Evaluation of energy saving and emission reduction effect of distributed energy system

Rong Ma, Yaotian Guo

State Grid Integrated Energy Service Group Co., Ltd., Beijing, 100053, China

Received August 30, 2023 Revised October 25, 2023 Accepted November 6, 2023

ABSTRACT
The conventional evaluation methods of energy conservation and emission reduction lack the discussion of quantification index of energy conservation and emission reduction potential, and the evaluation effect is poor. Therefore, an evaluation method for energy conservation and emission reduction of distributed energy systems is proposed, which considers system dynamics and demand response. According to the requirements of system dynamics analysis, the relational variables in the system dynamics model are determined. The input-output relationship of energy saving, and emission reduction effect evaluation is described by system dynamics equation, and the input-output relationship of energy saving, and emission reduction effect evaluation is determined. Based on the maximum profit objective function and the minimum cost objective function of the user, the continuum equation of the medium transmission process in the distributed energy system is obtained. The evaluation indexes of energy saving, and emission reduction effect are selected from the three aspects of power consumption side, power generation side and the system itself to realize the evaluation of energy saving and emission reduction effect. The experimental results show that the evaluation curve obtained by this method is basically consistent with the actual curve, and the evaluation accuracy is high.

Keywords: Demand response, Distributed energy system, Effect evaluation, Energy conservation and emission reduction, System dynamics
1. Introduction

Distributed energy system is a new form of energy organization, which can realize efficient energy utilization and reduce carbon emissions by dispersing the production and consumption of energy into several small energy systems [1-2]. Under the current global concern about climate change and sustainable development, it has become a task that cannot be ignored to establish a reliable and efficient distributed energy system. Energy saving and emission reduction is one of the core elements of the coordinated development of distributed energy system and environment [3-4]. In order to evaluate the energy saving and emission reduction effect of distributed energy systems, two important factors, system dynamics and demand response, need to be considered. It is of great significance to study the internal and external interaction of energy system by system dynamics for analyzing system behavior and predicting future trends [5-6]. Demand response focuses on adjusting energy supply according to the changes of users’ demand, so as to improve the utilization rate of energy resources and reduce energy waste. Therefore, it is of great significance to evaluate the energy saving and emission reduction effect of distributed energy systems.

Reference [7] puts forward an evaluation method of regional energy conservation and emission reduction efficiency in China based on the target-oriented method of extended DDF model. Based on the goal of energy saving and emission reduction in the national five-year plan, an extended direction distance function model including unexpected input and unexpected output is proposed, and energy saving efficiency, emission reduction efficiency and energy saving, and emission reduction efficiency are defined. Then, a weighted directional distance function model is constructed for the total factor efficiency index model of energy saving and emission reduction to reflect its dynamic changes. Reference [8] puts forward that the selection of “energy saving and emission reduction” demonstration cities is actually helpful to the pollution control in China.
Selection of comprehensive demonstration cities with national financial policies for energy conservation and emissions reduction is an important evaluation policy to promote the construction of ecological civilization in China. An accurate assessment of the environmental effects of this policy is of great significance to its promotion. The difference model in the difference is used to discuss the role of the model city policy in urban environmental governance. Reference [9] puts forward the development of Vietnam's road emission inventory and the evaluation method of future emission reduction policy intervention. In this study, the emission list of Vietnam's road transport base year in 2010, 2015 and 2019 was updated, and the years 2020, 2025 and 2030 were predicted. Generally speaking (base year of 2019), motorcycles contributed a lot of carbon monoxide, non-methane volatile organic compounds, PM10, PM2.5, organic carbon and methane (about 53%-89%), while BC, nitrogen oxides and sulfur dioxide mainly came from diesel-powered trucks (about 42%-76.3%). It is estimated that the national emissions of two rapidly developing cities (Hanoi and Ho Chi Minh) are 11%-16.2% and 16.6%-20.2% respectively, and carbon dioxide is considered to be the main pollutant (accounting for 41% of carbon dioxide equivalent) that causes global warming in Vietnam.

