Analysis of Laogang energy internet and construction of the cloud platform

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Abstract. Laogang solid waste recycling base deals with about 70% waste domestic garbage of Shanghai every day. By recycling the garbage, great amount of energy including electricity, heat and gas can be produced. Meanwhile, the base itself consumes much energy as well. Therefore, an energy internet has been designed for the base to analyse the output and usage of the energy so that the energy utilization rate can be enhanced. In addition, a cloud platform has been established basing on the three-layer cloud technology: IaaS, PaaS and SaaS. This cloud platform mainly analysing electricity will judge whether the energy has been used suitably form all sides and furthermore, improve the operation of the whole energy internet in the base.

1. Introduction

Solid waste is not only a serious pollution source, but also a valuable resource. There are many ways to recycle it such as landfill, incineration, biological treatment and so on. Through these ways, the circulation utilization of resources and the protection of the environment can be realized [1].

In the presence of solid waste treatment, there is recycling of energy in different ways. For example, a large amount of sludge will be produced during the treatment of leachate, and the sludge can be used as the raw material for waste incineration as well. Overall, the whole process of solid waste treatment achieves zero emission of pollutants, and produces and uses many energy resources like electricity from waste incineration power generation, landfill gas and many thing else [2,3].

Laogang base contains three kinds of energy: electricity, gas and heat, which can be either used or produced. Thus, the base is a large multi-energy system which has the prerequisite for the construction of the internet. In order to improve the efficiency of energy utilization and make full use of renewable energy, electricity, heat and gas are combined into an energy internet. It can make full use of the synergistic effect among different systems to change the multi-energy network system into an organic whole that operates and works together, so that the propose of energy saving, emission reduction and increasing the consumptive proportion of new energy can be achieved. On one hand, the energy internet can schedule the energy co-ordinately according to the requirements of the system, so as to improve the efficiency of the management and operation. On the other hand, it needs to explore the characteristics of disturbed energy to provide corresponding management plan [4,5].
2. Laogang base multi-energy system

2.1. Electricity network in Laogang
The whole base will produce and consume a great deal of electricity to maintain its operation. Leachate treatment plant uses the most, as it handles the Contaminants in the leachate. Besides, the garbage crane also needs to consume a great deal of electricity in the process of garbage pre-treatment, and the renewable energy management centre needs to ensure the daily usage of electricity. The rest energy will be sold to Shanghai Power Company at an agreed price. Both production and usage of electricity are shown in Table 1.

| Table 1. Production and usage of Electricity. |
|---------------------------------------------|
| Energy type |Energy point  | Amount            |
|------------|--------------|-------------------|
| Electricity| Production   |                   |
|            | Incineration plant | 300,000,000 kWh / year |
|            | Landfill gas power plant | 150,000,000 kWh / year |
| Usage      | Leachate treatment plant |               |
|            | Management center | 33,000,000 kWh / year |
|            | Garbage wharf   |                   |

2.2. Marsh gas network in Laogang
There are many units using gas in the base. For example, landfill gas and methane produced by leachate are used to produce electricity. After the purification of biogas, the methane can be used as a fuel for boilers or garbage trucks / ships which will greatly change the current status of traditional vehicle fuel and reduce the emission of harmful gases. As a clean energy, the promotion of gas vehicles / ships is called the green revolution. It is an important link between the gas network and the transportation network. The rest of methane will be stored in gasholders for other use at any time. Both production and usage of methane are shown in Table 2.

| Table 2. Production and usage of methane. |
|-----------------------------------------|
| Energy type | Energy point  | Amount            |
|------------|--------------|-------------------|
| Methane    | Production   |                   |
|            | Landfill site | 24,709,706 m³ / year |
|            | Leachate treatment plant | 65,700 m³ / year |
| Usage      | Biogas boiler | 2,710,600 m³ / year |
|            | Garbage truck / ship | 9,230 m³ / year |

2.3. Heat network in Laogang
In the process of leachate treatment, aerobic reaction will produce a great deal of heat energy, while anaerobic reaction also needs to consume a lot. Thus, there is a circulating heat exchanger, which can realize reasonable energy saving. Utilizing the heat energy produced during the process of power generation, can the sludge be dried and used as the raw material for the incineration plant. The heat energy produced can be used for the warming in the whole base. Excess energy will be sold to the neighbourhood. Both production and usage of heat are shown in table 3.

| Table 3. Production and usage of heat. |
|---------------------------------------|
| Energy type | Energy point  | Amount            |
|------------|--------------|-------------------|
| Heat       | Production   |                   |
|            | Incineration plant | 248,000MJ/year  |
|            | Landfill gas power plant | 172,000 MJ/year |
|            | Leachate treatment plant (aerobic tank) |             |
|            | Biogas boiler | 3,230,600 MJ/year  |
| Usage      | Leachate treatment plant (anaerobic tank) |             |
|            | Management center | 52,000MJ/year  |
|            | Laogang fish pond | 271,000 MJ/year  |
3. Energy internet in Laogang

As the distribution of the factories in Laogang is quite concentrated, and every factory has different energy and load, the utilization and the generation of each energy form is close and substitutable. As shown in Figure 1, the construction of the energy internet in Laogang can effectively solve the problems of the interconnection of different kinds of energy, and facilitate the comprehensive utilization of energy resources. It can fully realize the purpose of building an energy internet.

