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# Research on new energy consumption supported by deep learning in the context of integrated energy services

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**Abstract.** The use of renewable energy has alleviated the severe resource and environmental pressure at this stage. However, the discontinuity and randomness of renewable energy have brought risks to the system, resulting in serious problems of abandoning wind, light, and water, making it impossible to achieve large-scale access to renewable energy. This paper proposes a framework of renewable energy consumption system supported by deep learning, which can provide new solutions for renewable energy consumption under the background of integrated energy service system.

## 1. Introduction

With the rapid development of society, human demand for energy is still growing. At present, the main energy supplies are electricity, heat and natural gas. Traditional energy supply management does not consider the coupling relationship between different energy sources, and there is a large deviation between the analysis of a certain energy source and the actual situation. Collaborative analysis of multiple energy sources has attracted wide attention from scholars and companies. As early as 1998, the European Union began to study multi-energy collaboration; The United States proposed the Integrated Energy System (IES) development plan in 2001, which aims to strengthen the distribution of distributed energy and introduce a combined heat and power operation mode; Japanese companies have designed a complete energy system from the supply of future energy to the end of use, including heat, electricity, light energy, natural gas and other energy subsystems; Germany in 2008 The Federal Ministry of Economics and Technology launched the "E-Energy" plan, which covers the construction of an energy management system; Since 2015, China has issued a number of policies to promote the development of an integrated energy system. From 2015 to 2017, the National Development and Reform Commission has successively issued a number of documents to encourage the development of integrated operation of multiple energy sources and the construction of distributed renewable energy. These policies provide a good internal environment for the development of integrated energy systems.

Under the background of integrated energy services, more and more new energy power is connected to the grid, alleviating the environmental pressure caused by relying solely on thermal power. However, the production of new energy power is random, and the instability of the system is increased after being connected to the grid, which leads to serious wind and solar abandonment in the system. The consumption of new energy power is a difficult problem faced by power companies. The application of energy storage technology and equipment realizes the conversion of electric energy and other energy sources, and can be used as a reliable backup energy source, providing energy complementary services, and providing solutions for the consumption of large-scale new energy power. When energy storage equipment and links are added to the integrated energy system, the system's new energy consumption potential will inevitably change. Using scientific methods to predict the system's new energy power demand is of great significance to the power dispatch and marketing departments. Documents [1]-[3] equipped heat storage equipment in the cogeneration unit, and controlled the heat storage to decouple the constraint of “using heat to determine the electricity”, and discussed the principle of using heat storage equipment to absorb wind power. Gas generator sets are more flexible, which is conducive to the system's consumption of new energy with increasing penetration rate. Literature [4] established a mathematical model of CSP station, considered the heat storage and heat release efficiency of thermal storage equipment and its time sequence characteristics, and analyzed that under the premise of fully adopting CSP power generation, the grid-connected CSP station has the advantages of power generation cost, Renewable energy consumption and other aspects are considerable benefits. Literature [5] based on the demand of wind farms to absorb excess wind power and optimize their own output, and the response ability of integrated energy service providers (IESP) to meet this demand, proposed a wind farm-IESP cooperative operation model based on wind power consumption demand (WICOM), and with the goal of maximizing the benefits of IESP, considering the power generation/heat response capabilities of multiple types of energy supply equipment in IESP and the response characteristics of flexible loads, a day-ahead economic dispatch model of source-charged heat was established.

At this stage, the literature on IES new energy consumption research mostly focuses on the electric-heat combined system, ignoring the complicated cross-interconnection and coupling relationship among electric power, natural gas, and thermal systems. There are few results of quantitative analysis and research on the effect of energy storage equipment on the improvement of system wind and solar abandonment phenomenon.

## 2. Introduction to related knowledge

### *2.1. Integrated energy system*

The integrated energy system specifically refers to the integrated system of energy production, supply, and sales formed through organic coordination and optimization of energy generation, transmission and distribution, conversion, storage, and consumption in the process of planning, construction, and operation. It consists of a social energy supply network, energy exchange links and a widely distributed terminal integrated energy unit system. In this article, the integrated energy system mainly involves electricity and natural gas. The framework of the system is shown in Figure 1. Electric energy storage, cold storage and gas storage facilities together form the energy storage link of the system. With the further development of the integrated energy system, the future renewable energy power generation will play an important role in power supply.

