption of each enterprise, to ensure the stability of the power grid in the park and avoiding the waste of energy. First, based on the situation sensing technology[2], the comprehensive risk assessment of the park energy operation is developed to analyze the risks brought by the uncertainties of the distributed photovoltaic and enterprise energy consumption and to assess whether the adjustable resources in the park under the current energy utilization plan have enough flexibility to eliminate the risk. Then, from three levels including the day-ahead schedule, the intra-day schedule and the real-time correction, the optimization dispatch is designed to exterminate the risk of the park energy operation or to start the demand side response.

The autonomous control terminal

The autonomous control terminal deployed in enterprise is an energy gateway, which can integrate, monitor and control the enterprise's energy production and consumption, but also has the function of optimization analysis to ensure that the cold, hot and electric power in enterprise operate securely and economically[3]. First, the autonomous control terminal builds the model of adjustable devices for the Interruptible load, the shiftable load, energy storage facility, thermoelectric coupling device, standby power generation equipment and other resources in the enterprise. Then, under the precondition of guaranteeing the power supply stability, the adjustable ability and the cost of participating the demand response is calculated according to the optimization target of minimum energy consumption cost of the enterprise.

KEY TECHNOLOGIES

Enterprise self-approximate-optimal control

In the process of industrial production, it involves the coupling and transformation of various form of energy, such as cold, heat, electricity and gas[4]. Typical equipment in the factory are: gas turbine, photovoltaic units, waste heat boiler, absorption refrigerating machine, household air conditioning, gas boiler, battery storage, ice storage device and all kinds of steam driving equipment such as a necessary vulcanizing machine in a tire factory and so on. The multi - energy complementary model is the basis of the assessment and optimization control of the enterprise.

(1) cold energy system model

At one point，the cooling water flow required for each building cooling needs is calculated by the formula below.

$$L_i = \frac{Q_{c,i}}{C_w \cdot \rho_w \cdot \Delta t}$$

In the formula， L_i is the cooling water flow for building i, $Q_{c,i}$ is the cold load for building i at the point, C_w is the specific heat capacity at constant pressure of water, ρ_w is the density of water， Δt is the difference between the temperature of supply cooling water and return water.

(2) heat energy system model

For each heat load node, the heating temperature $\boldsymbol{T}_s$ signifies as the temperature of the hot water before it flow into the heat load. The output temperature $\boldsymbol{T}_o$ signifies as the temperature of the hot water after it outflow the load node. The heat power calculation formula is:

$$\boldsymbol{\Phi} = C_p \boldsymbol{m}_q (\boldsymbol{T}_s - \boldsymbol{T}_o)$$

In the formula， Φ is the heat power of the heat grid, C_p is the specific heat capacity of water.

(3) electricity system model

Suppose a n nodes system has m PQ nodes, n-m-1 PV nodes and single balance node, electricity system flow formula can be written as the following polar coordinates:

$$\begin{cases} \Delta P_i(x) = P_{Gi} - P_{Li} - U_i \sum_{j \in i} U_j (G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij}) = 0; i = 1,2,\cdots,n-1 \\ \Delta Q_i(x) = Q_{Gi} - Q_{Li} - U_i \sum_{j \in i} U_j (G_{ij}\sin\theta_{ij} - B_{ij}\cos\theta_{ij}) = 0; i = 1,2,\cdots,m \end{cases}$$

The goal of the enterprise self-approximate-optimal control is the highest multi-energy efficiency or the lowest cost[5,6], by dispatching all kinds of supply equipment of the enterprise. The dimension is different between multi-energy efficiency and energy cost. Therefore, the normalization is necessary[7] and then the goal of the self-approximate-optimal control can be signified as:

$$\min \ \lambda_1 \frac{C_{ATC}}{C_{ATC.\max}} + \lambda_2 \frac{\eta_{t.\min}}{\eta_t}$$

In the formula， C_{ATC} is the factory energy cost； $C_{ATC.\max}$ is the maximal factory energy cost without optimizing； η_t is the multi-energy efficiency， $\eta_{t.\min}$ is the lowest factory multi-energy efficiency without optimizing； λ_1 and λ_2 are the weight coefficients of energy cost and multi-energy efficiency, which could be determined by analytic hierarchy process.

