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Dynamic characteristics analysis of energy internet information ecological chain

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Abstract. As a special complex giant system, there exists coherent effect of numerous factors in the process of information exchange of energy Internet. To study energy Internet from the angle of information ecology can better grasp the process of information transfer, and the use of system dynamics method is advantageous to the quantitative analysis of influencing factors. In this paper, on the basis of the principle of information ecological chain, the method of system dynamics is employed to carry on system modelling analysis of the energy Internet information transfer process. The system dynamics model is built from three subjects' point of view: information producers, information transmission and information consumers, to analyse the relationship between various influencing factors and the impact on system ecological chain. The results of the study point out that the knowledge transformation time delay, the infrastructure spending level and the initial economic levels have greater influence on knowledge creation of energy Internet. The corresponding solutions are put forward according to the influence effect and degree.

Key words. Energy Internet, Information System, Ecological Chain, System Dynamics.

1. Introduction

Energy Internet is a huge information flow platform and resource storehouse with virtual space characteristics. Along with the development of the energy Internet, its relationship with the human society will become increasingly closer. The stability of the energy Internet information ecological environment is the need of normal human life and social stability. However, in the process of energy Internet construction, due to the long construction period, constantly update and development of technology, and the lack of unified planning, many problems have appeared in the information framework of energy Internet, including redundant construction, digital island,

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information pollution, inadequate information utilization, etc. In recent years, as the information ecology theory has aroused more attention in the academic circles, the introduction of information ecology theory into the energy Internet information resources management is conducive to a better understanding of the relationship between the energy Internet information elements and the mechanism of action, and the discovery of future law of development. It can also help solve the imbalance of energy Internet information resources management, and promote the coordinated development of energy Internet information ecosystem [1,2]. Information ecosystem is a complex system which changes over time, and it has the characteristics of nonlinearity and openness [3]. The traditional static equilibrium theory cannot solve the problems of information ecosystem [4]. This paper uses system dynamics method to simulate the dynamic changes of the whole energy Internet information ecosystem, more realistically reflects the relationship between the information ecological chain factors, and finally finds out the dynamic characteristics of the information ecological chain.

2. Literature Review

The study of information ecology can be divided into two stages [5]. The first stage is from the 1960s to the late 1980s, which is the budding stage of information ecology study. During this stage, the concept of information ecology was not clear, but people have begun to become aware of the issue of information ecology. The second stage is from the late 1980s to the present [6], which is the rapid development stage of information ecology study. Thomas H. Davenport and Laurance Prusak (1997)[7] formally put forward the concept of information ecology, introduced the concept of biology into information management, and opened up a new field of information management study. The development of information ecology in the past 20 years has made it become an important research field of information management, and its theoretical system has been preliminarily constructed. Capurro (2006) [8] put forward the concept of information ecology from the macro perspective and defined the external environment of information ecology. Canavese et al (2012)[9] proposed that the scientific information management should be carried out by combining fuzzy logic with the ecological system method. Garbach et al. (2015) [10]redefined the concept of information ecology, and put forward a new perspective of research on information ecology, including holism, actor network theory, evolutionary game theory and ecological cycle theory. Xu et al. (2017) [11] proposed the theory, concept and structure of the information ecological chain. The concept definition and research of information ecology have laid the theoretical foundation for this paper. In addition to the study of concept, the research methods of information ecology also include data statistic method, qualitative research method and model method. Zhu and Thatcher (2010) [12] applied the multiple regression analysis method to analyze the global reading data from 2003 to 2007, in order to explore the impact of national information ecology on global information ecology. Due to data limitations, the study was limited to the findings and did not study the mechanism. Trere (2012) [13] applied the information ecology framework and used the qualitative

analysis method of information ecology to explain the change mechanism of a school organization. Mathew (2011) [14] used the information ecology method to analyze the information changes of water industry and how to share knowledge to promote the management of water industry. As both studies above chose specific research objects, the model framework of their research is not universally applicable.

The research methods chosen in this paper include qualitative method and model method. Firstly, it uses qualitative study to analyze the connotation of energy Internet information ecological chain, and define the main elements and external environment of this information ecological chain. On this basis, it uses the system dynamics method to establish model and carry on simulation experiment. It also conducts sensitivity analysis of the involved parameters, finds out the key parameters of energy Internet ecological chain, and further discusses in detain the influence mechanism and effects of these parameters.

