Effect of the Digital Transformation of Power System on Renewable Energy Utilization in China

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ABSTRACT Renewable energy is the development direction of power system of China. To further boost the development of China’s power industry, the digital transformation of the power is underway. This study examined the panorama of digital transformation of power system of China. Through analyzing the effect of digital transformation on renewable energy utilization, three business applications were identified: short-term prediction of renewable energy output, renewable energy equipment maintenance, and intelligent power-grid maintenance. The implementation process and effect of the three business applications are analyzed by using the data covering 2012–2019 from three aspects: the short-term prediction accuracy of renewable energy output, the reduction of the fault restoration mean time for renewable energy equipment to the industry average, the reduction ratio of the mean time of power grid fault restoration to the industry average, and the rate of renewable energy utilization. The results indicated that digital transformation boosted the efficiency of renewable energy utilization. Based on the findings, the following suggestions are proposed for improving the digital transformation of the power industry and thereby promoting renewable energy utilization: 1) the first is to emphasize the scale efficiency of digital application in the early stage of digitization and renewable energy development, and emphasize the technical performance of a digital application in the middle and later stages of development; 2) the second is to enhance data accuracy, such as meteorological data, historical data for renewable energy power stations, power equipment status data, and strengthen the application of algorithms and computational models; 3) the third suggestion is to improve the overall digitalization rate of the power industry.

INDEX TERMS Digital transformation, power system, renewable energy, empirical analysis.

ACRONYMS

| ACRONYMS             |                  |
|----------------------|------------------|
| Data envelopment analysis | DEA           |
| Overall technical efficiency | OTE          |
| Pure technical efficiency | PTE          |
| Scale efficiency     | SE               |

I. INTRODUCTION
China proposes to achieve a carbon peak by 2030 and carbon neutral by 2060, so as to promote low-carbon development of power industry [1]. Renewable energy will become one of the main energy sources in the power system of China. Building a new type of power system based on renewable energy is the development direction of power system of China [2], [3].

The output of renewable energy power generation (such as wind power and photovoltaic) has natural randomness and volatility. Ensuring the utilization of new energy in the power system is a key problem in the operation of China’s power system [4], [5]. It is an important means for the power industry of China to ensure the stable utilization of renewable energy in the power system by constructing sufficient transmission channels, configuring energy storage, improving the
flexibility of power users, and using digital analysis and application of power business [6], [7]. Digital analysis and application of power business is an important combination field of power industry and industry 4.0. With the help of digital means such as data analysis, artificial intelligence algorithms and Internet of things technology, the information perception, feature extraction and intelligent control ability of new power systems can be improved [8], [9]. Digital technology has played an important role in supporting renewable energy consumption in the past, and the industry regards it as one of the breakthrough points of new power system in the future [10], [11]. Among them, the use of digital analysis application to improve the power system business capacity is an important work in the above means.

Researchers have carried out a lot of research on the application of digital technology in renewable energy power generation output prediction, renewable energy equipment maintenance and power grid equipment maintenance, and also conducted the application of digital technology on other aspects, such as energy system planning.

Accurate prediction of renewable energy output plays an important role in renewable energy power system operation and renewable energy utilization, and a large number of wind power units are integrated into power grid operation. High prediction accuracy of renewable energy output can be obtained by using the information of environment temperature, relative humidity, atmospheric pressure, and so on [12]. Iranian scholars use tree-based learning algorithms to achieve high-precision long-term wind energy prediction, and serve the reliable and efficient operation of large-scale wind power grids [13]. Wind power prediction is one of the effective ways to support the integration and absorption of large-scale wind power on power grid, combining the information of the day ahead numerical weather forecast and the neural network comprehensive prediction algorithm can effectively improve the accuracy of wind power prediction [14]. At the same time, using wind power output prediction information and wind farm joint scheduling operation strategy algorithm can effectively improve the capacity of wind power utilization [15].

The safe operation of renewable energy power generation equipment and power grid equipment directly affects the transmission and utilization of renewable energy power generation, neural network algorithm can effectively improve the fault detection accuracy of renewable energy power system equipment, improve the service quality of renewable energy power system for customers, and ensure the utilization of renewable energy [16]. The hybrid fault detection system for wind turbine blades driven by the data from wind farm supervisory control and data acquisition system can detect the early failure of blades accurately and improve the availability of wind turbine units [17]. Data-driven analysis of the health level of wind turbines can reasonably distribute the active power output of wind turbines and effectively improve the operation efficiency of wind farms [18]. Through data mining technology to analyse the power system fault information, the function of power grid fault diagnosis is further optimized [19].

