sustainability

Article

The Key Technology of Smart Energy System and Its Disciplinary Teaching Reform Measures

Dongdong Zhang [1,*], Jun Tian [1], Hui-Hwang Goh [1], Hui Liu [1], Xiang Li [1], Hongyu Zhu [1] and Xinzhang Wu [1,2]

[1] School of Electrical Engineering, Guangxi University, Nanning 530004, China
[2] School of Computer, Electronics and Information, Guangxi University, Nanning 530004, China
* Correspondence: dongdongzhang@gxu.edu.cn

Abstract: Based on the rapid development of new energy technology, modern information technology, intelligent management technology and different countries' strategic demand and deployment in the field of energy, the construction of intelligent energy systems is booming with the combination of new energy technology and Internet technology. The Energy Internet is the representative product of intelligent energy systems at the present stage. Its advantages are the effective promotion of energy saving, consumption reduction and optimization of deployment, thus improving the energy system. However, the large-scale construction of the Energy Internet requires a large number of professionals. In order to meet the needs of Energy Internet construction, the talent training mode of higher education is facing new challenges. To cultivate talents in Energy Internet construction, an effective measure is to reform the teaching system based on the current electrical engineering major in universities. This paper investigates the development and construction of the Energy Internet and the current situation of the electrical engineering discipline and puts forward teaching reform measures to transform the traditional electrical engineering discipline into an Energy Internet engineering discipline, considering course structure design, examination form, teacher allocation and teaching mode. This is important for promoting the large-scale construction of the Energy Internet and improving the competitiveness of graduates in the electrical engineering field.

Keywords: smart energy system; Energy Internet; information technology; electrical engineering; teaching reform

check for updates

Citation: Zhang, D.; Tian, J.; Goh, H.-H.; Liu, H.; Li, X.; Zhu, H.; Wu, X. The Key Technology of Smart Energy System and Its Disciplinary Teaching Reform Measures. *Sustainability* **2022**, *14*, 14207. https://doi.org/10.3390/su142114207

Academic Editor: Nien-Che Yang

Received: 26 September 2022
Accepted: 27 October 2022
Published: 31 October 2022

1. Introduction

Since the second Industrial Revolution gave rise to the global electric age, fossil energy, represented by coal and oil, has occupied the absolute dominant position in the global energy industry. However, currently, the abuses exposed by the excessive use of fossil energy are obvious, including energy exhaustion, environmental pollution, ecological destruction and global warming. The London Smog event in 1952 sounded the alarm. Therefore, in order to seek a sustainable development model with environmental protection as the purpose, the world urgently needs to carry out a clean and efficient revolutionary security transformation in the field of energy [1].

Since the 21st century, the rise and development of technologies related to renewable energies, represented by hydropower, wind power and photovoltaic energy, have created opportunities for achieving the above strategic objectives [2]. Renewable energy will replace a considerable part of fossil energy in the future because of its advantages of environmental friendliness and high efficiency. However, renewable energy has the problems of geographical dispersion, discontinuity, randomness, volatility and being uncontrollable [3], and the centralized and unified management mode of the traditional power network is not suitable for the large-scale and multi-type utilization of renewable energy [4]. A smart energy system, a new energy system, is proposed to deal with the problems faced by the promotion and popularization of the use of renewable energy [5]. A smart energy system, based on advanced information technology, intelligent management technology and power electronic technology, connects a large number of distributed energy collection and storage devices and energy networks of electric power, petroleum, natural gas and other forms (including various forms of renewable energy). Through information exchange and sharing as well as the mutual cooperation between various energy systems, the overall optimization of energy allocation, the balance between supply and demand and efficient transmission are realized [6]. The most representative embodiment of intelligent energy system in the new era is the Energy Internet (the construction of the Energy Internet is an important link in promoting the construction of intelligent energy systems in the new era) [7]. Figure 1 shows the architecture of the smart energy system.

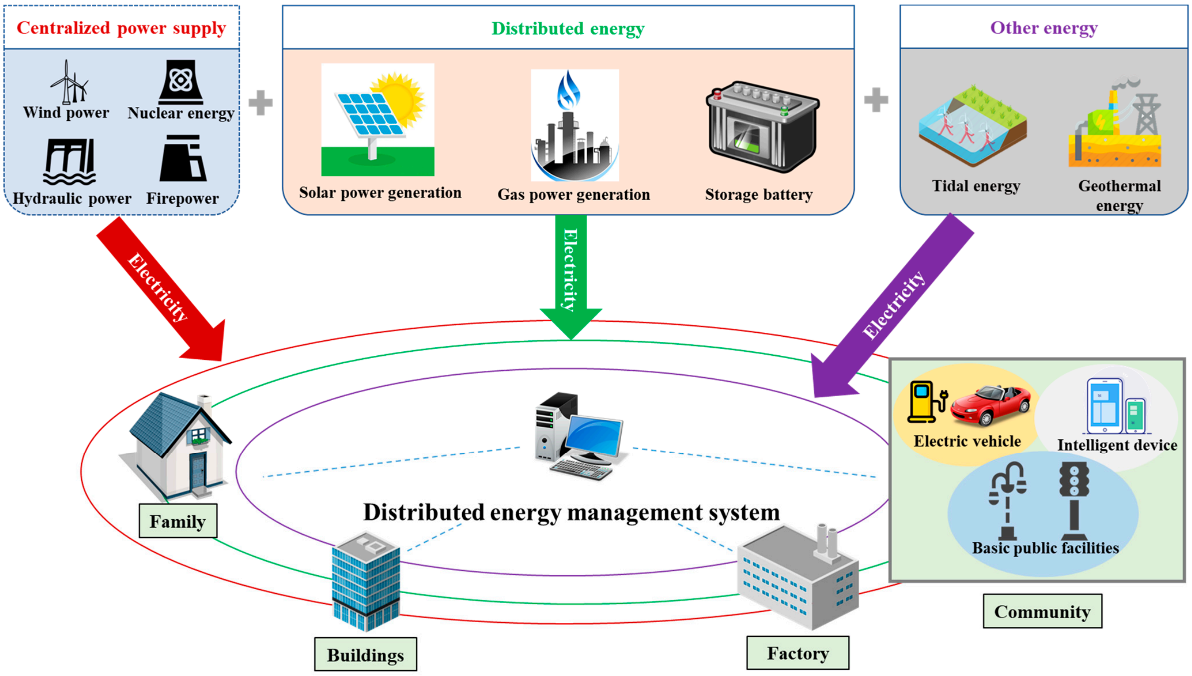

Figure 1. Smart energy system architecture.

In September 2015, the Chinese president delivered an important speech at the UN Development Summit held at the UN headquarters in New York, announcing China's initiative to explore the construction of a global Energy Internet and promote a clean and environmentally friendly mode to meet the global electricity demand. Then, in February 2016, a number of relevant departments in China jointly formulated and issued the document titled The Guidance on Promoting the Development of "Internet Plus" Smart Energy. The guideline clarifies the goal of perfecting the construction of the Energy Internet in China, indicating that the construction of a smart energy system in China has risen to the level of national strategy and entered the stage of substantive development. Since China launched the initiative of "Exploring the construction of a global Energy Internet" in 2015, important progress has been made in the development of the global Energy Internet, and more than 140 countries have introduced corresponding energy development policies.

In order to meet the national strategic layout in the field of energy and adapt to the development trends of today's world, the construction of the Energy Internet on a global scale has become inevitable [8]. However, the construction and development of the Energy Internet cannot be achieved without the joint efforts of a large number of professionals and technical personnel [9]. As a new field, the number of technical personnel is extremely limited. Therefore, it has become an urgent task to start educational and scientific research, studying the core technologies necessary for the construction of the Energy Internet, and training the talents needed for the construction of the Energy Internet. At present, many schools and power enterprises around the world have carried out considerable scientific research on smart energy systems. Among them, the number of Chinese organizations that have made achievements is the largest, and the representative ones include the State Grid Corporation of China, North China Electric Power University, Tsinghua University and so on. Many universities in the U.K. have also carried out relevant research, including Imperial College London, the University of Manchester, the University of Birmingham, the University of Liverpool, Cardiff University and so on. Institutions in other countries, such as Technische Universitaet Berlin, Polytechnic University of Turin, Aalborg University, the University of California, the Indian Institute of Science and the University of Lisbon, have also achieved a lot. Some of these universities established the Global Energy Internet University Alliance in 2018, aiming to jointly promote the research and construction of a global Energy Internet. Figure 2 shows the representative organizations of smart energy systems research around the world.

Figure 2. The representative organizations of the global scientific research on intelligent energy systems.

The composing structure and specific characteristics of the Energy Internet determine its intersection of multiple disciplines in technical characteristics. Its technical means cover the contents of computer technology, communication engineering, artificial intelligence, electrical engineering and other disciplines [10]. As a traditional discipline, electrical engineering has cultivated a large number of engineering construction and technical innovation talents for the development of the power industry in various countries through long-term development and innovation, and made important contributions to the development of the energy field [11]. At present, the most critical component of the energy system in most countries is still the power grid, and there are a large number of colleges and universities offering electrical engineering majors to cultivate talents for the power grid. Therefore, it is of great significance to carry out a teaching reform to rapidly establish a teaching system for training talents in the field of the Energy Internet by taking electrical engineering major as the basis and integrating the principles of information technology, intelligent management technology and theories of other forms of energy field which can break the traditional teaching mode and stimulate innovation [12]. Based on the characteristics of strong interdisciplinary, advanced concepts and focusing on the practical ability of Energy Internet technology [13], some universities in China (such as North China Electric Power University, Shandong University, etc.) have taken the lead in carrying out small-scale trials of talent training with the ultimate goal of establishing a new talent training system. Shanghai Electric Power University has become one of the first universities in China to offer undergraduate programs in Energy Internet engineering through careful discipline construction planning.

However, at present, among many universities and colleges in the world, the number of schools offering an Energy Internet engineering major or an electrical engineering major with an Energy Internet training direction is insufficient, and the promotion of corresponding education reform is also lacking. Based on the actual situation of the high-speed construction of global Energy Internet, the talent output of universities cannot meet the demand for a large number of talents. The core problem lies in the lack of clear consensus among many talent training units on the technologies and capabilities that professional talents should master to build the Energy Internet [14]. In addition, the optimal teaching reform method, teaching system and personnel training model also lack sufficient clarity. Based on the actual situation of the electrical engineering discipline in many talent training units at the present stage, this paper expounds the objective situation of education reform and the viewpoints and thoughts on the reform methods and modes of talent training for the Energy Internet. Firstly, it analyzes the specific characteristics and technologies involved in the Energy Internet [15]. Secondly, it investigates and analyzes the current situation of talent training and major offerings of the Energy Internet, the advantages and historical conditions of the current electrical engineering teaching reform and the problems and challenges faced by the reform. Finally, the paper puts forward and expounds ideas about the reform of talent training modes and the concrete measures and suggestions about the reform of the talent training education system, as well as the value and significance of the reform. In Section 2 of this paper, the specific characteristics of the Energy Internet and its potential problems are introduced in detail. Additionally, the technical system of the Energy Internet is analyzed in detail, which provides reference for the teaching reform measures in the following section; it also focuses on an important pillar of the Energy Internet, electric vehicles. In Section 3 of this paper, the construction of an Energy Internet discipline at the current stage is introduced, and the advantages of teaching reform based on the electrical engineering discipline compared with other engineering disciplines are analyzed, and the necessity and irreplaceability of teaching reform based on the electrical engineering discipline are emphasized. In Section 4 of this paper, by summarizing the Energy Internet technology system described in Section 2 and the actual situation of the existing electrical engineering discipline described in Section 3, as well as the current construction of the Energy Internet discipline, the ideas and specific measures for the Energy Internet-oriented teaching reform based on the electrical engineering discipline are proposed. In Section 5 of this paper, we emphasize the value of teaching reform and the work that needs to be carried out in the future in the field of energy and educational units. In Section 6 of the article, the overall ideas and the main points of view of the article are summarized.

2. Key Technologies and Disciplinary Characteristics of Smart Energy System

The Energy Internet is the representative achievement and product of the smart energy system [16]. It is the product of the deep integration of energy and the Internet. It is a new energy system with the characteristics of open interconnection of multi-energy, free energy transmission, open peer-to-peer access and so on, based on electrical engineering technology represented by power electronics technology and combined with relatively mature information technology and intelligent management technology at the present stage [17]. Therefore, the Energy Internet is another important topic after smart grids in the field of energy. The promotion and popularization of the Energy Internet has become a consensus in all countries of the world, and its development and construction speed are rapid. The fundamental reason is that the construction of the Energy Internet conforms to the global call for green and environmental protection in the energy industry [18]. In addition, through advanced information technology and Internet technology, the Energy Internet closely couples multiple systems such as conventional energy and distributed renewable energy with the power system as the core [19], forming a set of intelligent energy systems with more optimized energy management and allocation, which is of great significance for energy conservation [20]. Figure 3 shows the conceptual architecture diagram of the Energy Internet at the current stage.