![Figure 1. The Laogang base energy internet.](image)

4. Structure of the cloud

Laogang cloud computing system (as shown in Figure 2) is divided into three layers from bottom to the top: IaaS (Infrastructure as a Service), PaaS (Platform as a Service), and SaaS (Software as a Service) [6]. The main function of IaaS layer is to provide a virtual machine or other resources to users as a service. It will provide off-site server, storage and network hardware, which can be rented, and also save maintenance cost and working space. The hardware can be used to run corresponding

![Figure 2. Basic structure of cloud platforms.](image)
applications at any time. Next, PaaS provides a development platform to users as a service which can provide a variety of solutions to develop and distribute applications, such as virtual server and operating system. It can save the cost of hardware, and also make the dispersed studio to collaborate easier. Finally, the role of SaaS is to provide the applications to the users as a service. It will make sure that any application on a remote server can be running through the network.

5. Main function interface of the cloud platform

5.1. Real-time monitoring interface

The real-time electric monitoring interface which is the platform for big data analysis includes active power, reactive power, apparent power, bus voltage, transformer temperature and so on. The monitored data is sent up to cloud platform every 30s.

Figure 3 is the power monitoring interface, and it is made up of power analysis, electricity analysis, power factor analysis and frequency analysis. All the massive data, including a large amount of historical data and real-time data, are calculated according to the basic electrical calculation principle, and it is the basis for analysis of the power grid in energy internet.

Figure 4. Total electricity consumption interface.
5.2. Concrete analysis interface

The specific analysis interface includes electricity report, power analysis, network losses analysis, time-space equilibrium of load analysis, power quality analysis and systematic analysis. Through the intelligent monitoring equipment, which will measure the instantaneous three-phase voltage and current, installed in Laogang factories, the cloud platform will get the detail value of power, consumption, harmonics and so on after calculation, and then make an in-depth analysis\[7\].

5.2.1. Total electricity consumption report. Consumption is always what the consumers most concern about, for it is directly related to the bill they will pay. As shown in figure 4, there are electricity situation table, power consumption statistics and consumption curve in the interface. Users can select any period of time they need to display the data, because the database will never lose any datum recorded. To show the trends, year-on-year and link growth rate are calculated.

5.2.2. Power analysis. Active power is usually associated with the frequency, for the power of most electric equipment depends on frequency. While reactive power is closely linked with operating voltage of the system, for the voltage operation level will fluctuate if the reactive power is not balanced. In addition, there is a comparison between daily power curve and weather condition including temperature and humidity. This plays an important part in the power prediction as the curves have high correlation.

\[
\rho = \frac{\sum_{n=1}^{N} (x(n) - \bar{x}) (y(n) - \bar{y})}{\sqrt{\sum_{n=1}^{N} (x(n) - \bar{x})^2} \sqrt{\sum_{n=1}^{N} (y(n) - \bar{y})^2}}\]  

(1)

Figure 5. Power analysis interface.

By substitute \( x, y \) in equation (1) with power and weather condition, the correlation between power consumption and weather can be assessed. As shown in figure 5, there are active power table, maximum daily active power curve (together with weather condition), and peak curve of daily active power in the power analysis interface. It is similar with the reactive power analysis interface. Furthermore, time-space equilibrium of load analysis is also based on power of equipment. In this part, load rate, minimum load factor and maximum load equivalent hour which can be used to predict the electricity consumption of a certain user are calculated.

5.2.3. Power quality analysis. Power quality includes reactive compensation, harmonics and voltage quality. The balance of reactive power is essential to maintain the stability of power system. It is because reactive power fluctuation will cause instability of magnetic field and voltage to rise and fall. Another element contributes to systematic instability is harmonic which is inevitable [8].

THD (Total Harmonics Distortion) and VCF (Waveform distortion factor) are two factors used to determine the influence of harmonics. Their computation formula is as follows:
THD = \left( \sum_{i=1}^{50} G_i^2 \right)^{1/2} \quad (2)

VCF = G_1 \sum_{i=2}^{50} G_i \quad (3)

Where $G_i$ indicates voltage amplitude of one phase.

Figure 6 is the harmonic analysis interface including the THD and VCF data of any phase. There are also reactive compensation interface and voltage quality interface. The improvement of Power quality will not only improve stability and reliability of equipment, but also satisfy both demand and supply side.

6. Summary

The main contribution of this paper:

- On the basis of the current energy production and utilization in Laogang, analyse the operation of the energy in the system, and construct a hybrid energy interconnection system including power system, thermal system and natural gas system.
- Build a cloud platform that can monitor flow of electricity and determine whether the base or the users are using energy efficiently and with high quality using cloud architecture with three layers: IaaS, PaaS and SaaS.
- Analyse the multi-energy system in Laogang base which can be used as a typical example to demonstrate the development of solid waste recycling and energy internet.

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