In conclusion, digital technology has been widely used in the power system and digital transformation of power systems is going on. Through the use of advanced renewable energy output prediction, renewable energy station intelligent maintenance, power grid intelligent maintenance, the accuracy of renewable energy output prediction and the improvement of operational reliability of power system equipment are important and key factors affecting renewable energy utilization.

Researchers have also researched the effect of renewable energy utilization. EV fast-charging load can improve the flexibility of power dispatching and promote the utilization of renewable energy [20], [21]. The 2020 and 2030 energy strategies of the European Union increase renewable energy utilization [22]. Specific market mechanisms can promote renewable energy utilization [23]. The capacity of energy storage in renewable energy power systems has an impact on renewable energy utilization [24], [25]. The cooperation of the peak shaving effect of battery energy storage and thermal storage electric boiler coordinated operation is of great significance for the safe and stable operation of wind power [26]. Flexible electric vehicle charging mode is conducive to renewable energy utilization [27]. The effect of the superconducting fault current limiter (SFCL) on an electric power grid with the wind-turbine generation is also analyzed [28].

II. RESEARCH GAP

With the rapid development of renewable energy and power digitalization, researchers have carried out a lot of research on the application of digital technology in power system, and the impact of electric vehicles, energy storage, market mechanism and integrated energy system on the utilization of renewable energy. However, how to determine the relationship between digital transformation of power system and utilization of renewable energy and analyze the effect of the digital transformation on renewable energy utilization in power system as a very important problem has not been studied.

The purpose of the study is to analyze the changes of pure technical efficiency (PTE) and scale efficiency (SE) of digital transformation on renewable energy utilization and find the relationship between digital transformation of power system and utilization of renewable energy, and point out the development direction of digital transformation to support renewable energy power system.

The contributions of this study are: 1) analyze the impact of power digital transformation on renewable energy utilization. Constructs a quantitative method for analyzing the impact of China’s power digital transformation on renewable power systems. Taking the impact of China’s power digital transformation on renewable energy consumption as the analysis object, this paper analyzes the impact of power digital transformation on renewable energy utilization from
two aspects of PTE and SE to find the relationship between digital transformation of power system and utilization of renewable energy and find the relationship between digital transformation of power system and utilization of renewable energy. 2) Based on the results of impact analysis, in order to improve the renewable energy utilization capacity of power systems from the perspective of digital transformation, this paper puts forward suggestions on the optimized development path of digital application of power industry suitable for China and regions with different stages of renewable energy development.

The rest of this paper is organized as follows. Section 2 examines business application models that influenced renewable energy utilization in the process of digital transformation, as well as the effects of such applications. This section also presents a quantitative model for examining the effect of digital transformation on renewable energy utilization. Section 3 investigates the practical patterns of business applications that have important effects on renewable energy utilization. In addition, the data sources for the empirical analysis are described. In section 4, the influence of the digital transformation of power on renewable energy utilization in China is empirically analyzed using data collected from a region in Northwest China. In section 5, the development of PTE and SE of the effect of digital transformation of power system on renewable energy utilization in China is discussed, suggestions for promoting renewable energy utilization by means of the digital transformation of power in China and different stages of renewable energy development are proposed.

III. MODELING THE EFFECT OF THE DIGITAL TRANSFORMATION OF POWER SYSTEM ON RENEWABLE ENERGY UTILIZATION

A. INFLUENCING FACTORS

Digital transformation has been implemented in various industries in China, and digital transformation of power industry is the continuation and development of informatization.

Typical framework of digital transformation of the power grid industry in China is shown in Figure 1, and the typical framework of digital transformation of the power generation industry in China is shown in Figure 2 [29].

Various types of data-acquisition devices are used to enhance data-acquisition ability for the planning, design, and operation of power systems. Digitalized platforms and business services, as well as advanced algorithm applications, have been introduced to support the implementation of digitalization in the power industry.

Digitalization can help power planners and designers to more accurately understand the distribution of resources such as wind and solar energy, as well as the on-site construction of power facilities. It can also optimize planning and design schemes for power stations and grids. Digital transformation can, moreover, give managers accurate information regarding coal, power equipment, and other power-grid materials so they can develop optimal materials-management strategies. In short, the digital transformation of power can optimize power industry supply chain management.