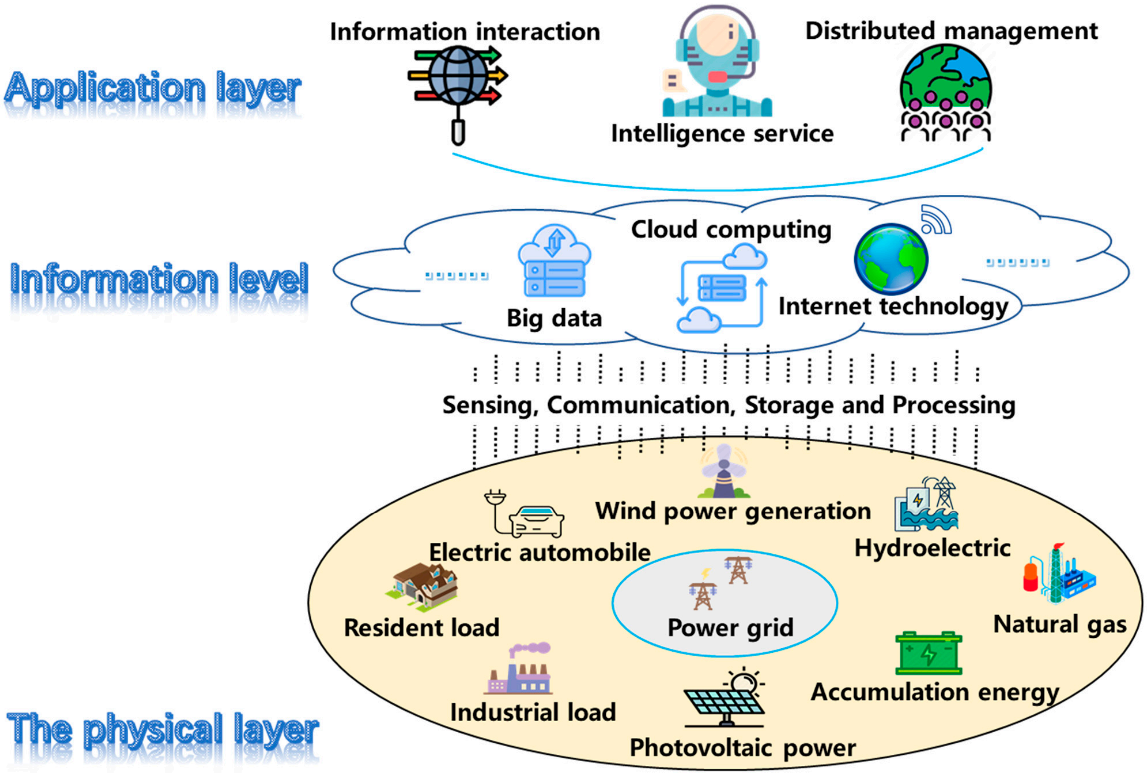

Figure 3. Consensual conceptual architecture diagram of the Energy Internet.

2.1. Characteristics of the Energy Internet

2.1.1. Essential Feature

Based on the construction concept and practical application of the Energy Internet, it mainly has five basic characteristics, namely renewable, distributed, interconnected, open and intelligent [21]. The renewable feature stems from the fact that renewable energy is the main energy supply of the Energy Internet [22]; the distributed feature comes from the fact that renewable energy has various and geographically dispersed characteristics [23]; interconnection is the most distinctive and fundamental feature of the Energy Internet [24]; openness is the requirement of the development mode of the global Energy Internet; and the intelligent characteristic is the guarantee for the Energy Internet to be at the forefront of the energy field. Table 1 explains the connotation of the five basic characteristics of the Energy Internet.

Table 1. Five basic features of the Energy Internet.

Essential Feature	Specific Connotation
Renewable	Renewable energy is the main source of energy supply for Energy Internet. Renewable energy power generation is intermittent and volatile, and its large-scale access will impact the stability of the power grid, thus promoting the transformation of the traditional energy network into Energy Internet [25].
Distributed	Renewable energy sources are diverse and geographically dispersed. For the most efficient collection and use of renewable energy, networks for on-site collection, storage and use of energy need to be established. These energy networks are individually small in scale and widely distributed, and each micro energy network constitutes a node of the Energy Internet. These elements constitute the distributed characteristics of the Energy Internet [26].
Interconnectivity	Large-scale distributed micro-energy networks cannot guarantee self-sufficiency and need to be connected for energy exchange to balance energy supply and demand [27].
Openness	Energy Internet should be a peer-to-peer, flat and two-way energy flow sharing network. Power generation devices, energy storage devices and loads can be "plug and play", which can achieve real-time and efficient transmission of energy [28].
Intelligent	Energy generation, transmission, conversion and use of energy in Energy Internet should have a certain level of intelligence. The existence of intelligence makes the monitoring, management and maintenance of Energy Internet more convenient [29].

2.1.2. Technical Feature

The composition of the Energy Internet shows that it is a new form of energy industry development that deeply integrates the Internet, energy production, transmission, consumption, storage and the energy market [30]. It has many technical features, including multi-capability collaboration, information interaction, supply and demand dispersion, equipment intelligence, transaction openness, etc. [31]. In the upcoming new round of global technological revolution and the great transformation of the energy industry, the deep integration of the energy industry with highly developed information technology and advanced Internet concepts will highly promote the development of new models, new business forms and new technologies in the energy field [32]. The specific technical characteristics of the Energy Internet can be analyzed from two specific levels.

The physical layer: At the physical level, the intelligent energy system represented by the Energy Internet mainly relies on control technology, cloud platform monitoring and maintenance technology and high-performance energy technology to achieve the purpose of optimized cooperative operation of various energy sources and efficient and green operation of the whole system [33]. The Energy Internet consists of multiple energy systems, including electricity, heat, gas and various renewable energy sources, serving many fields such as production, transportation and engineering [34]. Considering its composition and application scenario, it is not difficult to deduce that the technical characteristics of the physical layer lie in the fact that it supports the intelligent interconnection of multiple networks and the mutual transformation of all kinds of energy [35], realizes the optimal scheduling and optimal operation of energy systems through the mutual transformation of various energies and the complement of supply and demand [36] and finally realizes the optimal configuration of the whole energy system [37]. As mentioned above, the Energy Internet has the basic characteristics of distribution [38]. In the future of highly developed distributed energy, it has a strong advantage of convenience to directly convert all kinds of distributed energy into all kinds of energy required by users through technical means [39]. Therefore, the construction of the Energy Internet will take the construction of micro-grid units as the main technical characteristic [40]. After comprehensive analysis of the technical characteristics of the Energy Internet at the physical layer, the main advantages of the Energy Internet at the physical layer can be summarized as follows:

(1) A variety of energy systems achieve complementary advantages, avoid the second conversion of energy and consumption loss and effectively improve the utilization efficiency of comprehensive energy, which meet the requirements of the era of energy conservation and low carbon [41].
(2) All kinds of small-scale renewable energy are incorporated into the grid of the energy system, which improves the level of consumption and fully mobilizes all environmentally friendly energy sources that can be put into use [42].

Information layer: A high degree of information interaction is an essential requirement for the construction of the Energy Internet [43]. Therefore, the most prominent technical characteristics of the Energy Internet at the information level are information transparency and information sharing [44]. The main embodiment of information transparency is to make it open and transparent for the running state of energy network, the healthy state of energy equipment and the trading state of the energy market [45]. One of the problems of traditional energy networks represented by the power grid is that the actual information held by power grid companies and power users is seriously unequal [46]. The user side has a serious lack of information about the energy system, which can easily lead the operator to exploit the information monopoly [47]. Under the construction of the Energy Internet, real-time information sharing will be established between operators and users [48]. Users and all the main parties in the energy market will fully grasp the real-time information of the energy system [49], break the information monopoly of the energy system operators and ensure fair, just and open energy transactions [50].

2.1.3. Potential Problem

Security and privacy problems are important in the development and construction of the Energy Internet. In the future Energy Internet construction stage, in order to achieve a high degree of information of the entire energy system, it is inevitable to use some intelligent equipment and communication equipment in hardware, including smart meters, advanced metering infrastructure (AMI) and so on. However, although the use of these facilities will provide effective help for the construction of the Energy Internet, they will also generate potential risks in the security and privacy of the Energy Internet. For example, smart meters will be used in the construction of the Energy Internet. While smart meters can provide households with more autonomy regarding their energy consumption, they can also be a significant intrusion into the household's privacy [51]. In addition, advanced metering infrastructure (AMI) will be used in the measurement system of the Energy Internet. It plays an important role in providing near real-time two-way communication between consumers and energy systems, as well as providing a range of value-added services to increase customer satisfaction. However, given that its existing services are implemented in a centralized manner, it will still have security and privacy issues [52]. The construction of the Energy Internet should be based on full respect for human rights and protection of the privacy of each user. Therefore, security and privacy issues are problems that must be solved. Therefore, in the subsequent construction process, the technical means of giving consideration to both performance and security and privacy protection represent the key content of the study.

2.2. Energy Internet Technology System and Specific Related Technologies

As mentioned in the first section of this paper, the Energy Internet has the nature of multi-disciplinary intersection, so the technology of constructing the Energy Internet involves a wide range of fields [53]. Based on the current global conceptual consensus on the Energy Internet, the architecture of the standard system of Energy Internet technology can be divided into four layers, namely basic universality, energy grid, information support and value creation [54]. There is information interaction between every two parts. The basic universality part is the basic support part of the whole technical system, which mainly includes basic commonality, industrial control chips, new materials and devices, etc. [55]. The main contents of the energy grid include the distribution network and distributed energy, high-end power transmission and transformation equipment, renewable energy friendly access, safe operation and protection of the system, engineering design and environmental protection, equipment operation and maintenance, grid configuration and planning [56]. In addition to the information interaction between every two parts in the above seven parts, there are also energy and power flows between the distribution network and distributed energy, high-end power transmission and transformation equipment and renewable energy friendly access [57]. The function of the information support part is mainly to undertake the operation and management of the system, platform and information, including artificial intelligence, sensing and measurement, network and information security, automation system, digital platform and communication. There is information interaction between every two parts [58]. The final technical dimension is value creation. This level is based on the energy grid level and emphasizes the integration and application of emerging technologies and energy technologies [59]. The most distinctive feature is the integration and application of the power grid and information technology reflected in smart grid technology. The specific components include the electricity market, energy storage technology and application, user supply and demand interaction, energy blockchain, multi-energy conversion and comprehensive utilization, as well as business model innovation and decision support [60]. Similarly, there is information interaction between every two of the six parts mentioned above. Figure 4 shows the conceptual model of the Energy Internet technology standard system.

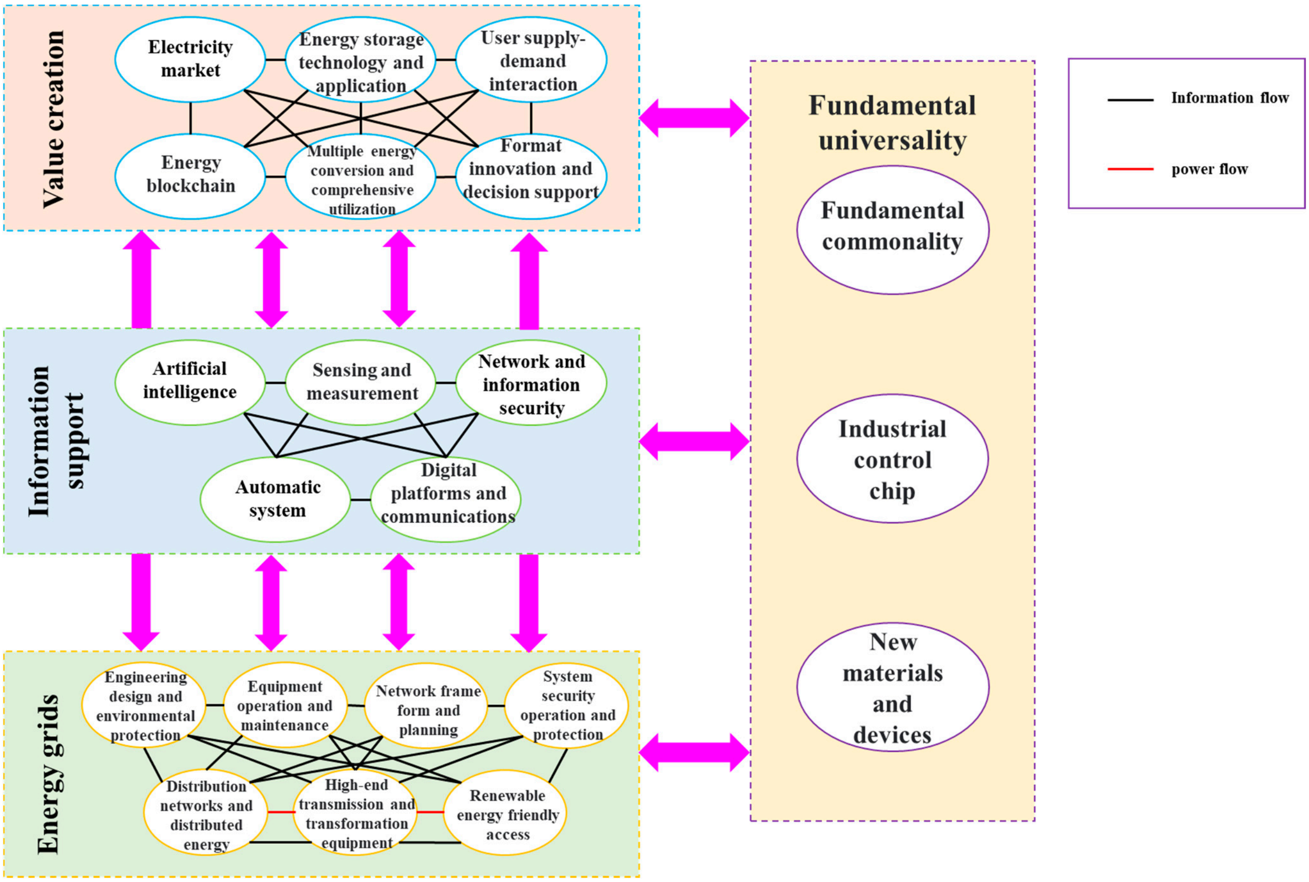

Figure 4. Conceptual model of the Energy Internet technology standard system.

According to the situation reflected by the concept of the Energy Internet technology standard system, the related technology of building the Energy Internet mainly involves the existing technology fields, including electrical engineering, communication engineering, computer and Internet of Things engineering, artificial intelligence and so on [28]. Related technologies in the field of electrical engineering are still power electronic technology, power system relay protection, power system overvoltage and other technical means applied in the current power grid construction (the main reason is that although the Energy Internet has added many new elements compared with the power grid, energy supply from the traditional power grid is still one of the core energy supplies of the Energy Internet; the traditional grid is still an important part of the Energy Internet) [61]. Related technologies in the field of communication engineering mainly include information sensing technology [62], wireless communication technology and so on (due to the large geographical span of energy deployment, condition monitoring and other problems, information interaction is required; therefore, some important technologies in the field of communication engineering are also essential elements for the construction of the Energy Internet [63]). The Energy Internet itself has many similarities to the Internet of Things. Both have the essential characteristics of high interconnection of each component element, but the objects are different (the Energy Internet targets all forms of energy, while the Internet of Things targets entities or various electronic products) [64]. Therefore, blockchain, network technology and programming in the field of computer and Internet of Things engineering are also important technologies for building the Energy Internet [65]. In particular, blockchain technology can play a key role in sustainable energy systems [66]. The technology in the field of artificial intelligence determines the upper limit of the development of the Energy Internet [67]. Applying AI and machine learning techniques to various traditional operational models of the Energy Internet can effectively promote its intelligent transformation. For example, considering the excellent real-time control and robustness of reinforcement learning method, it can be applied to the security and stability control of the power system. Through the design of online and offline control modes, or the design of more intelligent power system security and stability devices based on the algorithm, the control characteristics of the security and stability system can be further optimized. Then, the application of deep learning technology in the Energy Internet can play an important role in load prediction and control of the power grid and energy storage devices, fault diagnosis of power equipment, transient stability assessment of the power system, power big data fusion and anomaly detection and image recognition of power equipment. In addition, deep learning has advantages in feature extraction and model fitting. Considering the actual situation that a large number of new energy power stations, electric vehicles and energy storage devices are connected to the Energy Internet, the application of deep learning will effectively solve the power system problems with high dimensional, complex and coupling relations. The application of intelligent management technology and intelligent robot technology can provide effective help for the inspection and diagnosis of hardware equipment and the optimization of energy transmission and deployment of the Energy Internet. The existence of artificial intelligence technology can not only save human resources in the process of building the Energy Internet, but also complete some tasks that cannot be completed by human resources in the context of a large geographical span [68]. The related technologies required for the construction of the Energy Internet and their fields are displayed in Figure 5.