Therefore, this paper puts forward an evaluation method of energy saving and emission reduction effect of distributed energy system considering system dynamics and demand response. According to the needs of system dynamics analysis, the relevant variables in the system dynamics model are determined, and the input and output of the evaluation of energy saving and emission reduction effect of distributed energy system are systematically analyzed by using the system dynamics equation to determine the related variables simulated by the system dynamics model. Based on the consideration of energy consumption reduction, emission reduction, economic benefits and environmental benefits, the demand response model is established, and the evaluation index results of energy saving and emission reduction effect under the demand response condition are calculated by using the objective function. The distributed energy quantity is calculated from three aspects: energy consumption side, power generation side and distributed energy system. Combined with the extended evaluation method, the distributed energy quantity is evaluated to complete the evaluation of energy saving and emission reduction effect of distributed energy system. The contributions of this method are as follows:

1. This method not only considers the energy consumption and emission reduction effect of distributed energy system, but also considers the economic and environmental benefits. By establishing the system dynamics model, the input and output of the evaluation of energy saving and emission reduction effect of distributed energy system are systematically analyzed, and the relationship variables simulated by the system dynamics model are determined, which makes the evaluation process more scientific and rigorous.

2. On the basis of considering energy consumption reduction, emission reduction, economic benefits and environmental benefits, the demand response model is established, and the evaluation index results of energy saving and emission reduction effect under demand response conditions are calculated, so that the evaluation results are more in line with the actual situation.

(3) Calculate the distributed energy quantity from three aspects: energy consumption side, power generation side and distributed energy system, and evaluate it with extended evaluation method. This comprehensive evaluation can consider the weight and correlation of each index more comprehensively and provide a more comprehensive and accurate evaluation result.

2. Evaluation of Energy Saving and Emission Reduction Effect of Distributed Energy System

2.1 Evaluation of Energy Saving and Emission Reduction Effect under System Dynamics

The evaluation of energy saving and emission reduction effect of distributed energy system is based on the principle of system dynamics analysis [10,11], and the related variables in the system dynamics model are determined according to the needs of system dynamics analysis, and then the original data about the related variables are brought into the system dynamics model, and the input and output of energy saving and emission reduction effect evaluation of distributed energy systems are systematically analyzed by using the system dynamics equation, which provides data basis for the development strategy of distributed energy system [12]. According to the causality of distributed energy system, the relationship variables of system dynamics model simulation are determined. The main variables involved in the simulation calculation process are demand variables, energy generation variables, energy storage variables, power grid coupling variables and energy flow variables.

Demand variable: It mainly includes power demand, heat demand and cold energy demand, and the demand is related to the user's demand for electricity, heating and refrigeration.

Energy generation variable: It mainly includes solar power generation, wind power generation, biomass power generation and other renewable energy sources, as well as traditional energy sources such as gas and coal.

Energy storage variable: It usually includes battery energy storage, compressed air energy storage, thermal storage and so on. The state and capacity of energy storage equipment can affect the energy storage and release capacity of the system.

Power grid coupling variable: The coupling relationship includes power supply, current, etc. The distributed energy system is connected with the power grid through bidirectional power grid and microgrid.

Energy flow variable: Energy flow variables can include power transmission, thermal energy transmission and refrigeration energy transmission, and the flow of energy in distributed energy system is also one of the important contents of dynamics.

On the basis of system dynamics variables, the relationship between input and output of energy saving and emission reduction effect evaluation is described by using the following system dynamics equation, and the formula is as Eq. (1):
In Eq. (1), \( S \) represents the output value of energy saving and emission reduction effect evaluation; \( D \) stands for the increment of investment in energy saving and emission reduction effect evaluation; \( F \) stands for the operating capital cost of energy saving and emission reduction effect evaluation; \( T \) represents the capital cost of the organization for evaluating the effect of energy conservation and emission reduction; \( E \) represents the maintenance capital cost of energy saving and emission reduction effect evaluation; \( X \) represents the capital cost of purchasing sports facilities for evaluating the effect of energy saving and emission reduction; \( L \) stands for incentive fund for energy conservation and emission reduction effect evaluation; \( Z \) stands for the total output value of energy conservation and emission reduction effect evaluation; \( Y \) represents the proportion of funds for the evaluation of energy conservation and emission reduction effects; \( O \) represents the proportion of incentive funds for energy conservation and emission reduction effect evaluation. Using the above formula, the relationship between input and output of energy saving and emission reduction effect evaluation is determined, and the positive and negative feedback between the related variables involved is systematically described. The specific relationship is shown in Fig. 1.