Digital transformation can help management to accurately get more accurate prediction information of wind power, solar energy and water resources, while also providing information on power generation, power grids, and equipment status. This will facilitate accurate maintenance, management, and power dispatch planning; give flexibility to power system users; improve the efficiency of the power generation system; and promote the optimal utilization of various kinds of energy (e.g., renewable energy, thermal power, and hydropower). Therefore, from planning and design to production, operation, and materials management, digital transformation will improve every aspect of the power industry.

Renewable energy utilization capacity is the focus of the power industry of China. It is also a key empowering direction for the digital transformation of power system in China. We use the Delphi method to investigate and analyze impact indicators of digital transformation of power system on renewable energy utilization in China. From the perspective of renewable energy power generation, it needs the output prediction information of renewable energy power stations, the reliable operation of renewable energy power generation equipment and power grid equipment to achieve the effective utilization of renewable energy.

In the digital business application, short-term predictions of renewable energy output application enable power dispatching staff to know the generating capacity of renewable energy units and draw up dispatching and operational...
plans according to electricity market demand and the capacities of thermal power plants, hydropower stations, and other power stations. Moreover, renewable energy equipment maintenance guidance application can remind power station operators of the fault status of renewable energy equipment, support the planning of renewable energy equipment maintenance, ensure utilization efficiency, and smooth the implementation of renewable energy dispatching plans. Likewise, power grid equipment maintenance guidance application can provide grid operators with the fault status of power grid equipment, support the planning of equipment maintenance, guarantee the stable operation of power grid equipment, and provide power transmission channels for all power sources, including renewable energy and thermal power.

Based on the information, the short-term prediction of renewable energy output, renewable energy equipment maintenance, and intelligent power grid maintenance is achieved by optimizing the application of data and algorithms. Based on the operation requirements of renewable energy power stations and the functions of business application of power digitalization, the short-term prediction of renewable energy output application, renewable energy equipment maintenance guidance application, and intelligent power grid maintenance guidance application are directly connected to the formulation and successful implementation of renewable energy power generation plans.

Three major factors of use effect of these three applications that directly affect renewable energy utilization in the digital transformation process include the following: the short-term prediction accuracy of renewable energy output, the proportion of the mean time for the fault repair of renewable energy equipment to the industry average, and the proportion of the mean time for the fault repair of the power grid to the industry average. Thus, these three factors were chosen as the input indicators while the renewable energy utilization rate was chosen as the output indicator for the empirical analysis. Impact indexes of power industry digital transformation on renewable energy utilization rate are shown in Table 1.

Short-term prediction accuracy of renewable energy output is calculated by dividing the short-term output prediction value of renewable energy by the actual output value of renewable energy. The proportion of the mean time for the fault repair of renewable energy equipment to the industry average is obtained by dividing the average maintenance time of renewable energy power station after using the application of intelligent maintenance of renewable energy power station by the average maintenance time of renewable energy power station. The proportion of the mean time for the fault repair of the power grid to the industry average is obtained by dividing the average maintenance time of power grid maintenance intelligent maintenance by the average maintenance time of power grid equipment. Renewable energy utilization rate is obtained by dividing the utilized renewable energy by the renewable energy actual output.

**TABLE 1. Impact indexes of power industry digital transformation on renewable energy utilization rate.**

| Dimension          | Type                                      | Unit |
|--------------------|-------------------------------------------|------|
| Input indicator 1  | Short-term prediction accuracy of renewable energy output | %    |
| Input indicator 2  | The proportion of the mean time for the fault repair of renewable energy equipment to the industry average | %    |
| Input indicator 3  | The proportion of the mean time for the fault repair of the power grid to the industry average | %    |
| Output indicator   | Renewable energy utilization rate          | %    |

**B. DEA-BASED MODELING**

The influence of the digital transformation of power system in China on renewable energy utilization are complex and systematic, this influence is characterized by marginal-benefit uncertainty. Data envelopment analysis (DEA) is an efficient evaluation method for multiple input-output system. It can be used to analyze the influence of input indicators on the development efficiency of output indicators [30]. Given its high objectivity, DEA is an ideal analysis model for this study.

Compared with DEA models such as the CCR model, BBC model can get PTE excluding the influence of scale, SE and overall technical efficiency (OTE) based on variable conditions of returns to scale and has high objectivity [31]. BCC model is consistent with the analysis of this study.