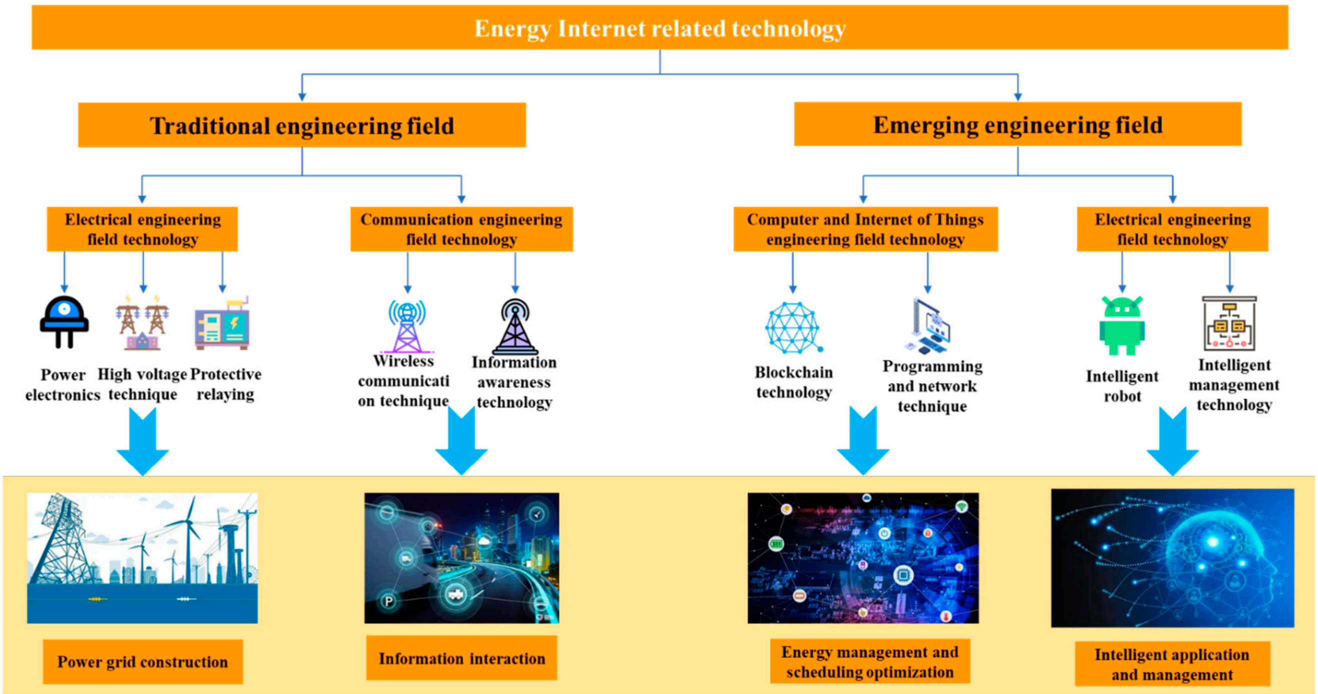

Figure 5. The related technologies required for the construction of the Energy Internet and their fields.

To facilitate teaching reform based on electrical engineering disciplines to cultivate talent for Energy Internet construction, we must consider the basic characteristics of the Energy Internet and associated technologies, introduce some new elements and train the talents to use interdisciplinary knowledge to solve practical problems.

2.3. The Important Pillar of the Energy Internet—Electric Vehicles

Up to now, electric vehicle-related technology has achieved exceptional results, and conventional energy vehicles are gradually being replaced. Electric vehicles are not only important means of transportation, but also important electric facilities and energy storage equipment, so they play an important role in the development of the Energy Internet. Through the connection with distributed and cooperative energy interaction network, electric vehicles not only give full play to the advantages and characteristics of the Energy

Internet, but have also become an important pillar in the development of the Energy Internet [69].

One of the characteristics of electric vehicles is the function of mobile distributed energy storage, which is mainly reflected in that electric vehicles belong to a large number of widely distributed small power consumption facilities and energy storage facilities. In the interaction between electric vehicles and the power grid, not only the charging requirements can be completed, but also the load of the power grid can be reduced. The combination of production and marketing in the Energy Internet is realized through the power grid's power transmission and electric vehicles' participation in the power grid dispatch. Another feature of electric vehicles is its full coverage of communication facilities. The integrated development of energy and communication is the core of the current Energy Internet development. The development of electric vehicles and charging piles needs complete coverage of communication facilities. Thus, in order to guarantee the precision of the measurement and realize real-time communication and integration of the energy system, the Internet of Things and the Internet should be included in the development of electric vehicles. This will guarantee that the Internet contains information on the vehicles' location and the initial power and charging demands during vehicle running [70]. As important power facilities and energy storage facilities, the effectiveness of communication between electric vehicles and other power suppliers should be ensured. Only in this way can important technical support be provided for the development of Energy Internet.

The key methods to promote the integration of electric vehicles and the Energy Internet include pile matching, power market development and intelligent integration. The main way to achieve vehicle pile matching is to promote the construction of electric vehicle charging piles in the Energy Internet system. To develop the power market, it is necessary to accelerate the large-scale development of urban distributed photovoltaic and promote the development of the power sales market. The realization of intelligent integration mainly depends on the development of unmanned driving technology. The main role of electric vehicles is to achieve integrated and intelligent development. Only by meeting the development requirements of the energy sharing economy can they have a greater economic and social advantage in the Energy Internet [71].

To summarize, electric vehicles constitute a key component and pillar of the Energy Internet. In order to promote the full development and construction of the Energy Internet, the research and development of electric vehicle-related technologies are indispensable.

3. Talent Training Model and Reform Direction of Electrical Engineering Subject under the Background of Intelligent Energy System

After the idea and construction concept of the Energy Internet was put forward, many universities in China carried out pilot training of talents in Energy Internet, and the pilot scope of training is almost all concentrated on the electrical engineering discipline. The reason is that it has obvious advantages to take teaching reform in the field of electrical engineering, which can quickly cultivate competent professionals to be put into the construction of global Energy Internet and strongly facilitate the green transformation and environmental protection reform in the field of energy. In this section, we analyze the specific advantages of the teaching reform for Energy Internet talent training based on the electrical engineering field, and investigate the current situation of the construction of the Energy Internet engineering major (taking China as an example) and the construction of the Energy Internet direction of the electrical engineering major.

3.1. Advantages of Carrying out Teaching Reform Oriented to Energy Internet Based on Electrical Engineering Major

Different from the emerging engineering disciplines such as information management and artificial intelligence, electrical engineering is a traditional engineering discipline with a rich history, solid development foundation and quite mature construction [72]. As far as universities around the world are concerned, as early as 1882, Columbia University became the first university to offer a major in electrical engineering, and the discipline of electrical engineering was formally established. In China, electrical engineering education was initiated in 1908 by the former Jiaotong University. The contents in Table 2 show when the electrical engineering major was first established in some universities in China and America.

Table 2. The opening time of electrical engineering major in each university of China and America.

Chinese Universities	Founding Time of Electrical Engineering Discipline (Year)	America Universities	Founding Time of Electrical Engineering Discipline (Year)
University of Communications	• 1908	Columbia University	• 1882
Tongji University	• 1912	Cornell University	• 1883
Zhejiang University	• 1920	Princeton University	• 1889
Southeast University	• 1923	University of Texas	• 1895
Tsinghua University	• 1932	Massachusetts Institute of Technology	• 1902

In China, since the first school set up the electrical engineering major, the development speed of electrical engineering discipline has been remarkable. Especially since the beginning of the 21st century, there has been a rapid increase in the number of schools setting up electrical engineering majors in universities throughout China. Figure 6 shows the changes in the number of schools offering electrical engineering programs in China. After long-term exploration and development, the discipline of electrical engineering has now formed a complete scientific education system, with many experienced teachers and researchers. At present, there are many colleges and universities offering electrical engineering-related majors in China. The most representative colleges and universities with strong discipline foundations include Tsinghua University, Xi'an Jiaotong University, North China Electric Power University, Huazhong University of Science and Technology, etc. Due to the large number of electrical engineering majors, the number of students is also ranked in the forefront of all engineering majors. With a complete education system, strong faculty and a large student base, it is possible to cultivate many high-quality engineering talents with less educational resources and time cost. This is the natural advantage of electrical engineering compared with emerging disciplines such as Internet of Things engineering and artificial intelligence.

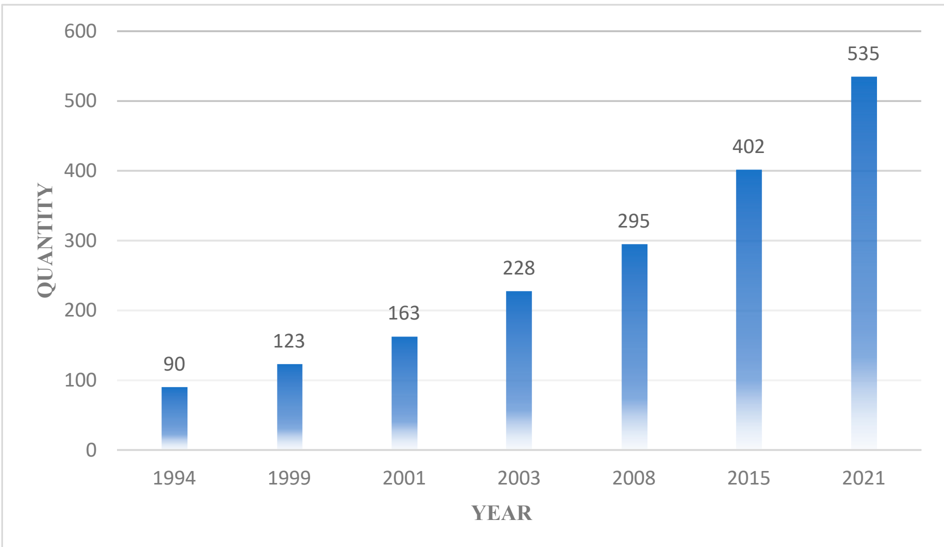

Figure 6. Changes in the number of schools offering an electrical engineering major in China.

At present, an important output direction of electrical engineering graduates is power grid construction. The foundation and core work of building the Energy Internet in the new stage is still the construction of the power grid [73]. With the grid and power system as the skeleton, information technology and management technology are introduced, and the traditional electric energy and other kinds of new energy are organically combined to form a complete energy network [74]. Therefore, the existing teaching contents of the electrical engineering discipline actually cover a considerable part of the core knowledge of building the Energy Internet. Thus, the teaching reform based on electrical engineering can avoid the subversive change in the orientation and teaching contents of the whole subject.

As mentioned above, the knowledge system of constructing the Energy Internet is multi-disciplinary. At the present stage, electrical engineering is a subject with a high degree of interdisciplinary teaching contents, and the interdisciplinary learning contents are mostly related to the core knowledge of building the Energy Internet [75]. In the early stage of electrical engineering discipline construction, the main contents of teaching were power system analysis, power system relay protection, high-voltage technology and power plant principle as the core contents of electricity. Nowadays, the teaching of electronics content has become non-negligible, and the relevant contents are analog electronic technology, digital electronic technology, power electronic technology and other course contents. One of the characteristics of the knowledge content of the current courses is that it mainly serves the automatic control of power systems and equipment, which is also the technical content required by the hardware facilities of each node of the Energy Internet. In addition, the required course contents of the electrical engineering major in the current stage are no longer limited to the contents of electricity and electronics, but also introduce some core courses of other disciplines with strong universality. The courses include the C language course involving programming (the core course of computer science), the microcontroller principle or MCU principle course involving microcomputer measurement and control (the core content of control engineering discipline) and the signal and linear system course involving information interaction (the core content of communication engineering discipline). Programming, microcomputer measurement and control and information interaction are important pillars of technical support for building the Energy Internet. Figure 7 shows the main teaching contents of the electrical engineering and automation major in the present stage.

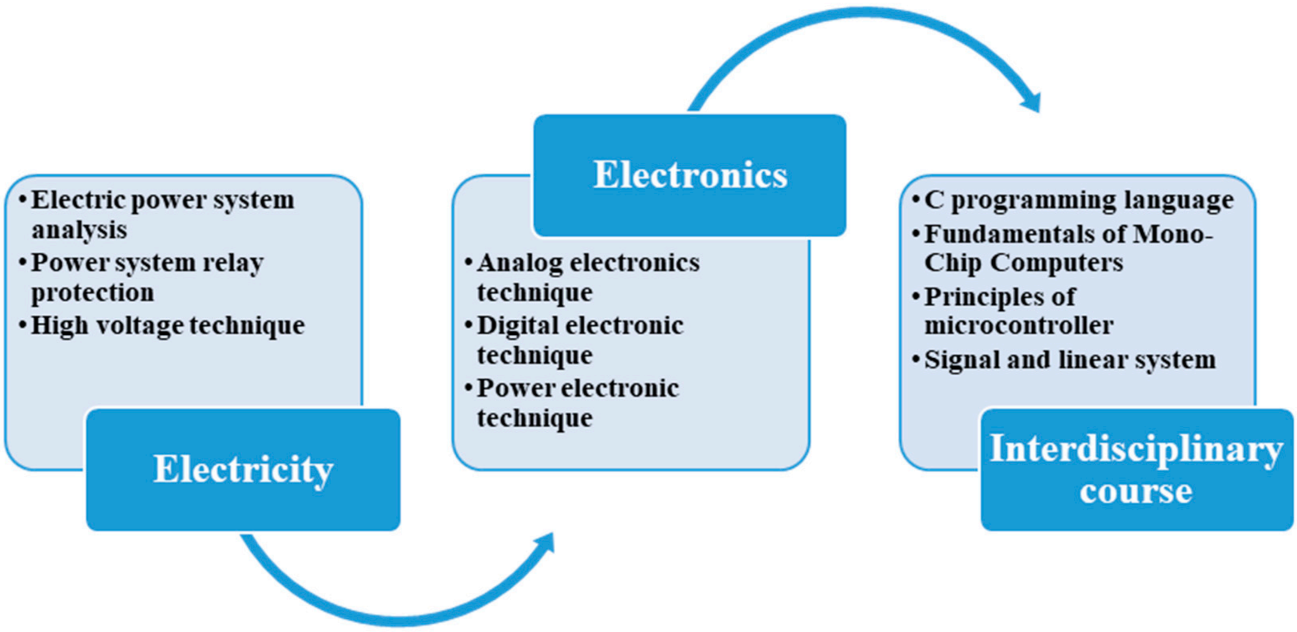

Figure 7. Main course contents of electrical engineering and automation.

