Research on Comprehensive Evaluation of Micro Energy Internet Based on Synergetic

Mingtao Hua*, Xun Dou*, Pan Zhang
School of Electrical Engineering, Nanjing Tech University, Nanjing 211816, China

*Corresponding author e-mail: douxun@163.com, hu542983759@qq.com

Abstract. Energy Internet is a product of the high integration of traditional energy system and Internet, which may break the existing energy landscape. The existing energy Internet assessment methods are lack of integrity and fail to fully reflect the core mechanisms and requirements of energy Internet. At the same time, the subjectivity of weight calculation is strong, which is easily influenced by human factors. Proceeding from the requirements of overall evaluation and focusing on the energy interconnection and complementary of micro energy Internet, this paper proposes a comprehensive evaluation indicator system of energy Internet based on the theory of Synergetics. The first-level indicator, which is the macro-performance of energy Internet, is put forward on the basis of the reference to traditional indicators and the energy interactive-collaborative in Synergetics. Secondary indicator is the subdivision of first-level indicator and represents the micro-elements that the first-level indicator fails to reflect. At the same time, the weight of each index is calculated by the principle of information entropy. Finally, Evaluation of Micro Energy Internet has guiding significance for the future construction of energy Internet.

1. Introduction

In the context of the third industrial revolution based on the Internet, with the increasingly serious problems of energy shortage and environmental pollution, the energy Internet, as a combination of traditional energy and new technologies, is becoming more and more serious. It has become a hot topic in academia and industry in recent years. The main problem is how to improve the comprehensive energy efficiency [1] by multi-energy cooperative utilization on the premise of environment-friendly.

In order to fully reflect the energy synergy rate of the energy Internet, many scholars have studied the concept and the overall architecture of the energy Internet. Literature [2] studies the reliability status and development trend of energy systems based on the background, connotation and structure of the energy Internet system. Literature [3] analyzes the current situation of energy Internet architecture and integration of each system, and points out the breakthrough direction of key energy Internet technologies, such as intelligent transmission network technology, energy storage technology, Internet information technology, etc. It provides reference for the development of energy Internet in our country.

The related evaluation work has also been carried out at the same time. Literature [4] based on the load demand of the distributed energy system, the optimization model of the distributed energy system is established by using the nonlinear integer programming method. Literature [5] based on the practical
experience of the demonstration area, the evaluation index system is established from the aspects of economy, energy, environment, society and engineering.

Most of the above-mentioned studies evaluate the energy Internet from a single energy point of view or focus on a certain aspect, and do not highlight the characteristics of energy synergistic utilization. Through the research of this paper, we hope to fully reflect the characteristics of the interaction and multi-interaction of the energy Internet, and provide a reference for the future development of the energy Internet as well as the evaluation of the value of the energy Internet in an all-round way.

2. Comprehensive Evaluation system of Energy Internet

2.1. Analysis of synergy characteristics of energy mutual micro-network
In order to describe the level of energy cooperative utilization in energy interconnection micro-grid from many angles, this paper establishes the evaluation index of function coordination, structure coordination and goal coordination based on synergetic theory [6].

Functional collaboration requires the coordination of the energy subsystems under the unified goal of the system according to their respective characteristics in the whole cycle and whole process of the operation of the energy interconnection micro-network. Because of the complex architecture and meticulous division of labor, the coordination of energy subsystems must be emphasized in order to realize functional coordination, which is the key to promote energy efficiency. Otherwise, the time-varying and spatio-temporal differences of the subsystems under specific targets may have an adverse effect on the stability of the system as a whole.

![Functional synergy](image)

**Figure 1.** Functional synergy

Goal collaboration is a means to guide the energy interconnection micro-net to complete successfully according to the specific goal. Through the coordination of the system goal, the phase goal and the energy subsystem goal, the optimization of the overall collaborative goal of the project can be achieved. The clear and quality goal is the premise of ensuring the economy and environmental protection of the system, which can improve the level of system utilization of renewable energy and improve the comprehensive energy efficiency.
2.2. Secondary indicator set

Functional synergy secondary indicator analysis

1) Safety and reliability

Energy network reliability refers to the annual operating hours of energy interconnected microgrids:

\[
NQ1 = \frac{T_a + T_b + T_c}{3T}
\]

In the formula: NQ1 is the reliability of the energy network; Ta, Tb, Tc are the normal annual energy supply time of the electricity, gas and heat network users in the park; T is the total time.

2) Average energy availability

Average energy availability refers to the energy supply coverage of energy interconnected microgrids:

\[
NQ2 = 1 - \frac{NQ5}{8760}
\]

In the formula: NQ2 is the average energy supply availability; NQ5 is the system average outage time.

3) Engineering safety

The safety and maintainability of each project related to the microgrid are evaluated in terms of (excellent, good, medium, pass, and poor).