According to Fig. 1, it can be seen that the input of each subject in the evaluation of energy-saving and emission-reduction effect is various, and the output corresponding to the input is also various, and the value return in the dominant direction is more prominent, and the input and output of energy-saving and emission-reduction effect evaluation are closely related. Increasing the output of energy-saving and emission-reduction effect evaluation, reducing the economic input of energy-saving and emission-reduction effect evaluation, and coordinating and controlling the input and output of energy-saving and emission-reduction effect evaluation in this state are the keys to promote the development of distributed energy systems. Taking the system dynamics method as the basic framework for evaluating the effect of energy conservation and emission reduction, the effect of energy conservation and emission reduction is evaluated in more detail and accurately by introducing the factors and influences of demand response, so as to improve the implementation effect of energy conservation and emission reduction strategies.

### 2.2 Effect Evaluation of Energy Saving and Emission Reduction under Demand Response

Demand response is a way to realize energy saving and emission reduction by adjusting users' demand behavior for energy in distributed energy supply and demand system. The effect evaluation of energy saving and emission reduction under demand response is mainly to evaluate and analyze the effect of energy saving and emission reduction that can be achieved through demand response [13]. In the evaluation of energy saving and emission reduction effect under demand response, the following aspects can be considered:

1. **Energy consumption reduction**: Energy consumption can be reduced through demand response measures, optimization of electricity consumption strategies, promotion of energy-efficient equipment, etc.

2. **Emission reduction**: The reduction of energy consumption will also lead to the reduction of emissions. By using low-carbon energy or adopting more environmentally friendly energy conversion methods and using renewable energy, the emission reduction effect will be more significant.

3. **Economic benefits**: Demand response measures involve investment costs such as technology upgrading and equipment renovation, but in the long run, the energy-saving and emission-reduction effects brought by them will also generate economic benefits.

4. **Environmental benefits**: The effect of energy saving and emission reduction caused by demand response has a positive impact on the environment, reducing the emission of atmospheric pollutants and alleviating the increase of greenhouse gases. Environmental quality indicators or ecological footprints are used to quantify environmental benefits in the assessment.

The evaluation method of energy saving and emission reduction effect of distributed energy system requires the establishment of demand response model, and the structure of demand response model is shown in Fig. 2.

The energy supplier encourages users to reduce the peak heat load demand through policies such as peak shifting, so as to improve the heat load curve, which is the heat load demand response based on incentives. Set the minimum supply limit value and
the penalty item of non-response and unfinished to alleviate the low response state caused by discomfort in the process of heat load reduction.

Assuming that \( V \) represents the profit value of the end user, the formula of the user’s maximum profit objective function \( \max V \) is expressed as Eq. (2):

\[
\max V = \frac{\Psi - \partial - N}{S \times L}
\]

In Eq. (2), \( \Psi \) represents the user’s response income; \( \partial \) stands for penalty term; \( N \) represents the user’s heat cost and response cost.

Assuming that \( t_0 \) is used to represent the response time, the \( \min V_0 \) formula of the minimum cost objective function is further derived and expressed as Eq. (3):

\[
\min V_0 = \Delta Q \times J_G \times t_0 \times o \times \Delta Q_o
\]

In Eq. (3), \( \Delta Q \) represents the actual heat load reduction of users; \( J_G \) represents the actual heat price; \( o \) represents the discount price after reducing the heat load; \( \Delta Q_o \) represents the thermal load before response.

The application of maximum profit objective function and minimum cost objective function in distributed energy system is analyzed, and on this basis, the continuous equation of thermal system in the process of media transmission in distributed energy system is obtained, as Eq. (4):

\[
L_{XFC} = \frac{S_{wp} \times q_w \times p_w}{\max V - \min V_0}
\]

In Eq. (4), \( q_w \) represents the node injection flow; \( p_w \) represents the output flow of the node; \( S_{wp} \) represents the correlation coefficient of nodes in the distributed energy system network.