A high degree of information and intelligence is a distinctive feature of the Energy Internet [76]. It is not a simple process to complete the construction of information and intelligence in conventional physical systems. Since the beginning of the 21st century, researchers around the world have put forward a new concept of a "smart grid" based on the technology in the field of electrical engineering, and it has achieved a certain degree of development up to now. The power system is a highly complex engineering system [77]. It is of great significance to apply advanced information technology and control technology to the power system, and to transform and upgrade the traditional power system to optimize and improve the efficiency and benefits of power facilities [78]. This is the concept of the smart grid. With the comprehensive arrival of the digital age and the information age, the trend of industrial system informatization is unstoppable, so the construction of the smart grid has realized the high integration of power system and information technology [79]. Figure 8 is the schematic diagram of the integration mode of power system and information technology. The application of information technology to power system planning and design, scheduling optimization, control and protection, as well as detection and maintenance, is the same as the concept of the Energy Internet [80]. Similarly, the Energy Internet also integrates the hardware facilities of physical systems with information technology, and finally realizes information interaction, scientific scheduling and interconnection of multi-energy systems [81]. Figure 9 is a schematic diagram of the integration mode of energy and information technology in the Energy Internet. Therefore, part of the construction of the smart grid can be regarded as the prelude to the construction of the Energy Internet, which is another advantage of building the Energy Internet based on the contents of the electrical engineering field. The construction of the Energy Internet can be realized more quickly and conveniently by referring to the concept and experience of building the smart power grid and organically combining part of the technical achievements with new technical means [82].

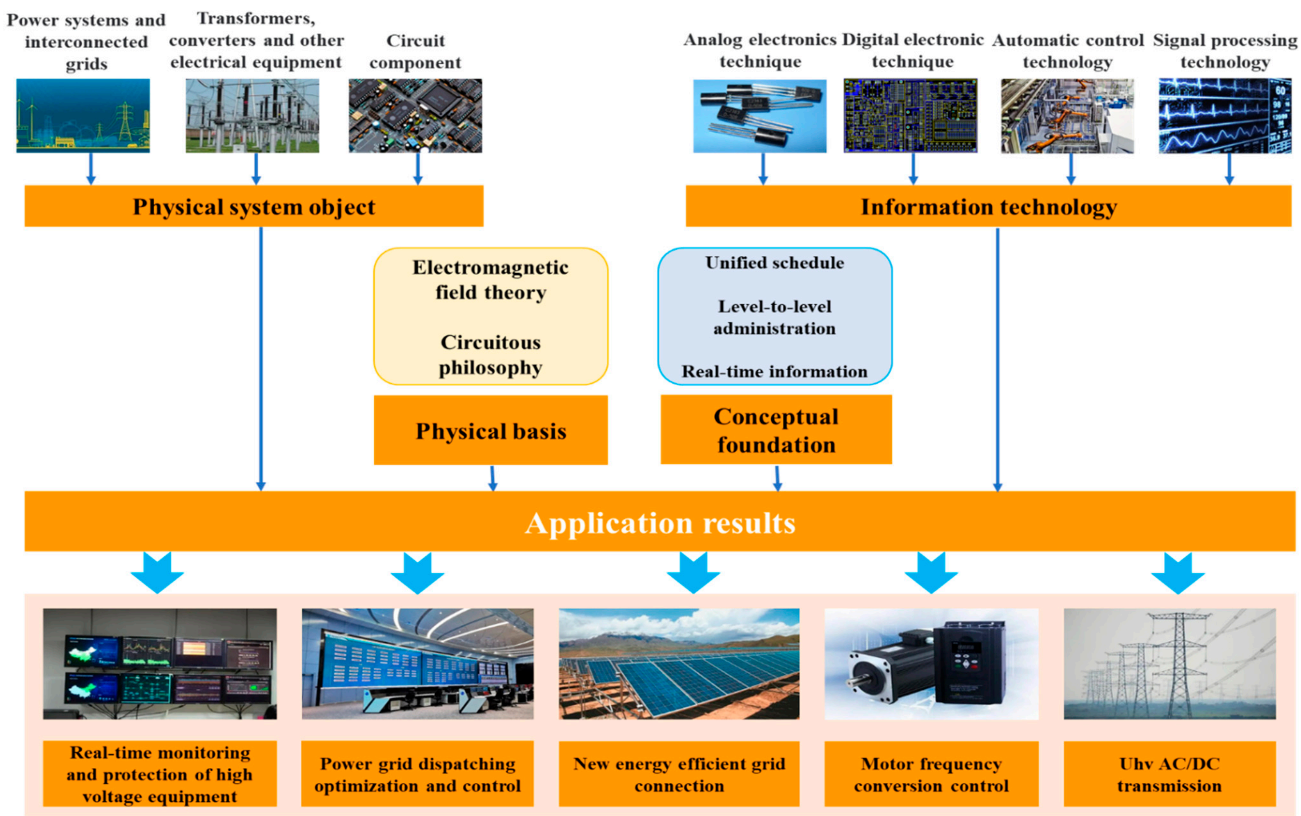

Figure 8. Schematic diagram of power system and information technology fusion model.

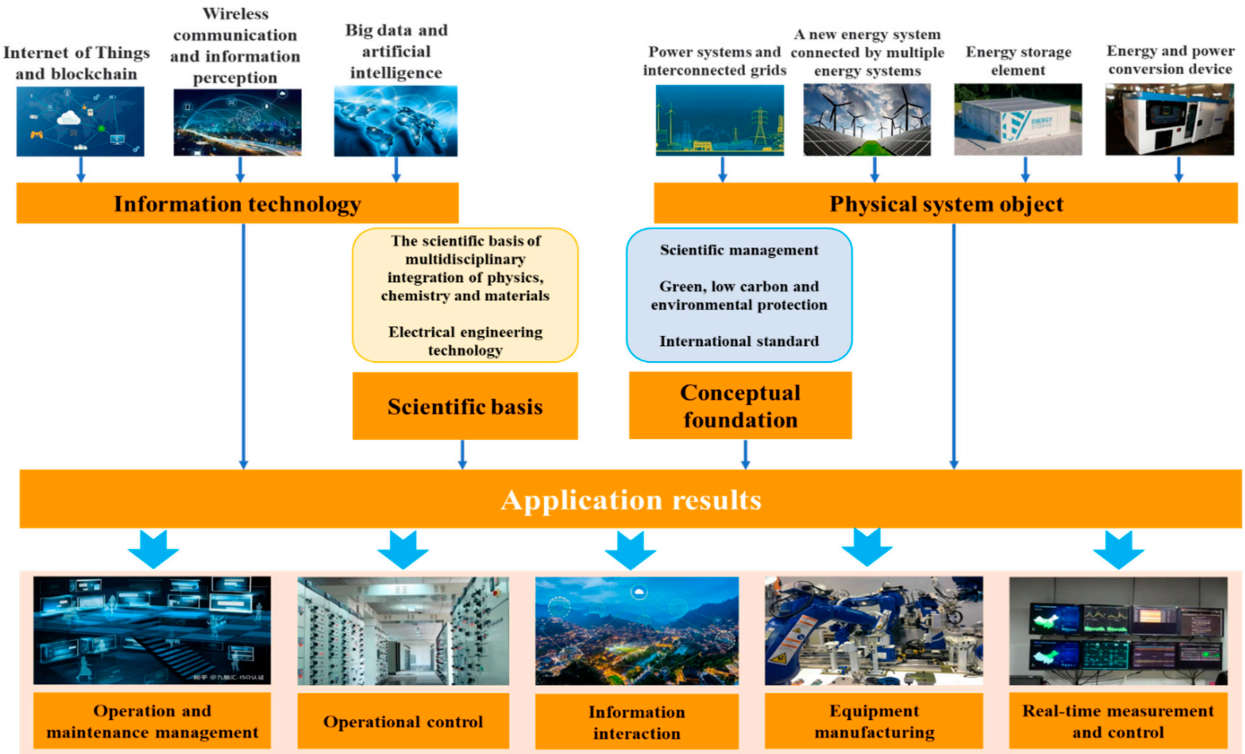

Figure 9. Schematic diagram of integration mode of energy and information technology in the Energy Internet.

To summarize, the development of electrical engineering started early, the discipline construction has been sufficient and the education system is scientific and complete. In addition, there are many colleges and universities offering relevant majors in the field of electrical engineering, forming a large base of teachers, researchers and high-quality students, which can quickly transform the training mode and produce a large number of professional talents. At the same time, the construction of the power grid is still a core part of the construction of the Energy Internet, so the core knowledge of electrical engineering can be effectively utilized. In addition, the teaching content of the electrical engineering and automation major has a high degree of interdisciplinarity, which is suitable for the actual situation of the Energy Internet, which has a high degree of interdisciplinarity [83]. Moreover, the smart grid, built on the basis of electrical engineering, has many similarities in concept and technology to the Energy Internet. For example, artificial intelligence technology has played an extremely important role in the energy system, so the experience and technology of the smart grid can be followed in the construction of the Energy Internet [84]. Finally, after a long period of discipline construction and development, many applications show that the electrical engineering discipline has successfully realized the intersection with the information discipline, which fully conforms to the construction concept and technical requirements of the Energy Internet [85]. Therefore, the teaching reform of talent training oriented to Energy Internet construction based on the electrical engineering discipline has natural advantages. It can achieve the goal with the fastest speed and the best effect through the smallest degree of reform, avoiding the risks to talent training caused by the subversive change in teaching systems and training modes.

3.2. The Current Situation of the Establishment and Construction of Energy Internet Engineering Major (Direction)—Taking China as an Example

Since the concept of the Energy Internet was proposed and the call of the Chinese government to build the Energy Internet was issued, some universities with strengths in electrical engineering in China have intensified the teaching reform and the construction of the Energy Internet engineering specialty [86]. At present, a small number of universities have started to enroll undergraduates or postgraduates majoring in Energy Internet engineering and have carried out corresponding teaching and training work. The representative ones are Tsinghua University, Xi'an Jiaotong University and Shanghai Electric Power University.

Shanghai Electric Power University and Xi'an Jiaotong University have established Energy Internet Engineering as a separate undergraduate enrollment major and enrolled students for the first time in 2021 and 2022 in the national college entrance examination. This major is set in the school of electrical engineering at both universities. However, Tsinghua University has not set up independent enrollment in the Energy Internet Engineering major, but it has set up two independent training systems in the direction of Energy Internet, one being an international undergraduate class of Energy Internet in the electrical engineering and automation major, and another being an Energy Internet undergraduate minor. In terms of graduate students, Shanghai Electric Power University started the enrollment program of Master of Engineering in the direction of Energy Internet for Energy Power in 2021.

The above Energy Internet engineering majors or directions have published their corresponding training programs. According to the training program of Tsinghua University's Energy Internet International Class, the construction of the Energy Internet is a global subject [20]. Therefore, students are positioned to be trained in accordance with international standards. As for the teaching design of this international class, in addition to the traditional electronics courses of electrical engineering (including power system analysis, analog electronic technology, etc.), the required courses include signal and system, computer programming fundamentals, computer network and technology. The contents of interdisciplinary courses include introduction to the Energy Internet, fundamentals of thermodynamics and heat transfer and big data technology and application. In addition, the program has developed a curriculum plan for exploratory learning, including analysis, control and design of electrical machines, power systems and power electronics. Many courses about new energy, the smart grid and the Energy Internet have been placed in the category of electives (specific courses include new energy grid-connection and power generation, multi-energy system modeling and analysis, energy strategy for sustainable development, operation and dispatch of the Energy Internet, etc.). At the same time, a high English level is required for students. According to the training program of the Energy Internet undergraduate minor at Tsinghua University (specifically targeted at students of majors other than electrical engineering major), the main discipline of this minor is electrical engineering. In addition to the traditional courses in electrical engineering, students will also need to study relevant content about intelligent energy and artificial intelligence. Specific courses concern the principles of the Energy Internet, intelligent processor and industrial control technology, smart grid, smart energy system, smart grid modeling and simulation, smart home, new energy generation and energy storage, etc. As for the postgraduate training program of Energy Internet in Energy Power of Shanghai Electric Power University, the target group is postgraduates rather than undergraduates, so the learning contents are more detailed. In addition to the traditional content of electrical engineering, as for the construction of the Energy Internet, the unique content of learning objectives or learning guidance given in the scheme mainly includes Energy Internet new energy generation technology, Energy Internet advanced energy storage and its application technology, Energy Internet advanced power electronics technology and its application, integrated energy system planning and operation, Energy Internet advanced information technology and its application, etc.

The construction of undergraduate and postgraduate programs of Energy Internet engineering at Chinese universities is still in its initial stage, and the few existing colleges and universities that set Energy Internet engineering as an independent major have just started to enroll their first batch of students in the past two years. Besides, the construction of the major is still not optimized, and it is still in the exploration stage. The teaching content is still mainly about electrical engineering, and only a few courses about artificial intelligence and new energy have been added. The same problem is seen in other countries around the world. At present, the construction degree and enrollment scale of the Energy Internet engineering major are still insufficient, and cannot meet the large number of talents needed to vigorously promote the construction of the Energy Internet. Therefore, it is an urgent task to carry out education reform in many colleges and universities that have the foundation of electrical engineering but have not yet implemented an Energy Internet engineering major or direction and to build the Energy Internet engineering major into an independent discipline with a relatively complete system. This is also of great significance to respond to the call of the government and realize green energy and environmental protection.