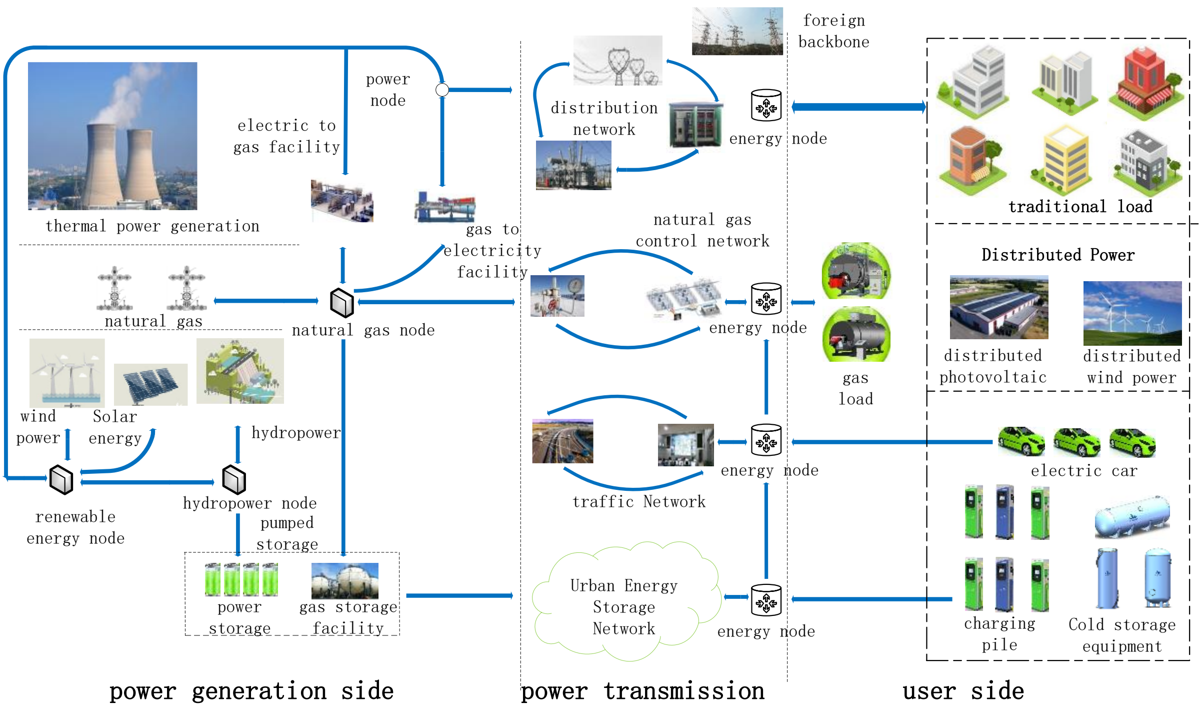


Figure 1. Framework of Integrated Energy System.

The integrated energy system can effectively coordinate the relationship between different energy supplies and form a coordinated adjustment mode of source, grid, load, and storage, so as to maximize energy utilization and optimize the interests of all parties. There are complex coupling relationships between different energy sources in the integrated energy system, and the analysis of any kind of energy cannot ignore the influence of other energy sources in the system. Traditional energy analysis methods separate the relationship between different energy sources, and often analyse a certain energy separately. This analysis method is obviously not suitable for the background of integrated energy services. At present, research on integrated energy services is based on the power system, while considering the impact of multiple energy sources and multiple power generation methods. The framework of the power system in the context of integrated energy services is shown in Figure 2. Renewable energy power generation is an important part of the integrated energy system and the future of the power industry.