The heat conservation equation is used to describe the transmission process of hot and cold fluids in the distributed energy system [14-15], and the total loss, output and input heat are 0, that is, \( L_{XFC} = 0 \). When there are different fluids in the node, the following mixed equation is constructed to obtain the evaluation results of energy saving and emission reduction effect under demand response, as Eq. (5):

\[
(\sum q_{w1} T_{w1}) = (\sum q_{w2} T_{w2})
\]

In Eq. (5), \( q_{w1} \) and \( T_{w1} \) respectively represent the mass flow and temperature input by the node; \( q_{w2} \) and \( T_{w2} \) represent the mass flow and temperature output by the node respectively.

Based on the above indicators, the effect of energy saving and emission reduction under demand response is quantitatively evaluated and analyzed by establishing a system dynamics model or a method based on data statistics. This evaluation is helpful to optimize the design and implementation of demand response measures to achieve the maximum energy saving and emission reduction effect.


3.1 Evaluation Index System

The evaluation method of energy saving and emission reduction effect of distributed energy system selects the evaluation index of energy saving and emission reduction effect from three aspects: power consumption side, power generation side and the system itself.

3.1.1 Power consumption side

(1) The proportion of investment in new energy grid-connected construction \( \varepsilon \), as Eq. (6):

\[
\varepsilon = L_{XFC} \times \sum_{i=1}^{N} \frac{\phi}{\phi} (q_{out} - q_{in})
\]

In Eq. (6), \( \phi \) represents the total annual investment in energy conservation and emission reduction construction of distributed energy systems; \( N \) represents the quantity of distributed energy; \( \phi \) represents the investment quota corresponding to the first \( i \) distributed energy in the construction process.

(2) Maximum load supply capacity \( G_0 \), as Eq. (7):

\[
G_0 = \sum_{i=1}^{N} D_i \times V_i \times \varepsilon
\]

In Eq. (7), \( V_i \) represents the assets corresponding to the maximum load capacity of the energy storage device in the distributed energy system; \( m \) represents the number of energy storage devices; \( D_i \) represents the maximum load supply capacity of the \( i \) energy storage device in the distributed energy system.

3.1.2 Power generation side

(1) The demand side in the system of electricity growth rate \( \mu \), as Eq. (8):

\[
\mu = G_0 \times \frac{P_i - P_{i-1}}{P_{i-1}}
\]

In Eq. (8), \( P_i \) and \( P_{i-1} \) respectively represent the total power saving realized in \( i \)-1 and \( i \) years when participating in DSM.

(2) Proportion of power consumption of charging station \( \iota \), as Eq. (9):

\[
\iota = \mu \times \sum_{i=1}^{W} \frac{W_i}{W}
\]

In Eq. (9), \( W \) represents the total electricity consumption of the distributed energy system; \( W_i \) represents the electricity consumption generated by the \( i \) charging station in the distributed energy system.

(3) Proportion \( \zeta \) of distributed power supply, as Eq. (10):
\[ \zeta = \sum_{i=1}^{n} \frac{H_i}{A} \]  
(10)

In Eq. (10), \( A \) represents the total power supply of the distributed energy system; \( H_i \) represents the grid-connected power of \( i \) distributed power supply in distributed energy system.

### 3.1.3 Distributed energy system

1. **Line loss management effect** \( \phi \), as Eq. (11):

\[ \phi = \zeta \times \frac{Z_{i-1} - Z_i}{Z_{i-1}} \]  
(11)

In Eq. (11), \( Z_i \) and \( Z_{i-1} \) respectively represent the comprehensive line loss rate of the distributed energy system in \( i \)-1 and \( i \) years.

2. **Low-carbon power dispatching proportion** \( \nu \), as Eq. (12):

\[ \nu = \phi \times \sum_{i=1}^{n} \frac{H_i}{E} \]  
(12)

In Eq. (12), \( E \) represents the total power supply of the distributed energy system.