4. Reform Measures and Challenges of Smart Energy System Discipline

In order to adapt to the demands of the development and construction of the Energy Internet, follow the strategy of global energy transformation and cultivate comprehensive technical talents with both basic knowledge in the field of energy and application abilities in information technology, many colleges and universities should implement teaching reform on the basis of the electrical engineering discipline as soon as possible, explore the model of the Energy Internet engineering major, and output applied talents. In the course of the teaching reform, we should give full consideration to the training mode and construction of electrical engineering at the current stage. At the same time, we should make full use of the existing advantages and experiences in the construction of Energy Internet engineering, scientifically and reasonably promote the reform of the education system, and avoid the subversive change in the existing education model and structure and the corresponding risk to talent training.

4.1. Thoughts on Teaching Reform

The development concept of the Energy Internet is the most advanced concept in the energy field at the current stage [87], and it is in the high-speed construction and development period. Thus, the demand for high-level talent is substantial. Therefore, in the process of reform, we must always grasp the central idea of training high-level talents who can master the most cutting-edge technology for the construction of the Energy Internet, ensure the pertinence and effectiveness of reform measures, and guarantee that the quantity and quality of talent output can maintain a high level and effectively promote the rapid development of the Energy Internet.

The construction of the Energy Internet is an important global strategic policy in the field of energy, and the research of Energy Internet technology is an important topic in the field of energy for all countries in the world [88]. The globalization of the Energy Internet is unstoppable. The talent training for Energy Internet construction should be carried out in accordance with international standards. During the educational reform, we should not only pay attention to the development of English teaching, but also pay attention to global energy concepts, energy policies and technical standards, and add elements in the teaching contents that adapt to the globalization of Energy Internet construction. For example, the proportion of bilingual courses should be increased appropriately, and the corresponding English textbooks or teaching materials should be selected.

As mentioned above, in the basic situation and related technologies of the Energy Internet, the knowledge system required for building the Energy Internet has a strong interdisciplinary nature, and the technical fields involve electrical engineering, communication engineering, artificial intelligence, computer science, Internet of Things engineering and other disciplines [89]. Although there is a certain degree of interdisciplinary component in the current course system of electrical engineering, and the content of the main required courses can basically serve the construction of the Energy Internet, there is still a gap compared with the need to build the Energy Internet. (For example, the current teaching content of electrical engineering basically does not involve the relevant knowledge of artificial intelligence, and artificial intelligence technology is a necessary technology for the construction of the Energy Internet). Therefore, in the process of teaching reform, it is necessary to add new interdisciplinary content to the existing curriculum of electrical engineering, improve the knowledge required for the construction of the Energy Internet and further enhance the interdisciplinarity.

Many interdisciplinary contents need to be supplemented to the original teaching content of electrical engineering, but the total amount of teaching hours should be controlled. Therefore, the original teaching content of electrical engineering needs to be appropriately simplified (mainly involving the contents in electrical engineering field which are not related to the construction of the Energy Internet), so as to provide enough class hours for the opening of new courses.

In addition, the talents needed for Energy Internet construction are applied engineering talents [90]. At the present stage, the construction of the Energy Internet is still in its infancy [91], and the technology is facing constant innovation. Therefore, higher requirements are put forward for the recruited talents' innovative ability and practical ability. In order to cultivate talents with good innovative ability and practical ability, courses related to design and exploration should be strengthened in the process of teaching reform, and the amount of class hours and assessment standards of these course should be increased appropriately, so as to ensure that students have creative thinking and practical ability to solve problems. The contents shown in Figure 10 reflect our thoughts and ideas on teaching reform.

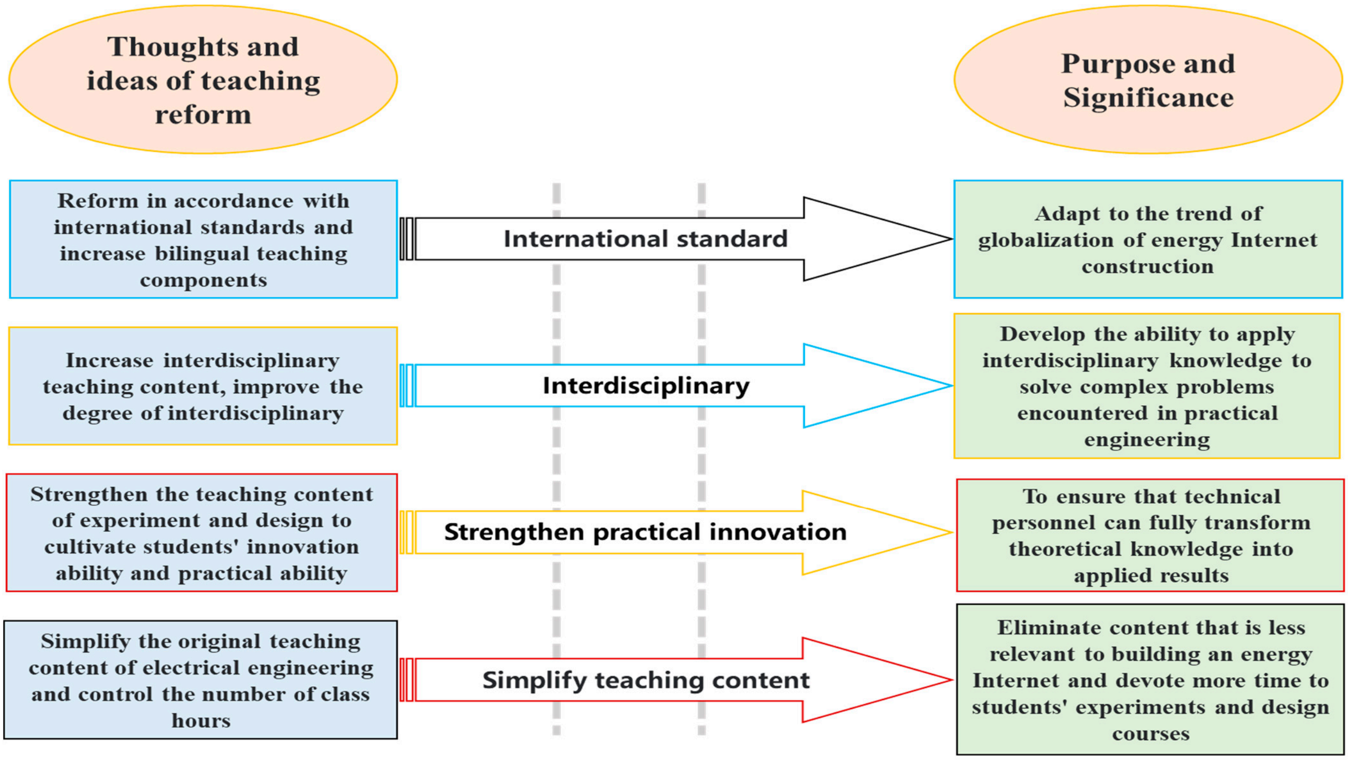

Figure 10. Thoughts and ideas of teaching reform.

4.2. Concrete Measures of the Teaching Reform

4.2.1. Energy Internet Major (Direction) Training Program

We investigated the training programs of electrical engineering-related majors in several schools at the present stage, combined with the training programs of Energy Internet engineering (direction) investigated above and the construction concepts and technical requirements of the Energy Internet, and put forward opinions and suggestions on establishing the training programs for the Energy Internet.

The training goal of the traditional electrical engineering discipline is to output talents who can master the operation principle of the power system and power equipment for the power grid and enterprises. However, it does not put forward excessive requirements for information technology, artificial intelligence technology and related knowledge of other energy sources except electric energy. Therefore, the training objectives of the Energy Internet engineering major, which will be vigorously built in the future, can be defined as follows: Cultivate comprehensive talents who can fully understand the basic operation and interconversion principles of electrical energy and other energy systems such as heat and wind [92]; understand the new energy concept with the purpose of green and environment protection [93]; master the basic knowledge of computer and artificial intelligence [94]; have the knowledge and skills to deeply integrate information technology into energy industry; fully understand the world's cutting-edge technologies and industrial technical standards in energy, information and the Internet of Things; and have high innovative ability and practical ability. The objectives can adapt to the actual needs of the long-term construction of the global Energy Internet in the future.

In addition to power grid construction, the most important part of Energy Internet construction is the application of information technology [74], with the need to achieve a high degree of integration of information technology into the energy system. Therefore, the key content of the training program should train students' professional ability not only in the field of electrical engineering, but also in the field of information engineering. However, the Energy Internet involves a wide range of knowledge, so students need to have a basic understanding of the related knowledge in artificial intelligence and the Internet of Things [95] and know which aspects could be combined with power technology and information technology.

To summarize, the core idea of the reform of the training program for students majoring in Energy Internet is to firmly master the core technology of building the Energy Internet [96]. At the same time, they should be familiar with all kinds of related technologies, establish correct energy concepts under the background of the new era, have enough innovation ability, and be able to solve practical problems with practical multidisciplinary ability and meet the actual application needs of Energy Internet construction.

4.2.2. Course System of Energy Internet Major (Direction)

One of the pillars of teaching reform is the adjustment of the contents of the curriculum [97]. In order to meet the requirements of strong cross-disciplinarity, the reform direction of the curriculum system must introduce new content on the basis of the original curriculum system of the electrical engineering major, so as to ensure the students' comprehensive knowledge learning in order to cope with the needs of building the Energy Internet in all aspects.

According to the curriculum system of the electrical engineering and automation major in most colleges and universities at present, the current teaching content is mainly courses in electrical engineering theory, taking electricity and electronics content as the core, supplemented by a few courses in computer programming, communication theory and electronic and electrical design. Table 3 shows the curriculum system setting of the electrical engineering discipline before the teaching reform.

Considering the technical needs of Energy Internet construction, the missing contents of the curriculum system of electrical engineering mainly include courses in computer network and technology, theoretical knowledge of the Energy Internet, other basic knowledge of energy, modern information technology and artificial intelligence. In order to build the Energy Internet engineering major, the curriculum system reform can set the curriculum content into the following categories (basic courses such as higher mathematics, university physics, ideological education and engineering drawing are no longer considered, and only basic courses and core courses of the major are considered): electrical engineering, information technology and control theory, energy management and energy conversion, and practice and design.

Table 3. The curriculum system before the reform.

Course Categories	Curriculum Name	
Electricity courses	• Electromechanics • High-voltage technology • Power system relay protection • Engineering electromagnetism	• Power plant engineering • Power system automation • Overvoltage and protection • Electromotor control technology
Electronics courses	• Circuitous philosophy • Analog electronics technique • Digital electronic technique	• Electric power system analysis • Power electronics • Programmable Logic Controller Theory
Related subject course	• Computer programming fundamentals • Signals and systems	• Information theory and power systems • Automatic control theory
Practical and design courses	• Short-circuit calculation and design of power system • Power electronic simulation design	• Embedded system practice • Single chip application design • Integrated practice of electronic technology

Electrical engineering courses are mainly oriented to the electric energy problems and power grid construction in the construction of the Energy Internet, which basically covers the main teaching contents of electrical engineering at the current stage, and can also be recognized as the backbone and core courses of the Energy Internet major.

Combined with the existing training programs of the Energy Internet engineering major or direction, and the actual demand of technologies of the Energy Internet from the field of electrical engineering, the course contents include: circuit principle, analog electronic technology, digital electronic technology, electrical machinery, power electronic technology, power system analysis, high-voltage technology, power system relay protection, power plant engineering, power system automation, overvoltage and protection, etc.

Information technology and control theory courses are mainly designed to train students to learn programming technology, communication technology, Internet of Things technology and blockchain technology, as well as emerging big data, artificial intelligence and other cutting-edge technologies [98]. Mastering the above technologies aims to achieve a high degree of integration of energy system and information technology [99], to achieve the informatization in the process of Energy Internet construction, and to finally realize the purpose of automatic control, scheduling optimization, information interaction, reasonable distribution, operation efficiency improvement and profit increase [100]. This part is the most critical and core courses except the electrical engineering courses. The reason is that the high degree of information and control automation of energy system is the development trend of the current stage in the field of energy, and it is also the specific embodiment of the forefront development of energy system technology, and it is also the most core and essential requirement of the construction of Energy Internet. Therefore, the course content design needs to include a series of cutting-edge courses in various fields and disciplines related to information technology, such as artificial intelligence and application, automatic control theory, big data analysis and processing, etc. The specific components of the courses include fundamentals of computer programming, signals and systems, computer networks and technologies, principles of automatic control, digital signal processing, data structure, information theory and power system, big data analysis and processing, artificial intelligence and its application, etc.

The Energy Internet is a new energy system covering electric energy and a variety of renewable energy types. The courses of energy management and energy conversion should mainly expand students' knowledge system from electric energy to other forms of energy. This can train students to master the theoretical principles and technical basis of the storage and conversion (with the electric energy) of all kinds of energy. Compared with the traditional power grid and the smart grid, the operation mode of the Energy Internet is a major revolution of the infrastructure and operation control of energy systems. The study of comprehensive energy courses can help students have a relatively comprehensive understanding of the Energy Internet, master the development trend of Energy Internet construction and master the cutting-edge knowledge direction required by the construction of the Energy Internet. The specific courses include an introduction to Energy Internet, thermodynamics and heat transfer fundamentals, renewable energy and future power technology, energy storage technology in smart grid, new energy generation and grid connection, energy transformation principle and technology, operation planning and scheduling of Energy Internet, etc.

The construction of the Energy Internet has high requirements for the talents' innovation ability and practical ability [101]. The courses of practice and design aim at cultivating students' creative thinking and examining their ability to transform basic theoretical knowledge into practical application [102]. In the training and education model of students in many countries (such as China), experiment and design have always been less valued, and the ability of experiment and design is also the weakness of most students, leading to students' high dependence on training from employers. Therefore, in order to train talents with a comprehensive ability to carry out Energy Internet construction, the course content of practice and design courses should be improved in the process of teaching reform, and the investigation should be appropriately strengthened. Based on the actual needs of building the Energy Internet in the future [103], and combined with the investigated existing training programs of Energy Internet engineering, the courses on practice and design can include short-circuit calculation design of power systems, power electronic simulation design, smart grid modeling and simulation, integrated practice of electronic technology, embedded system practice, SCM application design, multi-energy system modeling and analysis, etc. Table 4 reflects the expected setting of the curriculum system after the reform.