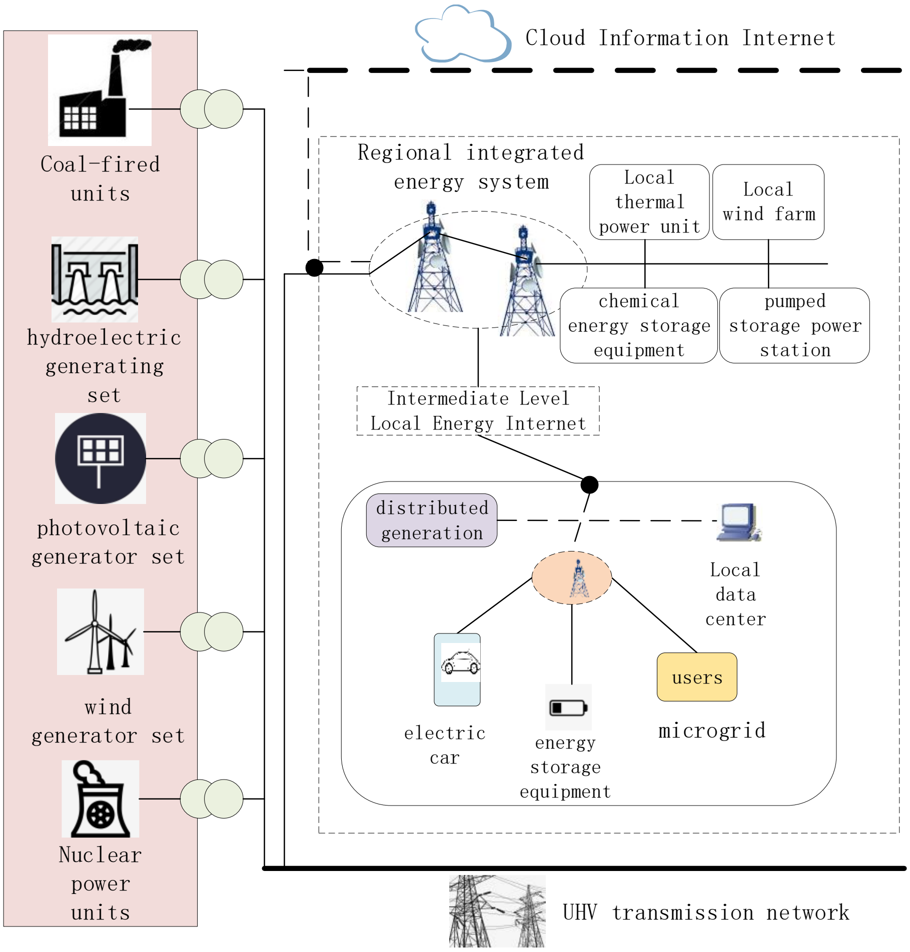


Figure 2. Power system architecture diagram.

### *2.2. Renewable energy consumption*

After a high proportion of renewable energy is connected to the power system, the flexible resources in the system should be fully utilized to maintain the balance between the flexible supply and demand of the power system. The North American Electric Reliability Association (NERC) believes that the flexibility of the power system is the ability of system resources to meet changes in demand; the International Energy Agency (IEA) clearly pointed out at the G8 summit in 2008 that the flexibility of the power system means the access to a high proportion of renewable energy Under the power system, the ability to ensure reliable operation; and the IEA pointed out that the flexibility resources mainly include conventional power plants, energy storage, interconnected grids and the demand side to meet the requirements of flexibility and balance.

In the future, due to the dual pressures of resources and the environment, a large number of renewable energy sources will be connected to the grid to assume the important task of power supply. However, unpredictability and full-scene feasibility are problems that must be solved in the process of renewable energy consumption. Unexpectedness refers to the difficulty in forecasting power generation caused by the randomness and instability of renewable energy sources such as wind power and solar power. From the perspective of the safe operation of the power grid, it is necessary to avoid large fluctuations in the power grid as much as possible. Consider curtailing wind and solar power to ensure the balance of the entire grid. Therefore, the unexpected nature of renewable energy output hinders the large-scale consumption of renewable energy.

Energy storage methods such as electrochemical energy storage used in current power systems mainly provide services such as intra-day peak shaving, frequency modulation, and hill climbing for power systems, which are used to smooth short-term (second, minute, hour)-scale power fluctuations. Deal with the problem of electricity imbalance between renewable energy output and load demand on a long-term (weekly, monthly, and yearly) scale. In order to achieve long-term energy translation, to smooth out the fluctuations in power over several days, weeks, and even seasonal, and to participate in the adjustment process of months, seasons, years and even new years, long-term, large-capacity energy storage technology is required. Reasonable power dispatch is an effective way to absorb renewable energy. Renewable energy generation forecasting and regional load forecasting are important research content to support dispatching plans. Data analysis combined with power big data and artificial intelligence technology has a good application prospect.