3. Composition of Energy Internet Information Ecological Chain

The energy Internet information ecological chain covers three aspects, and they are information subjects, information flow and information environment. The information subjects include electricity customers, power grid data acquisition unit, sensors, power grid dispatch centers, network centers, smart power grid information centers, etc. The information subjects are mainly divided into information producer (perception level), information transmitter (network level), information processor (platform level) and information consumer (application level). The information subjects are interconnected with each other to form the information path on which information can be transferred. The process of information transfer in itself must reflect the process of information translating into knowledge. During the transfer process, due to the influence of information environment, there appears complex network state. The information environment includes both internal and external environments. The internal environment includes power grid technology environment, infrastructure equipment environment, information security environment, etc. The external environment includes policy environment, economic environment, standard specification environment, etc.

4. System Dynamics Model of Energy Internet Information Ecological Chain

In the literature [11] the theoretical model of the information ecological chain is established. This model shows the transfer process of the information flow under the information environment between the information providers (information absorption and processing), transmitters (information storage and dissemination), consumers (information search and use) and disintegrators (information release and deletion), and the mutual adaptation between the information, flow, information and the information environment, in order to achieve information sharing and coop-

erative coevolution. On the basis of clarifying the causal relationship of the research object and determining the system boundary, this paper uses the theoretical model of information ecological chain to establish the system dynamics model of the information ecological chain of energy Internet. It then analyzes the relationship between information subject and information environment in energy Internet and the influence factors of knowledge conversion amount by using the system dynamics model.

4.1. Model hypothesis

Based on the research objectives of this paper, some basic assumptions are made for the system dynamics model to be constructed in this paper:

Hypothesis 1: the original information is represented in time order, with different information amount per cycle and random changes.

Hypothesis 2: the flow of information is one-way, that is, the flow is carried out in the order of information production, transmission, processing and consumption.

Hypothesis 3: when the information circulates among different time nodes, it is internalized and the internalization amount is determined by the information environment.

4.2. System causal relationship

The elements in the system form its functions and behaviors under the causal relationship. Through the analysis of the energy Internet information ecological chain, the causal relationship of the system is obtained according to the clarification of different information subjects.

In the information production process, the information producers use various methods to collect data and convert the original data into information. The original information is internalized to form information flow and flows to the information transmitter. The internalization amount of information is in positive correlation with the infrastructure level, technical level and economic level, while the economic level directly affects the level of technology and infrastructure. In addition, the infrastructure level is also affected by investment.

During the information transfer, the information transmitter receives the information flow from the information provider. During this process, a part of the information flow will be lost. The information transmitter also filters the information, and the filtered information is internalized to form the information flow and flows downstream. In this process, the internalization amount of information is mainly related to information coordination level and information security risks. The information coordination level is largely determined by the standardization level of information platforms, and the Information security risks are also affected by institutional guarantee.

During the information consumption, information flow is further processed to form knowledge. The total amount of knowledge is determined by the amount of information that is transferred from upstream, and is related to the demand of information. And knowledge amount determines the development of the economic

level.

4.3. System dynamics model

Through the analysis of the causal relationship above, the relationship between the elements of the model is untangled. This section uses the causal relationship to establish the system dynamics model of the energy Internet information ecological chain, and quantify the relationship between different variables and parameters. The system dynamics model is expressed as follows in the form of equation:

$$PI(t+1) = PI(t) + Information(t) - Information\,\mathrm{Pr}oduction1(t) \tag{1}$$

$$TI(t+1) = TI(t) + Information\,\mathrm{Pr}oduction1(t) - Information\,\mathrm{Pr}oduction2(t) \tag{2}$$

$$CI(t+1) = CI(t) + Information\,\mathrm{Pr}oduction2 - Knowledge \tag{3}$$

$$Techno\log yLevel(t) = alpha1 * \arctan(EconomyLevel(t)) \tag{4}$$

$$Information\ Internaliztion1(t) = PI(t)*(alpha2*TechnologLevel+alpha3*InfrastructureLeve \tag{5}$$