Table 4. The curriculum system after the reform.

Course Categories	Curriculum Name	
Electrical engineering courses	• Circuitous philosophy • Analog electronics technique • Digital electronic technique • Electromechanics • Power electronics • Electric power system analysis	• High-voltage technology • Power system relay protection • Power plant engineering • Power system automation • Overvoltage and protection
Information Technology and control theory courses	• Computer programming fundamentals • Signals and systems • Computer networks and technology • Automatic control theory • Digital signal processing	• Data structure • Information theory and power systems • Big data analysis and processing • Artificial intelligence and its applications
Energy management and energy conversion courses	• Introduction to the Energy Internet • Fundamentals of thermodynamics and heat transfer • Renewable energy and future electricity technologies • Energy storage in smart grid	• New energy generation and grid connection • Energy conversion principle and technology • Energy Internet operation planning and scheduling
Practical and design courses	• Short-circuit calculation and design of power systems • Power electronic simulation design • Integrated practice of electronic technology • Smart grid modeling and simulation	• Embedded system practice • Single chip application design • Multi-energy system modeling and analysis

After the teaching reform, a large number of courses in energy management, energy conversion and renewable energy would be added to the curriculum system, such as Introduction to the Energy Internet, New Energy Generation and Grid Connection. The knowledge content of these courses is important professional knowledge needed for the construction of the Energy Internet in the new era, which is not available in the original curriculum system of electrical engineering. Then, in terms of practice and design courses, there are also new courses such as multi-energy system modeling and analysis, smart grid modeling and simulation. These simulation courses are also designed to develop students' practical ability in the new energy field era. In addition, the new curriculum system also removed some of the original electricity and electronics courses, such as engineering electromagnetic, Programmable Logic Controller Theory and so on. The reason is that the teaching content of these courses is not helpful enough for the construction of the future Energy Internet. Removing these courses can allocate their class hours to a large number of new courses and reduce the pressure of students' courses as much as possible.

4.2.3. Teaching Model and Examination Form

The reform of the teaching mode is an important part of the teaching reform. At present, the teaching mode of the electrical engineering major is mainly theoretical teaching supplemented by experimental courses. We investigated the teaching situation of specialized courses of the electrical engineering and automation major in many universities in China, such as power system analysis, electrical machinery and other courses. The class hours of theoretical courses and experimental courses are basically maintained at the level of five-to-one or four-to-one. Attaching too much importance to theoretical courses while neglecting experimental courses would lead to a serious shortage of students' practical operation ability and ability to transform theory into practice. Energy Internet construction has especially high requirements for talents' practical ability, and students need to have sufficient practice in the process of learning in school so that they can solve various problems that may occur in the construction of the Energy Internet. The key point of the reform is to balance the class hour allocation between theory courses and practice courses. It is reasonable to adjust the class hour ratio of theoretical courses and experimental courses to three-to-one or two-to-one. In addition, a situation existing in many colleges and universities is that theoretical teaching is carried out first, and the experimental courses are concentrated at the end of the semester after the theoretical courses are finished; there is also another case where the experimental course is taught as a separate course and is given in a different semester from the theory course. This situation has a certain degree of irrationality. The reason is that the experiment is built on the basis of theory and is the practical verification of theoretical learning. Not carrying out experimental courses in time will not be conducive to guarantee the learning quality. Theory and practice are especially important for Internet engineering majors aiming at Energy Internet construction. In the process of reform, we should pay attention to the teaching of experimental courses in time after the teaching of theory, so as to deepen students' understanding of theory.

As for the assessment methods of theoretical courses and experimental courses, they mainly include daily evaluation, final examination and the writing of experimental reports. Most schools in China attach great importance to experimental reports and final examinations and have strict standards, which play a key role in ensuring the learning quality of theoretical and experimental courses for students. The part that needs to be strengthened in the reform process is mainly the daily evaluation part. Taking Chinese universities as an example, at present, most schools set the daily evaluation as high as 30 percent of the score, or as high as 40 percent at some schools. The proportion of daily assessment is relatively high, but the strength of daily assessment is often weak. At present, the assessment methods mainly include class attendance, homework submission and so on. If the intensity of daily evaluation is too low, it is easy to cause students to despise the quality of learning, but they can easily pass the overall assessment of the course. One of the effective measures to enhance the intensity of the daily evaluation is to modify the examination form to carry out in-class quizzes. This measure can not only effectively urge students to improve the learning efficiency and quality of each class, but also enable teachers to gather feedback on the teaching situation of each class.

One of the core and key contents of the teaching reform is to strengthen the teaching of practice and design. In order to strengthen the teaching of practice and design, both the contents and types of courses and the proportion of credits should be increased; in addition, the ways to better carry out the teaching of practice and design also need to be considered. At present, the teaching content of practice and design of electrical engineering major in colleges and universities mainly includes two types: one is engineering practice, and the other is curriculum design. The main teaching mode of engineering practice is to assign students to enterprises for internships, and then use internship reports as the assessment contents. The main teaching mode of curriculum design is to give students assigned design topics, let students design freely and then collect students' work for grading. As for the existing teaching model of engineering practice, it should be noted that only relying on the internship report cannot fully reflect the actual learning situation of students in the internship. Therefore, the assessment mode of engineering practice needs to be adjusted. In order to ensure students' learning quality in the internship, the actual operation inspection of the internship content can be added before the end of each enterprise internship, which constitutes the assessment contents together with the internship report. The development of practical operation inspection can effectively urge students to operate in the process of practice, so that students' operational ability in practice is guaranteed. As for the existing teaching mode of curriculum design, the main problem is that the quality of students' design works cannot be guaranteed. The main reason for this phenomenon is that students often lack knowledge in a certain part of the design process, resulting in poor quality of the whole work. In the reform, in order to solve this problem, some of the curriculum design tasks with higher overall difficulty can be adjusted from individual tasks to group tasks. The advantage of this measure is that it can give full play to the technical advantages of each member of the team, and they can choose their own areas of specialization and cooperation to jointly complete a work of excellent quality. In addition to ensuring the quality of works and effectively exercising students' independent thinking and creative ability, this method can also exercise students' teamwork ability, which is also a key ability in the future work. The construction of the Energy Internet requires the collaboration of people skilled in various technologies [104].

4.2.4. Faculty and Teaching Resources

Based on the reform of the curriculum system described above, the teaching content covers electrical engineering, new energy, physics, materials, computer, communication engineering, Internet of Things engineering and other fields. It is impossible to complete the planned teaching task only by relying on the teachers of electrical engineering at the present stage. In the early stage of Energy Internet engineering major construction, the solutions to this problem are as follows. Teaching is based on students majoring in electrical engineering. With the teachers at the college of electrical engineering as the main teaching force, the relevant teachers from the college of computer science, the college of physics and other schools are recruited to teach some new interdisciplinary courses in addition to the traditional basic courses of electrical engineering. These courses include program design, signal and system, new energy power generation and grid connection, artificial intelligence and its application, etc.

As for the change in teaching resources of the electrical engineering major, since the most critical goal of the reform is to strengthen students' practical ability and innovation ability, colleges and universities need to provide students with enough experimental equipment and practical operation space. The aim is to ensure that each student is able to perform experiments independently, avoiding group experiments due to the limited amount of equipment. Thus, it is essential to provide enough space for practical operation and ensure that each student can have sufficient practice with independent experiments.

5. Value and Significance of Teaching Reform and the Future Work

5.1. Value and Significance of Teaching Reform

The construction of the Energy Internet conforms to the background of the era. It is an important strategic policy in the field of global energy and an inevitable trend in the revolution of the global energy system. At present, colleges and universities all over the world lack the education for professional talents for Energy Internet construction. The construction of the Energy Internet engineering major is an important task in the current era. The discipline of electrical engineering has many advantages, such as early start, long development time, a large number of students, well-qualified teachers and a complete education system [105]. Among the major engineering disciplines at the present stage, the electrical engineering discipline is the most closely related to the Energy Internet, as the construction of the power grid and the integration of the power grid and information technology are central links in the construction of the Energy Internet. Based on the electrical engineering discipline, the teaching reform aimed at building the Energy Internet engineering major can effectively avoid the subversive change in the education system and prepare to implement the Energy Internet engineering major at the fastest speed [106]. This is of great significance for enhancing professional diversity in higher education [107]. In addition, the construction, operation and maintenance of the power grid is currently the first choice for electrical engineering graduates. We investigated the employment intentions of all the students (41 in total) of the Experimental Class of Electrical Engineering and Automation at Guangxi University, China, as shown in Figure 11.

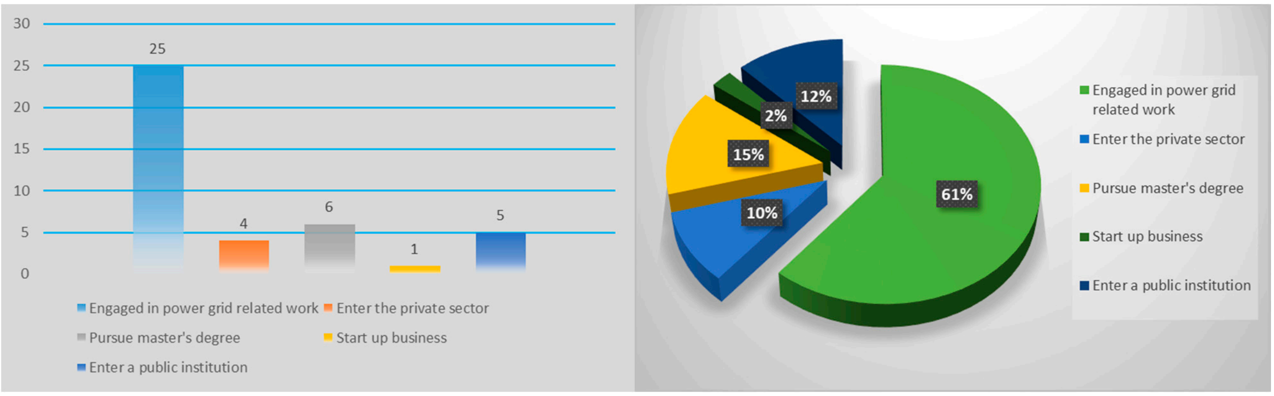

Figure 11. Employment intention survey of all members of the Experimental Class of Electrical Engineering at Guangxi University in China.

When the construction of the Energy Internet develops vigorously, the power grid will be incorporated into the framework of the Energy Internet, and the specialized technological talents in the energy industry will tend to be diversified. If a large number of electrical engineering students only master the existing technical and theoretical knowledge in the field of electrical engineering, it will not be enough to support the construction of the future Energy Internet, and they will lack sufficient competitiveness to enter the field of energy employment. Therefore, promoting education reform and actively building the Energy Internet engineering major is also an important measure to improve the competitiveness of students in future employment [108]. In addition, many countries around the world (such as China, the U.K., etc.) have taken the construction of the Energy Internet as the primary goal of the energy field construction, and the revolutionary trend in the energy field is unstoppable. One of the important features of the Energy Internet is the integration of electricity and other forms of renewable energy into the energy system. At present, the teaching content of electrical engineering is limited, and the technology of renewable energy and integrated energy system is not involved. If the teaching reform is not carried out in time and the status quo is maintained, the technical level and knowledge reserve of talents in the field of energy will be seriously affected, and they will not be competent for future Energy Internet construction work. The lack of high-level talents will seriously hinder the construction process of the Energy Internet and adversely affect a country's strategic deployment in the energy field. Delays in building the Energy Internet will gradually disconnect a country from the global energy system and cutting-edge energy technologies, with a series of adverse consequences. Therefore, the state must attach great importance to the cultivation of talents, and the teaching reform has a profound impact on the development of the energy field.

At present, the construction of the Energy Internet is still in the initial stage, and the concept and technology are still in the stage of exploration and improvement. Through the teaching reform of electrical engineering, relying on a large number of students majoring in electrical engineering, a large number of applied professionals who can be engaged in the construction of the Energy Internet can be quickly trained. This is of great significance for responding to a country's strategic needs in the energy field and promoting a green and low-carbon revolution in the global energy system. In a word, this teaching reform has an important impact on education, employment, social economic construction, strategic needs in the field of energy and the construction of a global new energy system.

5.2. Work to Be Done in the Future

The idea acquisition and measure proposal of teaching reform is only a part of the successful reform. The implementation of reform measures is still an important and arduous task. At the same time, revolutions in the energy field will continue over time, and innovations in the technology related to energy systems are inevitable. Accordingly, the knowledge reserve of technical personnel engaged in related work in the field of energy should also be updated with the development of the times. Therefore, the teaching reform of colleges and universities is a task that needs to be carried out for a long time.

Based on the teaching reform ideas and measures obtained from the experience of various teaching units at the present stage, the reform should be carried out as soon as possible to optimize the talent training mode and export talents with sufficient knowledge reserves and mastery of cutting-edge technology for the development of the energy field as soon as possible. At the same time, the educational auxiliary units of the energy discipline should pay enough attention to the emerging technologies, development concepts and guiding policies in the energy field, and formulate the next step of teaching reform measures according to the constantly updated technical system in the energy field, so as to cultivate technical talents whose knowledge reserve can keep up with the pace of the times.

6. Conclusions

Given the requirements of the new era and the commencement of the information age, the traditional development and operation mode of electric power and the power grid no longer meet the needs of the modern age. Intelligent energy systems represented by the Energy Internet will usher in a major revolution in the energy field and will rely on a high degree of information and intelligent technology means, incorporate a variety of renewable energy other than electric energy into the energy system, and fully implement green environmental protection in the energy field, comprehensively replacing the traditional power grid. Today, the construction of the Energy Internet has been mobilized, and more than 140 countries around the world have introduced relevant policies to facilitate its development. Among them, China's Energy Internet construction work has become an important global demonstration. The UHV line under construction has a length of 35,000 km, with a power transformation capacity, including conversion capacity, of 360 million kVA, and an annual power transmission capacity of more than 400 billion KWH. At the same time, the construction of the Energy Internet has played an important role in atmospheric and environmental governance. In the future, the construction of the Energy Internet needs to be further promoted. Therefore, technology research and talent training for the construction of the Energy Internet are important guarantees to promote the comprehensive development of the energy field in the new era.