2) Energy stability

1) System average outage frequency

The average outage frequency of the system refers to the average number of outages per unit time period.

\[
NQ4 = \frac{\sum \alpha_i \cdot N_i}{\sum N_i}
\]

In the formula: NQ4 is the average frequency of system outages; \(\alpha_i\) is the failure rate of the microgrid; \(N_i\) is the total number of users of the microgrid.

2) System average outage time

The average out-of-service frequency of the system refers to the average number of outages per unit time period.
\[ NQ5 = \frac{\sum \beta_i \cdot N_i}{\sum N_i} \]  \hspace{1cm} (4)

In the formula: \( NQ5 \) is the average outage time of the system; \( \beta_i \) is the annual average outage time of the microgrid; \( N_i \) is the total number of users of the microgrid.

3) System low battery expected value

The expected value of the system power shortage refers to the expected value of the power loss caused by the power failure of the user during the unit time period.

\[ NQ6 = \sum \chi_i \cdot T_i \]  \hspace{1cm} (5)

In the formula: \( NQ6 \) is the expected value of the system power shortage; \( \chi_i \) is the average load of the microgrid; \( T_i \) is the average annual outage time of the microgrid.

Target synergy secondary indicator analysis

(1) Economic benefit

1) Energy cost

\[ EQ1 = \frac{C_s}{R_s} \]  \hspace{1cm} (6)

In the formula: \( EQ1 \) is the energy cost; \( C_s \) is the total cost of all types of energy units; \( R_s \) is the total amount of energy consumption.

2) Average payback period

\[ EQ2 = \frac{T_{wa} + T_{wb} + T_{wc}}{3} \]  \hspace{1cm} (7)

In the formula: \( EQ2 \) is the average investment payback period; \( T_{wa} \), \( T_{wb} \), and \( T_{wc} \) are the electricity, heat, and gas cost recovery periods. Total number of users of the microgrid.

3) Social benefit

The impact of the micro-grid on society is assessed in terms of (excellent, good, medium, pass, and poor).

(2) Energy saving

1) Cumulative energy saving ratio

\[ EQ4 = \frac{R_c}{R_s} \]  \hspace{1cm} (8)

In the formula: \( EQ4 \) is the cumulative energy saving ratio; \( R_c \) is the total amount of energy saved in a fixed period; \( R_s \) is the total amount of energy consumption.

2) Clean energy consumption rate

\[ EQ5 = \frac{Q_n}{Q_m} \]  \hspace{1cm} (9)
In the formula: EQ5 is the clean energy consumption rate; Qn is the actual power generation of clean energy; Qm is the total installed capacity of clean energy.

3) CO2 comprehensive emission reduction
In the formula: EQ6 is the CO2 comprehensive emission reduction, and the CO2 comprehensive emission reduction is equal to the annual average CO2 emission reduction.

![Figure 3. Energy Interconnect Microgrid Evaluation Index System](image)

3. Conclusion
In this paper, the comprehensive evaluation system of energy Internet is established from the angle of synergetic theory, which solves the problem that the traditional evaluation is not enough to reflect the characteristics of the cooperative utilization of energy Internet, which is helpful to the embodiment of the value of the energy Internet. Through the analysis, using the evaluation index and method established in this paper, we can accurately evaluate the actual operation of the energy Internet, and verify the rationality of the evaluation index and method in practice.

Acknowledgments
This work was financially supported by Jiangsu Six Talents Summit Project (ZNDW-005) fund.

References
[1] MA Zhao, ZHOU Xiaoxin, SHANG Yuwei, SHENG Wanxing. Exploring the Concept, Key Technologies and Development Model of Energy Internet [J]. Power System Technology, 2015, 39 (11): 3014 - 3022.
[2] SUN Hongbin, GUO Qinglai, PAN Zhaoguang. Energy Internet: Concept, Architecture and Frontier Outlook [J]. Automation of Electric Power Systems, 2015, 39 (19): 1 - 8.
[3] YAN Taishan, CHENG Haozhong, ZENG pingliang, MA Zeliang, ZHANG Libo. System Architecture and Key Technologies of Energy Internet [J]. Power System Technology, 2016, 40 (01): 105 - 113.
[4] LI Gengfeng, BIE Zhaohong, WANG Ruihao, JIANG Jiangfeng, KOU Yu. Research Status and Prospects on Reliability Evaluation of Integrated Energy System [J]. High Voltage Engineering, 2017, 43 (01): 114 - 121.
[5] JIANG Ling, YUAN Yue, WANG Zheng, WANG Shouxiang. Evaluation Index System and Comprehensive Evaluation Method of Energy Internet in Innovative Demonstration Area of Smart Grid [J]. Proceedings of the CSU-EPSA, 2016, 28 (01): 39 - 45.
[6] CHENG Lin, LIU Chen, ZHU Shouzhen, et al. Study of Micro Energy Internet Based on Multi-Energy Interconnected Strategy [J]. Power System Technology, 2016, 40 (1): 132 - 138.