### 3.2 Effect Evaluation of Energy Saving and Emission Reduction

Evaluation method of energy saving and emission reduction effect of distributed energy system adopts extension evaluation method to evaluate energy saving and emission reduction effect, and the specific steps are as follows:

**Step 1:** Determine the matter element to be evaluated.

Suppose \( R = (A, B, C) \) represents matter element, where \( A = \{a_1, a_2, ..., a_n\} \) represents things; \( B = \{b_1, b_2, ..., b_n\} \) stands for magnitude; \( C = \{c_1, c_2, ..., c_n\} \) represents characteristics, and the expression of matter element \( R \) is as Eq. (13):

\[ R = \begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ \vdots & \vdots & \vdots \\ a_n & b_n & c_n \end{bmatrix} \]  
(13)

Representing energy saving and emission reduction data of distributed energy system by matter-element \( R_0 \), as Eq. (14):

\[ R_0 = R \times R_{abc} \times \nu \]  
(14)

In Eq. (14), \( R_{abc} \) represents the distributed energy system to be evaluated.

**Step 2:** Determine the classic domain.

Classical domain \( R_0 = \{a_0, b_0, c_0\} \) represents the energy-saving and emission-reduction grade of distributed energy system and its characteristic data range, where \( a_0 \) represents the \( j \)-th energy-saving and emission-reduction grade of distributed energy system; \( b_0 \) represents the value range of the classical domain of the matter-element model of the \( j \)-th energy saving and emission reduction level of the distributed energy system; \( c_0 \) represents the value range of each energy-saving and emission-reduction effect evaluation index in the evaluation system, as Eq. (15):

\[ R_p = \begin{bmatrix} a_{p1} & b_{p1} & c_{p1} \\ a_{p2} & b_{p2} & c_{p2} \\ \vdots & \vdots & \vdots \\ a_{pn} & b_{pn} & c_{pn} \end{bmatrix} = \begin{bmatrix} a_1 & b_1 & (c_{p1}, b_{p1}) \\ a_2 & b_2 & (c_{p2}, b_{p2}) \\ \vdots & \vdots & \vdots \\ a_n & b_n & (c_{pn}, b_{pn}) \end{bmatrix} \]  
(15)

In Eq. (15), \( c_{pj} \) represents the value range \((c_{pj}, b_{pj})\) of energy saving and emission reduction effect index \( c_{pj} \) in the evaluation index system.

**Fig. 3.** Overall flow chart of evaluation method for energy saving and emission reduction effect of distributed energy system.
Step 4: Calculate the weights corresponding to the energy saving and emission reduction effect indicators.

Step 5: Correlation function value.
Calculate the proximity \( \theta(v_i, X_{ij}) \) and \( \theta(v_i, X_{0i}) \) between point \( v_i \) and intervals \( X_{ij} \) and \( X_{0i} \) by the following formula, as Eq. (16):

\[
\begin{align*}
\theta(v_i, X_{ij}) &= |v_i - \frac{c_{0j} + b_{0j}}{2} | \times R_j \\
\theta(v_i, X_{0j}) &= |v_i - \frac{c_{0j} + b_{0j}}{2} | \times R_p
\end{align*}
\]  

(16)

Step 6: Comprehensive evaluation.

Let \( L_1(a_0) \) represent the correlation degree of distributed energy system \( a_0 \) with respect to the \( j \) energy saving and emission reduction level, and its expression is as Eq. (17):

\[
L_j(a_0) = \sum_{i=1}^{n} w_i \times \left[ \theta(v_i, X_{ij}) + \theta(v_i, X_{0j}) \right]
\]  

(17)

In Eq. (17), \( w_i \) represents the weight of the evaluation index of energy saving and emission reduction effect, and the evaluation result of energy saving and emission reduction effect of distributed energy system is obtained through the above formula, thus completing the research on the evaluation method of energy saving and emission reduction effect of distributed energy system considering system dynamics and demand response. The overall flow of the algorithm is shown in Fig. 3.