## 3. New energy power consumption system based on deep learning

The power system is undergoing an intelligent construction process. The application of a large number of power electronic technologies and equipment has greatly improved the perception of all aspects of the power system. At the same time, a large amount of power data has been accumulated. Massive power data contains a wealth of potential information, which can be used to predict the generation of renewable energy and the load data of power users, and provide a reasonable reference for power dispatch to improve the utilization rate of renewable energy. Data forecasting involves many factors, and the effect of each factor cannot be accurately described. It is difficult for traditional analysis methods to take into account these influences from different aspects. Once the forecasting model is determined, it is difficult to adjust. Deep learning is an important method in big data analysis. This chapter will discuss the renewable energy consumption system framework supported by deep learning.
This paper proposes a deep learning-supported renewable energy consumption system. Figure 3 shows the system's framework. The system is divided into three parts: power generation and energy storage, decision-making and scheduling, and users. The power generation and energy storage part is composed of fossil energy power generation, renewable energy power generation and energy storage facilities. Renewable energy power generation is divided into wind power, hydropower and photovoltaic power generation. Wind power and photovoltaic power generation are random and discontinuous. It is the main target of renewable energy consumption. The decision-making and dispatching part is composed of a renewable energy forecasting model supported by deep learning, a power load forecasting model, and an energy negotiation model. The forecasting model is responsible for power data analysis and providing data forecast results, while the negotiation model uses relevant power data and forecast data for energy Negotiation, the negotiation result provides reference for scheduling decision. The distribution network node is responsible for distributing electric energy to users. The user part includes ordinary users, commercial users, industrial users and other users.

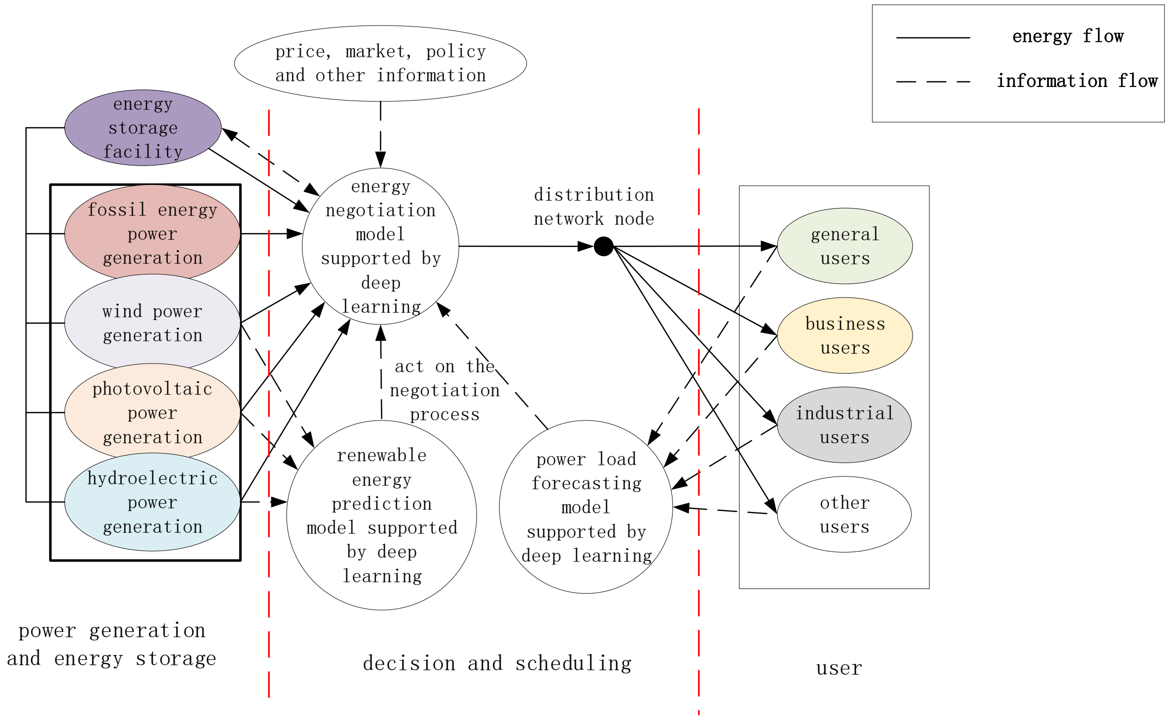


Figure 3. Framework diagram of renewable energy consumption system supported by deep learning

Renewable energy power generation methods are greatly affected by various factors. The renewable energy prediction model uses deep learning algorithms to model and analyze historical power generation data and related influencing factors to obtain power generation data for a period of time in the future. The mathematical description of this process is :

$$\Gamma(X) = Y \tag{1}$$

$$X = (x_1, x_2, x_3, \cdots) \tag{2}$$

In the above formula, $\Gamma$ represents the deep learning algorithm, **X** is the impact factor data set, **Y** is the model prediction result, and **x** is the data category that affects the prediction result.