With the continuous development of the era, changes in various fields are also underway, and higher education is the root of the cultivation of high-level talents. In order to ensure that each field of social construction can consistently cultivate sufficient high-level talents in the ever-changing environment, the teaching reform of higher education is inevitable, setting high requirements for the development and construction of higher education. The importance is not only reflected in the teaching reform of related majors in the energy field, but also the teaching reform of related majors in other fields. Therefore, in order to ensure the quality of higher education and keep up with the pace of social development and construction, how to carry out teaching reform, how to control the direction of teaching reform and how to ensure the quality of teaching reform will be important long-term topics for universities to tackle.

Author Contributions: Conceptualization, Conceptualization, D.Z.; Data curation, D.Z. and J.T.; Formal analysis, D.Z. and J.T.; Funding acquisition, H.L.; Investigation, D.Z. and J.T.; Methodology, D.Z., J.T. and X.L.; Resources, D.Z. and J.T.; Software, D.Z. and J.T.; Supervision, D.Z., H.-H.G. and X.W.; Validation, D.Z. and J.T.; Writing—original draft, J.T.; Writing—review & editing, D.Z., J.T. and H.Z., D.Z. and J.T.; Methodology, D.Z., J.T. and X.L.; Resources, D.Z. and J.T.; Software, D.Z. and J.T.; Supervision, D.Z., H.-H.G. and X.W.; Validation, D.Z. and J.T.; Writing—original draft, J.T.; Writing—review & editing, D.Z., J.T. and H.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported in part by the National Natural Science Foundation of China (5210071288); Guangxi Science and technology major project, China (2021AA11008); Guangxi Science and Technology Base and talent special project, China (2021AC19120); Guangxi Higher Education Undergraduate Teaching Reform Project, China (2021JGZ101); Industry-university-research Collaborative Education Program of the Ministry of Education, China (202102449078 and 202102449079); and the Open Research Project Programme of the State Key Laboratory of Internet of Things for Smart City (University of Macau) (SKL-IoTSC(UM)-2021-2023/ORP/GA30/2022).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ahmad, T.; Zhang, D. A critical review on comparative global historical energy consumption and future requirement: The story told so far. *Energy Rep.* **2020**, *6*, 1973–1991. [CrossRef]
2. Hui, H.; Zhu, G.; Wei, C.; Zhang, Y.; Zhao, J.; Dong, Z. Energy internet risk assessment framework. In Proceedings of the Power & Energy Engineering Conference (APPEEC), Brisbane, Australia, 14 January 2016.
3. Zhang, N.; Yang, G.; Wang, D.; Jin, T.; Li, X.; Zhang, Y. Discussion on the distributed intelligent development of energy internet. In Proceedings of the 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 20–22 October 2018.
4. Wu, X.; Ge, B.C.; Zang, T.; Liu, Y.; Zhang, Z.; Yang, F. Management system research of large-scale new energy development based on energy internet. In Proceedings of the 2017 IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 26–28 November 2017.
5. Tang, Y.; Mu, Z.; Du, C.; Lei, T. The Energy Accumulation of New Energy Internet Oriented to Customer Side. *Iop Conf.* **2018**, *170*, 042123. [CrossRef]
6. Li, B.; Yang, S.; Duan, F.; Yan, K. The Key Technologies about Energy Internet. In Proceedings of the 2015 2nd International Conference on Electrical, Computer Engineering and Electronics, Jinan, China, 24 June 2015; pp. 1506–1509.
7. Liang, J.; Luo, Y.; Yang, D.; Guo, X. Overview on Implementation Planning of Energy Internet Based on Energy Hub. In Proceedings of the 2017 5th International Conference on Machinery, Materials and Computing Technology, Beijing, China, 25–26 March 2017; Volume 126, pp. 738–744.
8. Wu, S.; Ji, G.; Duan, Q. Development Strategy of Energy Internet Industry for Power Grid Enterprises. In *International Conference on Frontier Computing*; Springer: Singapore, 2019.
9. Hao, L.; Long, W. Future Energy System in Low-Carbon Community-Energy Internet. In Proceedings of the International Conference on Computer Distributed Control & Intelligent Environmental Monitoring, Changsha, China, 19–20 February 2011.

10. Liu, X.; Liao, Z.; Chen, J.; Shen, H. Architecture of A Mobile Energy Internet. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *428*, 012003. [CrossRef]
11. Liu, D.; Xu, Z.; Li, C.; Shen, H. Reform and Exploration for Practical Teaching of Electrical Engineering and Automation. In Proceedings of the 2017 International Conference on Economics and Management, Education, Humanities and Social Sciences (EMEHSS 2017), Hangzhou, China, 15–16 April 2017.
12. Haiwang, C.; Chaogai, X.; Lili, D. Exploration on electrical and electronic teaching reform by information technology. In Proceedings of the 2010 International Conference on Educational and Information Technology (ICEIT 2010), Qingdao, China, 17–19 September 2010.
13. Ge, L.; Wang, Y.Q.; Qi, J.; Wang, H.; Lin, Q.; Peng, Y. The Content, Frameworks and Key Technologies of Power Internet of Things for Urban Energy Internet. *Electr. Power Constr.* **2019**, *40*, 91–98.
14. Zhang, Z.; Liu, Z.; Zhang, X.; Yin, S.; Wang, Y.; Xing, Y.; Dong, X.; Hu, E.; Li, Q. Model Construction and Construction Key Issues for Energy Internet Ecosystem. In Proceedings of the 2021 IEEE 5th Conference on Energy Internet and Energy System Integration (EI2), Taiyuan, China, 22–24 October 2021.
15. Tan, T.; Shi, J.; Liu, Y.; Zhang, J. Characteristics of Industrial Park Energy Internet and Key Technologies of Its Energy Management Platform. *Electr. Power Constr.* **2017**, *12*, 20–30.
16. Liu, T.; Zhang, D.; Dai, H.; Wu, T. Intelligent modeling and optimization for smart energy hub. *IEEE Trans. Ind. Electron.* **2019**, *66*, 9898–9908. [CrossRef]
17. Quan, T.; Xu, W.; Li, S.; Ye, X.; Xiang, Y.; Liu, J.Y.; Niu, Y.; Honh, J.H. Urban energy internet: Concept and key technology. In Proceedings of the 2016 3rd International Conference on Systems and Informatics (ICSAI), Shanghai, China, 19–21 November 2016.
18. Zhu, H.; Goh, H.H.; Zhang, D.; Ahmad, T.; Liu, H.; Wang, S.Y.; Li, S.W.; Liu, T.H.; Dai, H.; Wu, T. Key technologies for smart energy systems: Recent developments, challenges, and research opportunities in the context of carbon neutrality. *J. Clean. Prod.* **2022**, *331*, 129809. [CrossRef]
19. Chen, X.; Fu, W.; Li, Y. Operation Strategy of Power System Based on Energy Internet. In *Innovative Computing*; Springer: Singapore, 2020.
20. Xie, Y.; Wu, J.; Zhang, X.; Zhou, W. Exploration on the Development Model of Energy Internet in Large Region. In Proceedings of the 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 20–22 October 2018.
21. Zhu, Y.; Wang., J.; Wu, K. Open System Interconnection for Energy: A Reference Model of Energy Internet. In Proceedings of the 2017 IEEE International Conference on Energy Internet (ICEI), Beijing, China, 17–21 April 2017.
22. Zhu, J.; Xie, P.; Xuan, P.; Zou, J.; Yu, P.F. Renewable energy consumption technology under energy internet environment. In Proceedings of the 2017 IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 26–28 November 2017.
23. Liu, T.; Zhang, D.; Wu, T. Standardised modelling and optimisation of a system of interconnected energy hubs considering multiple energies—Electricity, gas, heating, and cooling. *Energy Convers. Manag.* **2020**, *205*, 112410. [CrossRef]
24. Ni, J.; He, G.; Lu, H.; Yang, D.; Chen, Y. Featured town energy internet design based on the flexible demand response resources. In Proceedings of the 2017 IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 26–28 November 2017.
25. Wu, Y.; Wu, Y.P.; Guerrero, J.M.; Vasquez, J.C. A comprehensive overview of framework for developing sustainable energy internet: From things-based energy network to services-based management system. *Renew. Sustain. Energy Rev.* **2021**, *150*, 111409. [CrossRef]
26. Guo, M.; Xia, M.C.; Chen, Q.F. A review of regional energy internet in smart city from the perspective of energy community. *Energy Rep.* **2021**, *8*, 161–182. [CrossRef]
27. Zhou, K.; Yang, S.; Shao, Z. Energy Internet: The business perspective. *Appl. Energy* **2016**, *178*, 212–222. [CrossRef]
28. Jiang, Z.; Han, J.; Liu, W.; Chen, Z.; Li, N.; Wang, S.Y.; Zhang, X.; Liu, C. Energy Internet—A New Driving Force for Sustainable Urban Development. *Energy Procedia* **2018**, *152*, 1206–1211.
29. Li, J.; Herdem, M.S.; Nathwani, J.; Wen, J.Z. Methods and applications for Artificial Intelligence, Big Data, Internet of Things, and Blockchain in smart energy management. *Energy AI* **2023**, *11*, 100208. [CrossRef]
30. Wei, Y.; Dai, S.; Yu, J.; Wu, S.; Wang, J.Y. Research on Status and Prospects of Battery Energy Storage Stations on Energy Internet. In Proceedings of the 2019 IEEE 3rd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), Chengdu, China, 15–17 March 2019.
31. Cheng, L.; Ji, X.; Zhang, F.; Liang, C.H.; He, H.L. Internet information applied in the energy internet planning: A review and outlook. In Proceedings of the IEEE Conference on Energy Internet & Energy System Integration, Beijing, China, 26–28 November 2017; pp. 1–5.
32. Zhang, D.; Zhu, H.Y.; Zhang, H.C.; Goh, H.H.; Liu, H.; Wu, T. Multi-objective optimization for smart integrated energy system considering demand responses and dynamic prices. *IEEE Trans. Smart Grid* **2022**, *13*, 1100–1112. [CrossRef]
33. Su, J.; Huang, W.; Qu, X.; Zhang, T.; Wang, L.; Xu, S.; Yan, X.; Ma, J. Analysis of Energy Efficiency Evaluation Indexes for Energy Internet. In Proceedings of the 2019 IEEE Sustainable Power and Energy Conference (iSPEC), Beijing, China, 21–23 November 2019.
34. Ren, L.; Wang, L.; Zhao, X.G. Focus on the Development of Energy Internet in China. In Proceedings of the 2015 International Conference on Applied Science and Engineering Innovation, Jinan, China, 30–31 August 2015.

35. Chen, Z.X.; Zhang, Y.J.; Cai, Z.X.; Li, L.C.; Liu, P. Characteristics and technical challenges in energy Internet cyber-physical system. In Proceedings of the 2016 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe), Ljubljana, Slovenia, 9–12 October 2016.
36. Chen, G. Time-efficient strategic power dispatch for district cooling systems considering the spatial-temporal evolution of cooling load uncertainties. *CSEE J. Power Energy Syst.* **2021**, *5*, 037.
37. Lin, C.; Ning, Q.; Fang, Z.; Kong, H.C.; Huang, X.J. Energy Internet: Concept and practice exploration. In Proceedings of the 2017 IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 26–28 November 2017.
38. Zhu, C.; Zhao, L.; Li, Y.; Sha, Z.C. Analysis and Study on the Architecture for Integrated Smarter Energy Management System. In Proceedings of the 2018 China International Conference on Electricity Distribution (CICED), Tianjin, China, 17–19 September 2018.
39. Hu, M.; Dou, X.; Zhang, P. Research on Comprehensive Evaluation of Micro Energy Internet Based on Synergetic. *IOP Conf. Ser. Mater. Sci. Eng.* **2019**, *677*, 042052. [CrossRef]
40. Ding, R.; Xing, B. Research and Implementation of Energy Harvesting Nodes in Internet of Things. *Video Eng.* **2014**, *8*, 62–65.
41. Wang, C.F.; Cao, J.; Li, F. Space Energy Internet System. In Proceedings of the 2017 4th International Conference on Information Science and Control Engineering (ICISCE), Changsha, China, 21–23 July 2017.
42. Zhang, D.; Liu, T. A multi-step modeling and optimal operation calculation method for large-scale energy hub model considering two types demand responses. *IEEE Trans. Smart Grid* **2019**, *10*, 6735–6746. [CrossRef]
43. Zheng, Y.; Luo, Y.; Shi, Y.; Cai, N.; Jiao, L.; Guo, D.; Lyu, Y.; Yin, H. Design of energy internet based on information internet. In Proceedings of the 2017 IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 26–28 November 2017.
44. Zhang, W.; Li, J.; Zhou, J. The Requirement and the Key Technologies of Communication Network in Internet of Energy. In *International Conference on Human Centered Computing*; Springer: Cham, Switzerland, 2016.
45. Zhang, D.; Zhao, J.; Dai, W.; Wang, C.; Jian, J.; Shi, B.; Wu, T. A feasible region evaluation method of renewable energy accommodation capacity. *Energy Rep.* **2021**, *7*, 1513–1520. [CrossRef]
46. Cai, J.; Shuxian, L.I.; Fan, B.; Tang, L. Blockchain Based Energy Trading in Energy Internet. *Electr. Power Constr.* **2017**, *38*, 24–31.
47. Zhang, Y. Research on Power Marketing Mode from the Perspective of Energy Internet. In Proceedings of the 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 20–22 October 2018.
48. Dunnan, L.; Mi, L.; Yaru, M.; Zhou, H.; Li, J. Transaction analysis of multi market players based on global energy Internet. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *242*, 022020. [CrossRef]
49. Li, Z.; Pang, B.; Zhao, J.; Dunnan, L.; Li, G. Research on Energy Internet Market Trading System. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *371*, 042038. [CrossRef]
50. Dou, J.; Long, Z.; Meng, S.; Zeng, M.; Sung, C.J. New Business Models for Power Grid Enterprises in the Context of Urban Energy Internet. In Proceedings of the 2017 International Conference on Material Science, Energy and Environmental Engineering (MSEEE 2017), Xi'an, China, 26–27 August 2017.
51. Zhang, X.-Y.; Kuenzel, S.; Córdoba-Pachón, J.-R.; Watkins, C. Privacy-Functionality Trade-off: A Privacy-Preserving Multi-Channel Smart Metering System. *Energies* **2020**, *13*, 3221. [CrossRef]
52. Zhang, X.-Y.; Córdoba-Pachón, J.-R.; Guo, P.; Watkins, C.; Kuenzel, S. Privacy-Preserving Federated Learning for Value-Added Service Model in Advanced Metering Infrastructure. *IEEE Trans. Comput. Soc. Syst.* **2022**. [CrossRef]
53. Fan, Y.; Pei, G.; Duan, M.; Liu, Y.Y.; Wu, X.; Zhang, Z. Key technologies and development prospect of urban energy internet. In Proceedings of the 2017 IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 26–28 November 2017.
54. Wang, S.; Xu, K.; Xu, J.; Chi, F.; Zhang, X.; Zhang, L. Comprehensive theoretical and evaluation system of integrated energy system. *IOP Conf. Ser. Earth Environ. Sci.* **2018**, *168*, 012035. [CrossRef]
55. Cao, J.; Yang, M.; Zhang, D.; Ming, Y.; Meng, K.; Chen, Z.; Lin, C. Energy Internet: An Infrastructure for Cyber-Energy Integration. *South. Power Syst. Technol.* **2014**, *8*, 1–10.
56. Zhang, X.; Wang, H.; Wang, B.; Kun, H. Research on the Framework of the New Urban Energy Internet Demonstration Project. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *647*, 012142. [CrossRef]
57. Lei, M.; Yang, D.; Sun, Y.; Zhang, H.G. Construction of Energy Hub Model and Optimal Scheduling of Energy Internet. In Proceedings of the 2017 36th Chinese Control Conference (CCC), Dalian, China, 26–28 July 2017.
58. Zeng, M.I.; Han, X.; Sun, J.; Dong, L.; Huang, W. Key Issues and Prospects of Automated Demand Response under Energy Internet Background. *Electr. Power Constr.* **2017**, *38*, 21–27.
59. Wang, J.; Sun, S. Research on block chain technology in energy Internet. In Proceedings of the 2nd International Conference on Computer Engineering, Information Science & Application Technology (ICCIA 2017), Wuhan, China, 8–9 July 2017.
60. Li, J.; Zhang, P.; Peng, Y.; Li, X.; Zhang, L.; Sun, Y. Energy Internet Business Ecosystem Analysis. In Proceedings of the 3rd Conference on Energy Internet and Energy System Integration (EI2), Changsha, China, 8–10 November 2019.
61. Liu, K. Development Path Exploration of Energy Internet. *Electr. Power Constr.* **2015**, *36*, 5–10.
62. Gao, Z.; Qiang, Y.; Tang, B.; Wang, J. Design of Layered Network for Information Communication of Energy Internet. In Proceedings of the IEEE International Conference on Computer and Communication Engineering Technology, Beijing, China, 18–20 August 2018.