$$InfrastructionLevel(t) = alpha5 * EconomyLevel(t) * alpha4 * Funding(t) \tag{6}$$

$$EconomyLevel(t) = Delay1(alpha10 * Knowledge(t),\ time\ delay1) \tag{7}$$

$$\begin{aligned} & Information\ Internalization2(t) \\ = \ & TI(t) * (alpha8 * Techno\log yLevel + alpha7 * CollaborationLevel + SecurityLevel * alph \end{aligned} \tag{8}$$

$$CollaborationLevel(t) = alpha9 * \arctan(StandardLevel) \tag{9}$$

$$SecurityLevel(t) = EXP(-Safegurard\ Measures) \tag{10}$$

$$Knowledge(t) = CI * R \tag{11}$$

In these equations, PI represents information production quantity, TI represents information transfer quantity and CI represents information consuming quantity. According the equations, the system dynamics model can be shown as Fig 1.

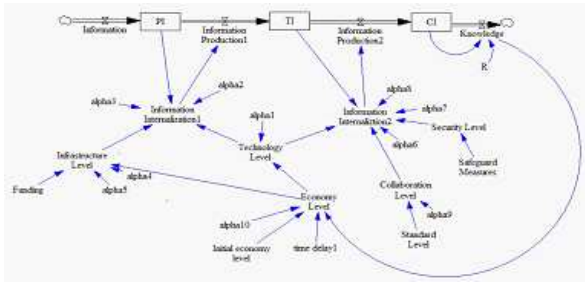

Fig. 1. The system dynamics model of energy Internet information ecological chain

5. Simulation Experiment

In this paper, Vensim is chosen to carry on the system dynamics simulation of energy Internet information ecological chain. The simulation period is set up to be 300, the initial amount of information complied with the independent random distribution, and the initial amount of knowledge is 0. Information flows in the information ecosystem, and useful information ultimately transforms into knowledge. Therefore, the knowledge amount can be used to observe model behavior, characteristics and change rules. Figure 2 shows the information transformation amount and the knowledge amount changes of the system model.

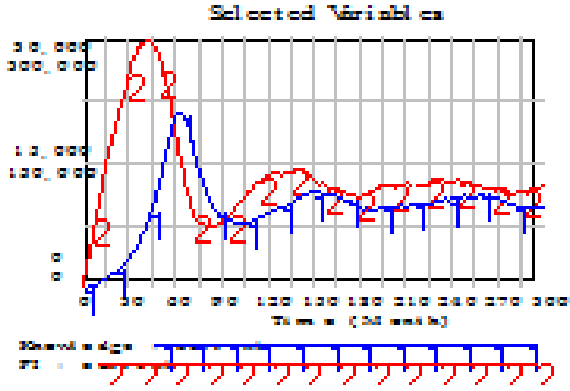

Fig. 2. The change of information transfer quantity and knowledge quantity

It can be seen from Figure 2 that, in the early period of the whole information ecological system operation, the information transformation amount is greater than the knowledge output. With the accumulation of knowledge amount, the uplifting of economic development level, and the continuous improvement of information ecological environment, the information ecological chain enters into the growth period, and the total amount of knowledge achieves rapid growth. As the information transformation amount reduces, the energy Internet information ecological chain enters into mature period during which both the information transformation amount and knowledge amount are in decline. At this time, as both economy and technology

have developed to a higher degree, there remains a greater amount of knowledge transformation which is even more than the amount of information transformation. Eventually the information ecological chain enters stable period, and the amount of information transformation and knowledge amount maintain a relatively stable level with slight fluctuation. The simulation results have demonstrated the classical changing process of information life cycle and reflected the reality. Thus, the system dynamics model is scientific and reliable.

The parameter sensitivity analysis of the system dynamics model shows that, most of the parameters have influence on the knowledge amount transformation, and the influence is not huge. The parameter which has a greater influence on the change of knowledge amount is the time delay of the knowledge transformation into economic level. Figure 3 shows the changes of the knowledge amount under different transformation time delay. It can be seen from Figure 3 that, the quicker the transformation, the greater the knowledge amount will be, and the faster the growth rate of the knowledge amount. In addition, different transformation time delay does not exert essential influence upon the maximum knowledge production, and there is little difference between the maximum knowledge production brought by different time delay.