The principle of the electric load forecasting model is similar to that of the renewable energy forecasting model. It also uses historical load data and influencing factors for analysis and forecasting. The mathematical description of the load forecasting model is:

$$\Psi(D) = L \tag{3}$$

$$D = (d_1, d_2, d_3, \cdots) \tag{4}$$

In the above formula, $\Psi$ represents the deep learning algorithm, **D** is the impact factor data set, **L** is the prediction result, and **d** is the data category that affects the load prediction result.

The energy negotiation model is responsible for the two tasks of decision-making and energy grid connection. Decision-making refers to the use of the forecast data of the above two models and other related data to determine the output of renewable energy. The mathematical description is:

$$\Theta(Y, L, O) = S \tag{5}$$

$$S = (\alpha_W, \alpha_S, \alpha_t) \tag{6}$$

In the above formula, $\Theta$ represents the deep learning algorithm, **O** is the influencing factors such as electricity price and policy, $\alpha_w$ is the output of wind power, $\alpha_s$ is the output of photovoltaic power, and $\alpha_t$ is the output of hydropower. The final grid connection process of renewable energy is:

$$E = \alpha_w + \alpha_s + \alpha_t \tag{7}$$

Among them, **E** represents the total amount of grid-connected renewable energy .The above formula can predict the electric load and renewable energy, and the energy negotiation model can give the output of renewable energy. Through the guidance of the mathematical model, a renewable energy consumption system supported by deep learning can be constructed more clearly.

## 4. Conclusion

In the context of integrated energy services, the relationship between different energy sources is more complicated, and the consumption of renewable energy needs to consider many factors. Based on the analysis of the integrated energy system, this paper proposes a framework of renewable energy consumption system supported by deep learning, which has certain reference value for the large-scale consumption of renewable energy in the future.

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## References

[1] Liu F., Yang X., Huang H.T., Zhang M.X. (2016) Comprehensive optimization of microgrid energy under operation mode of thermo-electrolytic coupling with cogeneration. Journal of Electric Power System and Automation., 28(01):51-57.

[2] Lv Q., Chen T.Y., Wang H.X., Li L., Lv Y., Li W.D. (2014) Electric heating integrated dispatching model of power system with heat storage. Power Automation Equipment., 34(05):79-85.

[3] Wei Z.B., Huang Y.H., Gao H.J., Shui Y. (2018) Joint Economic Dispatching of Regional Energy Internet Including Electricity-to-gas and Thermal Electrolysis Coupling Cogeneration Unit. Power System Technology., 42(11):3512-3520.

[4] Gu Z.P., Kang C.Q., Chen X.Y., Bai J.H., Cheng L. (2015) Operation optimization of electric heating energy integrated system considering heating network constraints and analysis of wind power consumption benefit. Proceedings of the Chinese Society of Electrical Engineering., 35(14):3596-3604 .

[5] Zhao S.Q., Suo Q., Ma Y.F., Dong L. (2020) Wide-area complementary planning method for renewable energy based on complex adaptive system theory. Power System Technology.,2020,44(10):3671-3681.

[6] Jiang H.Y., Du E.S., Zhu G.P., Huang J.H., Qian M.H., Zhang N. (2020) Summary and prospect of seasonal energy storage for high-proportion renewable energy power systems. Automation of Electric Power Systems.,44(19):194-208.

[7] Ma J., Li Q.Y., Ding Y., Fu K.Y., Liu S.F., Jin J. (2020) Evaluation index system and calculation method for flexibility of distribution network with high-permeability renewable energy. Journal of Electric Power System and Automation, 2020 ,32(09):99-104+112.

[8] Wen Y.F., Yang W.F., Wang R.H., Xu W.T., Ye X., Li T. (2020) Review and Prospect of Constructing 100% Renewable Energy Power System. Proceedings of the Chinese Society for Electrical Engineering., 40(06):1843-1856.