63. Sun, Z.; Liang, W. A Survey of Communication Technologies for the Energy Local Area Network in the Energy Internet. In Proceedings of the 2016 6th International Conference on Advanced Design and Manufacturing Engineering (ICADME 2017), Zhuhai, China, 23–24 July 2016.
64. Wang, L.; Han, S.; Guo, L.; Huo, M.; Chen, H.; Chen, G. Analysis of typical characteristics and main functions of urban energy internet under city energy reformation. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *585*, 012039. [CrossRef]
65. Xin, S.; Chen, M.; Zhu, Y.; Li, T. Research on the Application of Blockchain Technology in Energy Internet. In Proceedings of the 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 20–22 October 2018.
66. Wu, J.; Tran, N. Application of Blockchain Technology in Sustainable Energy Systems: An Overview. *Sustainability* **2018**, *10*, 3067. [CrossRef]
67. Li, S.; Li, S.; Qu, D. Discussion on Integration Technology for Local Energy Internet–ScienceDirect. *Energy Procedia* **2018**, *145*, 558–563.
68. Liu, D.N.; Xu, E.F. Technical System of Energy Big Data Analyzing in the Context of Energy Internet. In Proceedings of the 2017 5th International Conference on Mechanical, Automotive and Materials Engineering (CMAME), Guangzhou, China, 1–3 August 2017.
69. Khizir, M.; Graham, E.T.; Sayidul, M.; Hossain, M.J. Integration of electric vehicles and management in the internet of energy. *Renew. Sustain. Energy Rev.* **2017**, *82*, 4179–4203.
70. Feng, X.; Hu, J. Research on the identification and management of vehicle behaviour based on Internet of things technology. *Comput. Commun.* **2019**, *156*, 68–76. [CrossRef]
71. Mohamed, L.; Tiago, A.; Mohammad S, J.; Gerardo J, O.; Claudio, M.; Joao, P.S.C. Coordinating energy management systems in smart cities with electric vehicles. *Appl. Energy* **2022**, *307*, 118241.
72. Wang, H.; Fu, Q.C. Teaching Reform and Practice of Electrical Engineering and Electronics Curriculum to Strengthen Engineering Quality and Innovative Ability. In Proceedings of the 2015 International Conference on Advanced Management Science and Information Engineering (AMSIE 2015), Hong Kong, China, 20–21 September 2015.
73. Igbinovia, F.O.; Kupka, J. The Prospect of the Internet of Renewable Energy (IoRE) in Electricity Networks. In Proceedings of the IEEE International Symposium on Technology and Society (ISTAS), Medford, MA, USA, 15–16 November 2019.
74. Zhang, S.; Zeng, M.; Liu, D.; Li, Y. Complex Adaptive Characteristics of Energy Internet in Bilateral Evolution Process. *Electr. Power Constr.* **2017**, *38*, 34–40.
75. Zhang, D.; Zhu, H.; Zhang, H.; Goh, H.H.; Liu, H.; Wu, T. An optimized design of residential integrated energy system considering the power-to-gas technology with multi-functional characteristics. *Energy* **2022**, *238*, 121774. [CrossRef]
76. Zhou, X.; Wang, F.; Ma, Y. An overview on energy internet. In Proceedings of the 2015 IEEE International Conference on Mechatronics and Automation (ICMA), Beijing, China, 2–5 August 2015.
77. Zhang, D.; Li, C.; Goh, H.H.; Ahmad, T.; Zhu, H.; Liu, H.; Wu, T. A comprehensive overview of modeling approaches and optimal control strategies for cyber-physical resilience in power systems. *Renew. Energy* **2022**, *189*, 1383–1406. [CrossRef]
78. Li, H.; Li, W.; Miao, B.; Li, B.; Liu, C.; Lv, Z.P. Research on the Operation Mode of Intelligent-town Energy Internet Based on Source-Load Interaction. In Proceedings of the IOP Conference Series Earth and Environmental Science, Chongqing, China, 25–26 November 2017.
79. Gang, W.; Bao, X.; Hai, Y.; Hou, Z.S.; Zhu, L.; Han, H.Y.; Peng, L. Research on Global Energy System Based on Intelligent Mobile Internet Technology. In Proceedings of the International Conference on Intelligent Control & Computer Application, Zhengzhou, China, 16–17 January 2016; Atlantis Press: Paris, France, 2016.
80. Chen, X. Energy-Use Internet and Friendly Interaction with Power Grid: A Perspective. In Proceedings of the 2020 IEEE International Conference on Energy Internet (ICEI), Sydney, NSW, Australia, 24–28 August 2020.
81. Joseph, A.; Balachandra, P. Energy Internet, the Future Electricity System: Overview, Concept, Model Structure, and Mechanism. *Energies* **2020**, *13*, 4242. [CrossRef]
82. Tsoukalas, L.H.; Gao, R. From smart grids to an energy internet: Assumptions, architectures and requirements. In Proceedings of the International Conference on Electric Utility Deregulation & Restructuring & Power Technologies, Nanjing, China, 6–9 April 2008.
83. Chen, S.; Wei, W.; Li, D.; Zhong, M. Research about Architecture and Key Technology of User Side Internet of Energy. In Proceedings of the International Conference on Sustainable Energy & Environment Engineering, Zhuhai, China, 12–13 November 2016.
84. Liu, L.; Chen, S. The Application of Artificial Intelligence Technology in Energy Internet. In Proceedings of the 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 20–22 October 2018.
85. Yang, T.; Han, Z.; Yang, F.; Liang, Y.; Gao, J.; Ji, X. Coordinated Optimal Configuration Method of Hybrid Energy Storage Systems in Energy Internet System. In Proceedings of the 2019 IEEE Innovative Smart Grid Technologies-Asia (ISGT Asia), Chengdu, China, 21–24 May 2019.
86. Ning, B.; Zhu, B.H.; Wu, S. Exploration and Reform on Engineering Teaching of Electronics in Electrical Engineering. *Appl. Mech. Mater.* **2012**, *174–177*, 3452–3455. [CrossRef]
87. Hong, Z.; Feng, Y.; Li, Z.; Wang, Y.; Zheng, H.; Li, Z.; Tan, J. An integrated approach for multi-objective optimisation and MCDM of energy internet under uncertainty. *Future Gener. Comput. Syst.* **2019**, *97*, 90–104. [CrossRef]
88. Cheng, L.; Yu, T.; Jiang, H.; Shi, S.; Tan, Z.; Zhang, Z. Energy Internet Access Equipment Integrating Cyber-Physical Systems: Concepts, Key Technologies, System Development, and Application Prospects. *IEEE Access* **2019**, *7*, 23127–23148. [CrossRef]
89. Hao, Y.; Zhou, C.; Zhang, X.; Zhao, D.; Li, F.; Wang, H. Power Line Communication Challenges in the Energy Internet. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *645*, 012079. [CrossRef]

90. Hao, L.; Long, W.; Song, Y.; Liu, F. The Analysis and Application of Energy-Internet in the Low-Carbon Community. In Proceedings of the ASME 2010 4th International Conference on Energy Sustainability, Phoenix, AZ, USA, 17–22 May 2010.
91. Wang, J.; Song, D.; Bai, H.; He, Q. Research on Integrated Energy Service Mode of Park-level Energy Internet. In Proceedings of the 2017 3rd International Forum on Energy, Environment Science and Materials (IFEESM 2017), Shenzhen, China, 25–26 November 2017.
92. Geng, Z.; Meiling, L.; Dahua, Z.; Zhou, L.; Li, L. Research on the business QoS and trustworthy and controllable strategies mechanism for energy internet. *Iop Conf.* **2017**, *52*, 12–32.
93. Yang, J.; Yuan, B.; Zhang, F.; Luan, F.; Lu, G.; Xu, Z. Research on the Application Prospect of Energy Storage Technology in Energy Internet. In Proceedings of the 2019 IEEE 3rd International Electrical and Energy Conference (CIEEC), Beijing, China, 7–9 September 2019.
94. Cao, W.; Li, B.; Zheng, A.; Qi, B.; Yang, Z.; Su, Y. The architecture and technology of demand response within Energy Internet. In Proceedings of the 2016 China International Conference on Electricity Distribution (CICED), Xi'an, China, 10–13 August 2016.
95. Pang, B.; Song, L.; Liu, D.; Li, G. Application Research of Blockchain Technology in Energy Internet. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *621*, 012065. [CrossRef]
96. Li, X.; Li, J.; Li, L.; Guo, X.; Kang, Y.; Guo, X. Research on Implementation Methods of Power Grid Technology Supporting Energy Internet Construction. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *558*, 052013. [CrossRef]
97. Rui, Z.; Liu, J.; Liu, M.; Wang, C.; Xin, W.; Kan, F.; Gao, E.; Wang, B. Research on Electrical Technology Course Reform based on Professional Certification of Engineering Education. In Proceedings of the International Conference on Education, Shenyang, China, 1–3 January 2016.
98. Xiao, Z.; Hua, H.; Cao, J. Overview of the Application of Artificial Intelligence in Energy Internet. *Electr. Power Constr.* **2020**, *40*, 63–70.
99. Zhao, Z.; Li, H.; Wang, X.; Li, Z.; Yu, Z.; Zhang, Z.; Song, X. Research on Evaluation Index System of Urban Energy Internet Development. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *446*, 022052. [CrossRef]
100. Ahmad, T.; Zhu, H.; Zhang, D.; Tariq, R.; Bassam, A.; Ullah, F.; AlGhamdi, A.S.; Alshamrani, S.S. Energetics systems and artificial intelligence: Applications of industry 4.0. *Energy Rep.* **2022**, *8*, 334–361. [CrossRef]
101. Tang, Y.; Fan, Q.; Meng, F.; Zhang, L. Benefit Evaluation Indicators and Methods for Regional Energy Internet. In Proceedings of the 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, China, 20–22 October 2018.
102. Xiao, W.U.; Jun, D.U.; Qiang, Y.J.; Lu, P. Teaching Reform and Practice of Comprehensive and Designing Experiment in Electrical Professional Course. *Res. Explor. Lab.* **2009**, *28*, 124–125.
103. Guo, L.; Wang, L.; Wang, Y.; Yang, J.; Dong, H.; Zhou, M. Research on multi-source coordination evaluation model of regional energy Internet. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *508*, 012023. [CrossRef]
104. Ucker, R.S.; Baliga, J.; Ayre, R.; Hinton, K.; Sorin, W.V. Energy and the Internet. In Proceedings of the OECC/ACOFT 2008—Joint Conference of the Opto-Electronics and Communications Conference and the Australian Conference on Optical Fibre Technology, Sydney, Australia, 7–10 July 2008.
105. Jiang, S.; Chen, Q.W.; Guo, L. Evaluation Model of Electrical Control Teaching Mode Reform Effect Based on Deep Convolution Neural Network. In Proceedings of the International Conference on E-Learning, E-Education, and Online Training, Xinxiang, China, 20–21 June 2021; Volume 390, pp. 441–451.
106. Guo, M.L.; Wang, P. Carrying out Teaching Reforms of Electrical Engineering Speciality to Cultivate Application-Oriented Talents. *Res. Explor. Lab.* **2009**, *28*, 83–86.
107. Hao, W.; Fu, Q. Electrical Engineering and Electronics Teaching Aiming for Excellence Engineer Program. In Proceedings of the International Conference on Advances in Social Science, Guangzhou, China, 26–27 December 2014.
108. Liu, Y.; Qi, T.; Le, W.; Luo, D. Establishment of an Electronic Curriculum Group to Enhance the Effectiveness of Electrical Teaching Reform. In Proceedings of the 2016 International Conference on Education, E-learning and Management Technology, Xi'an, China, 27–28 August 2016.