A variable return to scale-based BCC model was used to analyze and evaluate the effect of the digital transformation of power industry on renewable energy utilization in China. This allowed for identifying the OTE, PTE, and SE of renewable energy utilization generated by digital transformation. The basic BCC model is shown in equations (1) and (2).

\[
\begin{align*}
\min_{\theta} & = V_D \\
\text{s.t.} & = \sum_{j=1}^{n} \lambda_j x_j + S^- = \theta x_0 \\
& = \sum_{j=1}^{n} \lambda_j y_j - S^+ = y_0 \\
& = \sum_{j=1}^{n} \lambda_j = 1 \\
\lambda_j & \geq 0, S^- \geq 0, S^+ \geq 0 (j = 1, 2, \ldots, n)
\end{align*}
\]
The dual BCC model is

\[
\begin{align*}
\max & \quad \mu^T y_0 + \mu_0 = V_p \\
\text{s.t.} & \quad W^T x_j - \mu^T y_j - \mu_0 \geq 0 (j = 1, 2, \ldots, n) \\
W^T x_0 &= 1 \\
W^T &\geq \epsilon e_m, \mu^T \geq \epsilon e_s
\end{align*}
\]

where \( x_j \) is the input variable, \( y_j \) is the output variable, \( x_0 \) is the initial input, \( y_0 \) is initial output, \( \lambda_j \) is the weight coefficient, \( S^- \) is the input slack variable, \( S^+ \) is the output slack variable, and \( \theta \) is measured distance.

We build a BCC computational model using the Mydea software to achieve the BCC calculation. The calculation process is as follows.

FIGURE 3. The calculation process of the BCC computational model.

IV. PRACTICAL ANALYSIS AND DATA SOURCES

A. PRACTICAL ANALYSIS OF THE DIGITAL TRANSFORMATION OF POWER SYSTEM IN CHINA

1) SHORT-TERM PREDICTION OF RENEWABLE ENERGY OUTPUT

Figure 4 shows the mechanism of the short-term prediction of renewable energy output. Numerical weather prediction information, the historical output data of renewable energy power stations, and weather station data served as the basic input data. A multisource (including numerical weather predictions) data-based model for the short-term prediction of renewable energy output was analyzed and calculated to obtain predicted values for the output power of renewable energy power stations in the next 24 hours.

With more accurate numerical weather prediction, accumulated historical output data for renewable energy power stations, and the sophisticated use of data-mining algorithms, the short-term prediction of renewable energy output will become increasingly accurate.

FIGURE 4. Mechanism of the short-term output prediction of renewable energy.

2) RENEWABLE ENERGY EQUIPMENT MAINTENANCE

In the maintenance of renewable energy equipment, combined online-offline maintenance has been adopted based on digital platforms for renewable energy power stations. This is combined with online equipment inspection, operation, and maintenance, as well as offline routing inspection.

Figure 5 shows the mechanism of renewable energy equipment maintenance. Real-time online monitoring of equipment-operation status in renewable energy power stations is implemented using digital platforms and equipment fault-detection systems. Prediction and early warning of possible equipment problems are performed using data-analysis technology based on on-site meteorological data and operational data from power generation equipment. When an equipment fault alarm occurs, the inspection, operation, and maintenance staff of the renewable energy power station will immediately carry out on-site equipment maintenance.

Implementing renewable energy equipment maintenance aims to hasten equipment fault diagnosis and repair. With the advances in monitoring technologies and improvements in the data-analysis capacity of digital platforms, the mean time to the fault restoration of renewable energy equipment has been reduced.

3) INTELLIGENT POWER-GRID MAINTENANCE

Intelligent power grid maintenance depends on the power grid equipment status monitoring system and the data-analysis capacity of the digital analysis platform. Figure 6 shows the implementation mechanism for intelligent power grid
maintenance. By monitoring the operational status of power grid equipment in real-time, the system will give early warnings about exceptions and fault events and send a fault message to operations and maintenance staff, based on which fault maintenance will be carried out.

FIGURE 6. Mechanism of intelligent power grid maintenance.

The purpose of implementing intelligent power grid maintenance is to spot faults in power grid equipment more quickly and reduce maintenance time. With progress in monitoring technologies for the operational status of power grid equipment and the data-analysis capacity of digital-analysis platforms, the mean time for power grid fault restoration has also been reduced.

B. DATA SOURCES FOR THE INDICATORS OF THE DIGITAL TRANSFORMATION OF POWER

Renewable energy is developing rapidly in China. Abundant renewable energy resources that feature favorable development conditions have been discovered in a region in Northwest China. The region has become well known for its rapid development in the installed capacity of renewable energy power. During 2012–2019, the installed capacity of renewable energy power in this region grew dramatically from 3.59 million kW to 20.342 million kW, for a cumulative increase of 16.752 million kW and an annual increase of 2.393 million kW.