The constraint conditions of the self-approximate-optimal control model include cold, heat, electrical constraint, equipment physical constraint and energy consumption constraint and so on. In order to realize the cascade utilization of heat energy, the traditional heat power balance constraint is changed to the heat power balance constraint based on energy grade. Then the utilization technology and recycling technology of heat energy can be clarified. Thus, the cascade utilization and optimization in the factory of energy are realized.

A mixed integer linear programming method is used to optimize the model and output the factory's economic optimal dispatch plan. By dispatching the operation mode and output power of each device in the factory, the circulation waste heat energy in the factory can be fully utilized to significantly reduce the daily operating cost of the system and realize the economic optimization operation of the factory.

Park energy supply risk assessment method

It may raise risk to the operation of the park because of the uncertainty of distributed photovoltaic and enterprise production, such as the risk of unsafe power supply, tie-line power off-limits risk, the heating power shortage risk and so on. The risk assessment enables the park operators to accurately grasp the safety indicators and corresponding economic factors of the park's power supply system. They would decide whether it is necessary to adjust the enterprise's energy consuming plan and realize the efficient energy using in the park[8]. The risk assessment needs to introduce the index of the risk index which can represent the system risk and establish a reasonable evaluation index system. Considering the multi-energy coupling of cold-heat-electricity-gas and multi-user agent in integrated energy system, the risk assessment index system should be supplemented and updated from the traditional electrical power system. More energy type risk assessment indicators have been put forward covering electricity grid (power, voltage, etc.), heat grid (heat-supply temperature, heat supply grid pressure, etc.), cold grid (cold temperature, cold network traffic, etc.) and gas grid (pipe pressure, pipe flow, etc.). This paper proposes a multidimensional risk assessment index system as shown in Fig.2 respectively from viewing angle of the operators and the users.

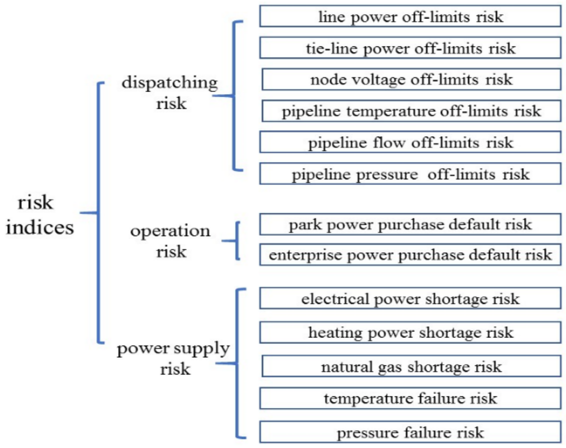

Fig.2 Integrated Energy System Risk Assessment Indicators

The integrated energy system event risk is defined as the product of the risk occurrence probability and its severity level as shown in the following formula:

$$R_{isk}(X_f)=\sum_i P_r(E_i)\times S_{ev}(E_i,X_f)$$

In the formula, X_f is the system operation mode, E_i is the i'th fault, $P_r(E_i)$ is the probability of occurrence of the fault E_i, $S_{ev}(E_i,X_f)$ is the severity level of the system after the fault E_i occurred in the operation mode X_f. $R_{isk}(X_f)$ is the system operational risk indicator in the operation mode X_f.

Park optimization dispatching method

Coordination and optimization dispatching is the core function to realize the economic operation of the park. It synergizes the operation of different controllable resources, raises the utilization efficiency of distributed photovoltaic, reduces the peak load and improves the total energy efficiency. The optimization scheduling can be divided into three parts: the day-ahead plan, the day rolling and the real-time correction, which can be combined with each other to form a multi-time scale optimization scheduling framework.