4. Experimental Analysis

In order to verify the effectiveness of the evaluation method of energy saving and emission reduction effect of distributed energy system considering system dynamics and demand response, experiments were designed to verify it. Set up an experimental environment, select a small-scale area as the experimental scene, simulate the distributed energy system, and collect the energy data of each node in the experimental scene area. The experimental object selected in this experiment is a core distributed energy project in a city, and the overall construction area of this project is about 1200m². In order to compare the actual evaluation effects of different evaluation methods on the energy saving and emission reduction potential of the project, this experiment uses MATLAB simulation software to build the experimental object, and builds a simulation experimental environment by retrieving the parameters in the original construction scheme, including the main hardware and software equipment as follows:

Hardware: the server is configured as a 500G hard disk, which supports hot-plug hard disks and has uninterrupted power supply. In addition, two computers with 10M network bandwidth are configured.

Software: The server version is Microsoft.NET 4.0, and the client is configured as IE 6.0 Web browser. The platform is developed in C# language, and ASP.NET is used as the research and development environment.

The specific experimental process is as follows:

Step 1: Data collection: Collect the energy data of energy production, transmission and consumption nodes in the experimental environment, and monitor and record the energy flow with sensors and metering equipment. At the same time, the data of user demand, energy demand and peak-valley period are obtained.

Step 2: System dynamics modeling: Based on the collected data, the mathematical model of distributed energy system is established by using the modeling technology of system dynamics and Vensim software. The model includes the relationship between energy supply and demand, energy transmission process and price of each node, and considers uncertain factors.

Step 3: Design of demand response strategy: According to the energy demand data in the model, design the appropriate demand response strategy according to the experimental environment and research purpose. Use forecasting and optimization algorithms to adjust energy supply, improve energy resource utilization and reduce energy consumption.

Step 4: Simulation and evaluation: Apply the model and demand response strategy to the experimental environment for simulation and evaluation. Observe the operation of the system and the change of energy consumption through simulation experiments and record relevant data. At the same time, the effects of energy saving and emission reduction under different strategies are compared, so as to evaluate the effectiveness and feasibility of the method.

Step 5: Result analysis: According to the simulation and evaluation results, data analysis and result interpretation are carried out. The benefit index of energy saving and emission reduction is calculated and compared with the traditional evaluation method. According to the above process, the distributed energy system selected for this test is shown in Fig. 4.

Solar radiation intensity, wind speed and discharge rate can reflect the energy saving and emission reduction of distributed energy system. The above indicators are evaluated by the proposed method, reference [7] method and reference [8] method, and the evaluation results directly affect the evaluation accuracy of energy saving and emission reduction effect. The evaluation results of the three methods are shown in Fig. 5.

It can be seen from Fig. 5 that the evaluation curves of solar radiation intensity, wind speed and discharge rate obtained by...
the proposed method are basically consistent with the actual curves, while the evaluation curves of solar radiation intensity, wind speed and discharge rate obtained by the methods of reference [7] and reference [8] deviate from the actual values. Through the above tests, it can be seen that the proposed method can accurately complete the evaluation of energy saving and emission reduction effect of distributed energy system.

The energy-saving and emission-reduction data of distributed energy system are used to form a state sequence. When the value of the state sequence is 1, it indicates that the energy-saving and emission-reduction effect of the system is good; when the value of the state sequence is -1, it indicates that the energy-saving and emission-reduction work of the system is ineffective. The evaluation results of energy-saving and emission-reduction effects of different methods are shown in Fig. 6.

As can be seen from Fig. 6, the state sequence values obtained by the methods in Reference [7] and Reference [8] are quite different from the actual state sequence values of distributed energy system, and the state sequence values obtained by the proposed method are consistent with the actual state sequence values of distributed energy system, indicating that the proposed method has high evaluation accuracy and good evaluation effect in the evaluation of energy saving and emission reduction effect of distributed energy system. Because the proposed method constructs the demand response model, analyzes the operation characteristics of distributed energy system, and obtains the operation data, so as to improve the accuracy of the evaluation results and provide high-precision data support for the evaluation of energy saving and emission reduction effect of distributed energy system.

The load generated by distributed energy system during operation is measured, and three alternative energy-saving and emission-reduction effect evaluation schemes are set up. Based on the characteristics of three energy-saving and emission-reduction effect evaluation schemes, the index set of energy-saving and emission-reduction effect evaluation is normalized, and the index function of each alternative scheme is constructed. Table 1 is a record of relevant parameters of three energy-saving and emission-reduction effect evaluation schemes.