While developing renewable energy, the region managed to reduce the wind and solar power abandonment rate from 14.4% in 2012 to 2.76% in 2019. Meanwhile, the efficiency of its renewable energy utilization increased from 85.6% to 97.24%—a cumulative increase of 11.64%.

This region has experienced every developmental stage, from facing serious problems in renewable energy utilization (e.g., high wind and solar power abandonment rates) to making efficient use of renewable energy. In this way, it is a typical region of renewable energy development in China. Thus, the region was chosen as the sample for this study. Data on renewable energy in the region during 2012–2019 are collected from the report and the company statistics data of State Grid Energy Research Institute and used to analyze the effect of digital transformation on the efficiency of renewable energy utilization[32].

V. EMPIRICAL ANALYSIS OF DIGITAL TRANSFORMATION’S EFFECT ON RENEWABLE ENERGY UTILIZATION

The data for input indicators 1,2 and 3 and output indicator using for the BCC model are shown in Table 2. Figure 7 illustrates the variations in the data presented in Table 2.

FIGURE 7. Trends in characteristics of the digital transformation of power industry and the renewable energy utilization rate in a region in Northwest China.

With progress in the digitalization of power systems, the short-term prediction accuracy of the renewable energy output of the region improved year by year, from 84.20% in 2012 to 91% in 2019. At the same time, the proportion of mean time to the fault repair of renewable energy equipment to industry average dropped from 77% to 28.50%, and so had rate of the mean time to power grid fault repair to industry average—from 84.50% to 45%. By contrast, the renewable energy utilization rate improved from 85.60% to 97.24%.

The renewable energy utilization rate changed in the same direction as the short-term prediction accuracy of renewable energy output; it changed in the opposite direction as the mean time to the fault restoration of renewable energy equipment and of the power grid to the industry average. According to this trend, the increase in the short-term prediction
accuracy of renewable energy output helped improve the utilization rate of renewable energy, and so did the decrease in the mean time to the fault restoration of renewable energy equipment and of the power grid to the industry average.

The effect of the digital transformation of power industry on the efficiency of renewable energy utilization was quantitatively analyzed using the Mydea application. Table 3 presents the results for OTE, PTE, and SE; Figure 8 shows the variation trends.

### TABLE 3. Results for the effect of the digital transformation of power industry on the efficiency of renewable energy utilization.

| Year | OTE  | PTE  | SE   |
|------|------|------|------|
| 2012 | 0.582| 1.002| 0.581|
| 2013 | 0.619| 1.001| 0.618|
| 2014 | 0.657| 0.981| 0.670|
| 2015 | 0.688| 1.000| 0.688|
| 2016 | 0.74 | 1.000| 0.740|
| 2017 | 0.807| 1.004| 0.804|
| 2018 | 0.919| 1.002| 0.917|
| 2019 | 1.092| 1.099| 0.994|

According to the analysis of variations in the efficiency of renewable energy utilization in the region during 2012–2019, the OTE of renewable energy utilization rose from 0.582 to 1.092 with the enhancement of the short-term prediction accuracy of renewable energy output and the reduction in the mean time to the fault restoration of renewable energy equipment and the power grid to the industry average. This suggests that the OTE of renewable energy utilization progressively increased with the stimulation of the three factors.

The PTE of renewable energy utilization rose with fluctuations from 2012 to 2016, and a significant increase occurred during 2016–2019. The SE of renewable energy utilization also increased from 0.581 to 0.994, narrowing the gap between the actual scale and the optimal level. Driven by the three factors identified in this study, the SE of renewable energy utilization rapidly approached the optimal level. In the early stage of development, the improvement of SE is more remarkable than PTE, and in the middle and late stage of development, the PTE is significantly improved.

### VI. CONCLUSION AND SUGGESTIONS FOR DIGITAL TRANSFORMATION AND RENEWABLE ENERGY UTILIZATION

#### A. MAJOR CONCLUSION

This paper focuses on the PTE and SE of the effect of digital transformation of power system on renewable energy utilization in China. A quantitative analysis model is built based on the BCC model which can analyze the PTE and SE. Short-term prediction accuracy of renewable energy output, reduction in the mean time to the fault restoration of renewable energy equipment to the industry average, the reduction ratio of the mean time to power grid fault restoration to the industry average are chosen as input indicators to carry out an empirical analysis of the effect of digital transformation of power system on new energy utilization.