Once there is a demand for cutting load peak in the park, the controllable resources of every enterprise can be dispatched, to realize the multi-energy demand response of industrial parks. The autonomous control terminal of each enterprise can optimize the internal energy using plan of the enterprise, evaluate its own controllable ability and corresponding quotation and report it to the energy management system of the park. The energy management system of the park executes situational awareness and risk assessment, which also optimizes the cutting peak capacity of each enterprise. The energy management system and the enterprise autonomous control terminal can adjust the utilization plan of resources and reach a consensus to realize the optimized using of cold, heat and electric resources in the park. The process of demand response is shown in Fig.3.

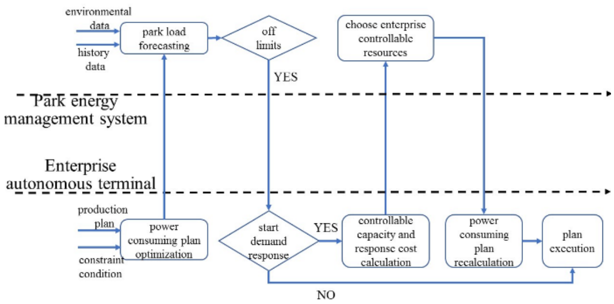

Fig.3 The process of demand response

APPLICATION

The test version of the IEMS has been developed and deployed in the Mingzhu industry park of Guangdong province, which covers 12 square kilo meter and is one of the first demonstration areas of distributed PV, and the peak electric load is 34.5 MW. Before the project conducted, the heat load will be 106 ton per hour. The cooling load will be 15MW.

This system has designed to include ten functions. The functions of Adjustable ability calculation, Energy efficiency analysis, Self-approximate optimal control and fault handling, belong to the enterprise self-optimizing control system. The Park coordination and optimization dispatch subsystem has the next 6 functions, such as energy efficiency analysis, user interaction management, situational awareness, risk assessment, optimization dispatching, VPP supporting.

The front page of the system is shown in Fig.4.

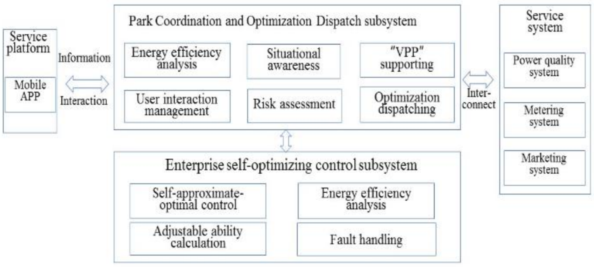

Fig.4 The framework of industry park operation and control system

EXHIBIT SYSTEM

Aiming at some new features in the industrial park such as the various energy forms, the large differences in each energy characteristics, the flexible interaction between multi-user and multi-time scales and the high proportion of renewable energy and so on, an open system architecture based on the information service bus is researched in this project. Several key technologies including the metadata management, the integrated modeling method covering the whole process of source-grid-load-storage and the extends IEC61970/61968 standard CIM model are also developed. In view of the diversity and confounding of multi-energy data, a complex information system method with hierarchical distribution is introduced. The IEMS including the autonomous control terminal and the park energy optimization dispatching system is designed and developed. Parts of the IEMS interface are shown in Fig.5 and Fig.6.

Fig.5 System main page

Fig.6 Electrical energy storage resource monitoring

CONCLUSION

By the integrated designing of multi-energy integrated energy dispatching system and the construction of demonstration projects, this project has yielded numbers of achievements in distribution system integrated planning, interactive mechanism of demand response in industrial parks with multiple participants, multi-energy coordinated control method and so on. By studying the integrated planning and design method of regional integrated energy management system, an integrated solution that includes planning strategies, assessment methods, software platforms, and implementation suggestion is formed.

Through this project, the park energy supply reliability will be higher while the cost will be less with the adjustable resources fully utilized. In the demonstration park, the peak load of the park can be curtailed more than 20%, and the electricity purchased from outside the park less than 20%, which can decrease the coal consumption about 6,000 ton per year and can suspend 48 million yuan on grid investment for the supply company.

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