Combined with the contents in Table 1, three evaluation schemes of energy saving and emission reduction effects are described. Calculate the total energy efficiency ratio of distributed energy system respectively and use this index to quantify the ideal degree of energy-saving concept, energy-saving method and energy-saving means of energy-saving emission reduction effect evaluation scheme. The higher the total energy efficiency ratio, the better the effect of the selected scheme, and the calculation formula is as Eq. (18):

\[
U = \frac{U_t}{U_o} \times 100\% \quad (18)
\]

In Eq. (18), \(U\) represents the quantitative result of the ideal degree of energy saving and emission reduction of the embodiment; \(U_t\) stands for energy efficiency ratio of distributed energy system; \(U_o\) is expressed as the energy efficiency ratio of an ideal distributed energy system. According to the results calculated by the above formula, the energy-saving potential of the three schemes is calculated, as Eq. (19):

\[
Q = 1 - U \quad (19)
\]

In Eq. (19), \(Q\) represents the energy-saving potential released by the distributed energy system. The higher the energy-saving potential value, the better the effect of the selected scheme.
Table 2. Energy Saving and Emission Reduction Effect Table of Three Energy Saving and Emission Reduction Effect Evaluation Schemes

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Plan</th>
<th>Name</th>
<th>Specific content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plan A</td>
<td>Annual energy saving and emission reduction assessment scheme</td>
<td>Evaluate the energy saving and emission reduction effect of a system, building or organization within one year.</td>
</tr>
<tr>
<td>2</td>
<td>Plan B</td>
<td>Project-level life cycle assessment scheme</td>
<td>Evaluate the energy saving and emission reduction effect of a specific project, and consider the whole life cycle from project planning, design, construction to operation and retirement.</td>
</tr>
<tr>
<td>3</td>
<td>Plan C</td>
<td>Evaluation scheme of emission reduction effect at policy and government level</td>
<td>Evaluate the effect of energy conservation and emission reduction measures at the policy and government levels.</td>
</tr>
</tbody>
</table>

According to the above discussion, the ideal degree of energy saving and emission reduction effect of the other two energy saving and emission reduction effect evaluation schemes is quantified and their energy saving potential is calculated, and the calculated data are recorded and plotted as shown in Table 2.

As can be seen from Table 2, under the comparison of three energy-saving and emission-reduction effect evaluation schemes, the energy-saving and emission-reduction effect of Scheme B is more ideal, and its energy-saving potential is basically brought into play, while the energy-saving and emission-reduction effects of the other two schemes have not reached the ideal level of Scheme B. Therefore, based on the above analysis, it is concluded that the best energy-saving and emission-reduction effect can be achieved by applying the energy-saving and emission-reduction effect evaluation scheme of Scheme B, and this result is the same as that obtained by the above evaluation model in this paper. Therefore, through the above discussion, it is proved that the method proposed in this paper can realize the evaluation of energy saving and emission reduction effect of distributed energy system in practical application, and the evaluation results have higher factual basis, which can provide more powerful basis for the implementation of distributed energy system projects.

5. Conclusions

In this paper, an evaluation method of energy saving and emission reduction effect of distributed energy system considering system dynamics and demand response is proposed. The evaluation curves of solar radiation intensity, wind speed and discharge rate obtained when evaluating the distributed energy system are basically consistent with the actual curves, which can accurately complete the evaluation of energy saving and emission reduction effects of the distributed energy system. The state sequence value is consistent with the actual state sequence value of the distributed energy system, and it can achieve the effect of energy saving and emission reduction in practical application. It shows that the application of this method can better understand the operation mechanism and optimization strategy of distributed energy systems and promote the development of clean energy. However, there are still limitations of dynamic characteristics in this study. In the future research, we should consider more influencing factors and dynamic characteristics, such as weather and equipment status, establish a more accurate and reliable system dynamics model, and make important contributions to the development of clean energy and the realization of sustainable development goals through continuous exploration and research.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author contributions

R. M. (Master) wrote the manuscript.
Y. T. G. (Bachelor) revised the manuscript.

References