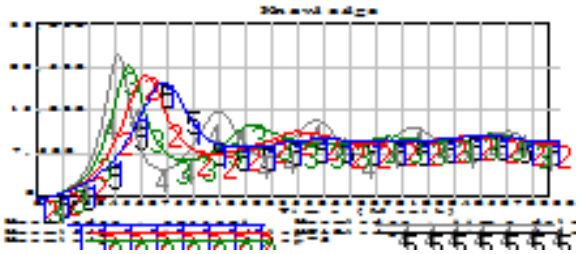

Fig. 3. The relationship between knowledge quantity and transferring delay time

6. Conclusions

The energy Internet information ecosystem is a huge complex system. The paper aims to analyze the dynamic changes of the energy Internet information ecological chain, and grasp the system change rules and characteristics. It starts from the three links of information flow transfer to analyze the influence factors of energy Internet, and uses method of system dynamics to build energy Internet information ecological chain model. On the basis of verified correct model, it carries on simulation experiment to obtain factors with greater influence on the ecological system, and then conducts a comparative analysis of these factors and arrives at valuable conclusions.

In this paper, the system dynamics method is used to study the complex energy information ecosystem, which provides a new research approach for the information management researchers. What is worth mentioning is that different types of information ecological chain could face different external environments. Thus, the targeted analysis should be carried out in establishing the system dynamics model.

References

[1] B. L. Chen, A. Zeng, L. Chen: *The effect of heterogeneous dynamics of online users on information filtering.* Physics letters A *379* (2015), No. 43, 2839–2844.

[2] M. L. Weber, M. J. Hine: *Who inhabits a business ecosystem? the technospecies as a unifying concept.* Technology innovation management review *5* (2015), No. 5, 31–44.

[3] S. Elliot, J. Webster, J. Corbett: *Winning the SDG battle in cities: how an integrated information ecosystem can contribute to the achievement of the 2030 sustainable development goals.* Information Systems Journal *27* (2017), No. 4, 427–461.

[4] G. Bianconi, P. Laureti, Y. K. Yu: *Ecology of active and passive players and their impact on information selection.* Physica A: Statistical mechanics and its applications (2004), No. 332, 519–532.

[5] B. Dorschel, J. Gutt, O. Huhn: *Environmental information for a marine ecosystem research approach for the northern Antarctic Peninsula (RV Polarstern expedition PS81, ANT-XXIX/3).* Polar biology *5* (2016), No. 39, 765–787.

[6] R. Capurro: *Information Ethos And Information Ethics-Ideas To Take Responsible Action in the Field of Information.* Nachrichten fur dokumentation *1* (1988), No. 39, 1–4.

[7] H. Thomas: *Davenport.Information ecology: Mastering the information and knowledge.* Oxford: Oxford university press (1997) 10–20.

[8] R. Capurro: *Towards an ontological foundation of information ethics.* Ethics and information technology *8* (2006), No. 4 175–186.

[9] D. Canavese, N. R. S. Ortega, L. L. Giatti: *Ecosystem approach and the Fuzzy logic: a dialectical proposal for information on environmental health.* Engenharia sanitaria e ambiental *4* (2012), No. 17, 363–368.

[10] K. Garbach, M. Lubell, D. C. Faj: *Payment for ecosystem services: the roles of positive incentives and information sharing in stimulating adoption of silvopastoral conservation practices.* Agriculture ecosystems & environment *8*, (2012), No. 156, 27–36.

[11] X. Xu, W. He, P. Yin: *Business network information ecological chain: A new tool for building ecological business environment in IoT era.* Internet research *2* (2016), No. 26, 446–459.

[12] L. Zhu, S. M. B. Thatcher: *National information ecology: a new institutional economics perspective on global e-commerce adoption.* Journal of electronic commerce research *1* (2010), No. 11, 53–66.

[13] E. Treré: *Social movements as information ecologies: exploring the coevolution of multiple Internet technologies for activism.* International Journal of Communication *34* (2012), No. 12, 6–19.

[14] S. Mathew: *Fishery-dependent information and the ecosystem approach: what role can fishers and their knowledge play in developing countries.* ICES Journal of Marine Science *68* (2011), No. 8, 1805–1808.

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