Digital transformation would contribute to improving the utilization rate of renewable energy. In the early stage of digital development, the improvement of SE of business application of power digitalization has a significant impact on the utilization rate of renewable energy. In the middle and late stages of development, the improvement of technical efficiency has a significant impact on the utilization rate of renewable energy. The main conclusions are as follows.

1) As a result of progress in digitalization, the application efficiency of the short-term output prediction of renewable energy, renewable energy equipment maintenance, and intelligent power grid maintenance constantly improved from 2012 to 2019. With steady improvements in the short-term output prediction of renewable energy and the constant reduction in the mean time to the fault restoration of renewable energy equipment and the power grid, the power industry obtained increasing business efficiency.

2) Digital transformation has become an important means for China’s power industry to improve industry wide production efficiency and energy utilization efficiency. The short-term output prediction of renewable energy, renewable energy equipment maintenance, and intelligent power grid maintenance have significantly affected the efficiency of renewable energy utilization during the digital transformation of power industry.

3) From 2012 to 2019, the renewable energy utilization rate changed in the same direction as the short-term prediction accuracy of renewable energy output and in opposite directions as the mean time to the fault restoration of renewable energy equipment and the power grid. Under the joint action of enhanced short-term output prediction and reduced time to fault restoration, the OTE, SE and PTE of the digital transformation of power system on the renewable energy utilization are improved, the efficiency of renewable energy utilization continued to rise. This indicates that digital transformation has helped to boost the efficiency of renewable energy utilization.
4) From 2012 to 2016, the PTE of power digital transformation on renewable energy utilization remained at about 1. With the increasing SE of digital transformation of power system on renewable energy utilization, the utilization rate of renewable energy increased significantly; From 2016 to 2019, with the significant improvement of PTE of digital transformation of power system, the utilization rate of renewable energy increased significantly.

In the early stage of digital business application, the short-term prediction of renewable energy output, the maintenance guidance of renewable energy equipment and the guidance of intelligent maintenance of power grid are used in a large scale, which directly promotes the improvement of renewable energy utilization. When the three types of business applications reach a certain scale, the improvement of the technical performance of the three business applications is more important for the improvement of renewable energy utilization.

B. SUGGESTIONS

1) In the process of large-scale development of renewable energy, the promotion and application scale of business application of digital transformation should be more emphasized in the early stage of development, the technical performance requirements of business application of digital transformation should be more emphasized in the middle and later stage of development. In the development of renewable energy and business applications of digital transformation, the SE of the effect of three types of business applications of digital transformation on renewable energy utilization is increased significantly in the early stage, the PTE of the effect of three types of business applications of digital transformation on renewable energy utilization is increased significantly in the middle and later stage of development.

In different development stages of renewable energy power system, the application scale of three types of business applications of digital transformation in renewable energy power stations and power grid operation should be increased to guarantee the efficient utilization of renewable energy in early stage, the technical performance of three types of business applications of digital transformation should be more increased in the middle and later stage.

2) Improve the application of accurate data, advanced algorithms and computational models. Meteorological data, historical data of renewable energy power stations and equipment status data are the analysis basis of three types of business applications: short-term prediction of renewable energy output, the guidance of renewable energy equipment maintenance and guidance of power grid intelligent maintenance, algorithms and computing models are the running engines supporting the three types of business applications. The accuracy of data and the advanced and complete degree of algorithm and calculation model play an important role in improving the application effect of three types of business applications.

It is necessary to continuously improve the perfection and accuracy of data required by three types of digital business applications, and continuously improve the advanced ability of algorithm and the completeness of calculation model in the process of digital and renewable energy development.

3) Improve the overall development of the digital transformation of power system. Under the digital transformation of power system, the increased application efficiency of the short-term prediction of renewable energy output, renewable energy equipment maintenance, and intelligent power grid maintenance has boosted the efficiency of renewable energy utilization together. These three business applications have played a collaborative role with the support of data, algorithms, and business models.

The cooperation of these three business applications is a course of integrated development that depends on the collaboration of data, algorithms, and business models. To better support the digital transformation of power industry for renewable energy utilization, it is important to give overall consideration to data collection, algorithm optimization, business model, application collaboration of these three business applications and promote digital transformation in a coordinated manner.

Short-term prediction of renewable energy output, renewable energy equipment maintenance guidance and power grid intelligent maintenance guidance have a direct impact on the improvement of renewable energy utilization, indirect impact of other business applications of digital transformation of power system on renewable energy utilization should be paid attention to promote renewable energy utilization in the future.

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