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# Smart City Energy Interconnection Technology Framework Preliminary Research

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**Abstract.** to improve urban energy efficiency, improve the absorptive ratio of new energy resources and renewable energy sources, and reduce environmental pollution and other energy supply and consumption technology framework matched with future energy restriction conditions and applied technology level are required to be studied. Relative to traditional energy supply system, advanced information technology-based "Energy Internet" technical framework may give play to energy integrated application and load side interactive technology advantages, as a whole optimize energy supply and consumption and improve the overall utilization efficiency of energy.

## 1. Introduction

Energy provides the energy source required by human living and production, every time of industrial revolution is completed depending on the innovation in energy type and operation method. In recent years, China's energy industry has obtained remarkable achievements and but also is facing severe challenges. At generation side, China develops fast in renewable energy sources, by far ranks global 1st in terms of wind power installed capacity, but absorption is a serious problem, in 2016 only within state grid scope, the waste wind and solar power quantity reach 46,500,000,000 kilowatt hours, there is a long way to go for such target that carbon dioxide emission reaches peak value in 2030. At energy using side, China's unit GDP energy consumption is about 70% higher than world average level, energy use efficiency directly restricts our economic transition, to further improve energy efficiency is extremely urgent. According to incomplete statistics, in terms of energy consumption proportion of China, urban energy consumption accounts for 70%, which is anticipated to be above 80% in 2030, therefore, the future development trend is to reinforce study in fields of urban energy source complementary, new energy consumption and coordination control and to improve urban energy utilization factor. From development in recent 5-10 years, fast-developing Internet not only profoundly changes people's living and working modes but also transforms and overturns many traditional industries, Energy Internet is just the product of energy and Internet deep integration, which has become the new focus concerned by international academic circle and industrial circle and the new front development direction and important issue comes after smart power grid for the energy industry. Internationally in early stage study with "Energy Internet" as the theme was firstly carried out. Energy Internet definition given by reference [1] gives the definition of energy Internet, i.e. "Energy Internet



is one complex multi-grid flow system formed by electric system as the core, Internet and other front information technology as base, and distributed renewable energy sources as the main primary energy through tight coupling with natural gas network, transportation network and other systems". The reference [2] and others analyse the connotation and key technologies of Energy Internet. The reference [3-5] and others discuss and introduce several concepts and key technologies of Energy Internet, author of this paper as per his/her own understanding designs the concept and framework of Energy Internet facing smart city, hoping to contribute to industry understanding of Energy Internet, forming resultant force and promoting the sound development of Energy Internet.

## **2. Current situation and basic concepts of Energy Internet**

As one cross-disciplinary frontier concept, the connotation of Energy Internet developed constantly, it is difficult to give standard definition accepted by all people. In fact, it is not necessary to give exact definition, just like smart power grid which has no standard definition by far but core connotation of which has been agreed and accepted by academic circle, industrial circle and society. Although it is hard to make definition, it is necessary to define the development targets, concepts, characteristics and basic framework of Energy Internet, which is of great importance in promoting development of the relevant disciplines and industries.

### *2.1. Energy Internet research status*

Above "Energy Internet" technical framework is the conceptual assumption of future overall system of energy supply, as to development of smart city in future, advanced information and communication technology-based and energy interactive thoughts inclusive studies are carried out generally at home and abroad. Except the assumption as to "Energy Internet" at present, all America major research institutions and universities are conducting the relevant studies. As to user interaction, in terms of demand side response America has entered into practical use stage, in power grid full-time "load regulation service provider" appeared and is used to provide power grid with load dispatching service; while Japan is based on micro-grid and distributed generation dedicated to study "PLC Router" titled electric energy control technology and the relevant devices. In china, study regarding future energy supply technology has been highly values, SGCC makes clear that "Energy Internet" is future smart grid which is the foundation platform carrying the third industrial revolution and has overall promoting effect thereon. At present, SGCC has actively developed and deployed the relevant study works. Energy development in China at present faces the four problems of total quantity supply, resource allocation, energy efficiency and ecological environment. The problems above may be improved by increasing the proportion of clean power generation and improving energy efficiency.

Energy Internet technical framework said in this paper makes unified allocation of energy resources, optimizes and guides energy development and use , and finally enables clean power generation proportion increase and energy efficiency improvement and overall energy resources allocation optimization centering on electric energy so as to transfer the energy development mode from consumption type to sustainable, renewable and more environmentally friendly development track and realize safe, clean, environmental friendly development of energy supply[6-8], the series measures is of great importance for the establishment and development of smart city.

### *2.2. Development target*

The development target of Energy Internet may be summarized into the following three points.

1) Energy marketization: As the hand grab to break industry barrier, promote energy marketization, promote innovation and entrepreneurship in energy field, and reshape energy industry. Based on information Internet, Energy Internet may provide various participants and large quantity of users with open platform to reduce entry cost and facilitate the connection of supply and demand parties so that transactions of equipment, energy and service may be more convenience and efficiency, all-win result achieved, and public entrepreneurial enthusiasm and innovation capability are activated to provide lasting power to energy revolution.

2) Energy high efficiency: Energy Internet enables open interconnecting and schedule optimization of various types of energy, provides conditions for energy comprehensive development, gradient utilization and energy sharing, and may greatly increase the combined service efficiency of energy.

3) Energy greening: Energy Internet may via coupled complementary of various resources, application of various stored energy and demand side response support the access and consumption of high permeability renewable energy.

### 2.3. Main concepts

On basis of traditional energy grid Energy Internet introduces Internet concept and has the following new connotations.

1) Open. Open is the core concept of Energy Internet and is rich in connotations mainly reflected in the following terms: open interconnecting of various types of energy sources, open peer access of different equipment and systems, open participation of various participants and terminal users, open energy market and transaction platform, open energy innovation and entrepreneurship environment, open Energy Internet ecosphere, open data and standard, etc.

2) Interconnection. Interconnection is the important appearance of open, provides platform for energy sharing and transaction, connection between supply and demand is the base for Energy Internet creating value. Interconnection includes interconnecting of various energy types, various kinds of energy systems, multiple variant equipment and different sorts of participants.

3) User-centered. The design of user-centered is the key for success in commerce of Energy Internet. Acceptation and extensive participation of users may effectively promote the Energy Internet to create value in links of energy production, running, management, consumption, transaction, and service, etc. User-centered design stresses to provide extreme user experience and meet not only the different levels of convenient energy use requirements but also easy energy production and transaction requirements of users.

4) Distributed. Distributed pattern is the major driving force for Energy Internet development. Photovoltaic and other new energy sources are suitable for distributed pattern and users will become distributed energy producer and consumer. Under distributed conditions, to guarantee the plug and play of energy production and consumption and energy balance at any time and all places, the distributed optimization and control requirements are high.

5) Sharing. Sharing is the spirit of Energy Internet, if there is no sharing mechanism, the open interconnecting of physical devices may not form effective energy market and good innovation and entrepreneurship environment.

### 2.4. Main characteristics

The key characteristic of Energy Internet is the deep integration of Internet concept and technology which is mainly reflected in the following aspects.

1) Support open interconnecting of multiple types of energy sources and improve the comprehensive service efficiency of energy.

2) Support the access and absorption of high permeability renewable energy sources.

3) Support the free multilateral Internet framework of energy free transmission and user wide access.

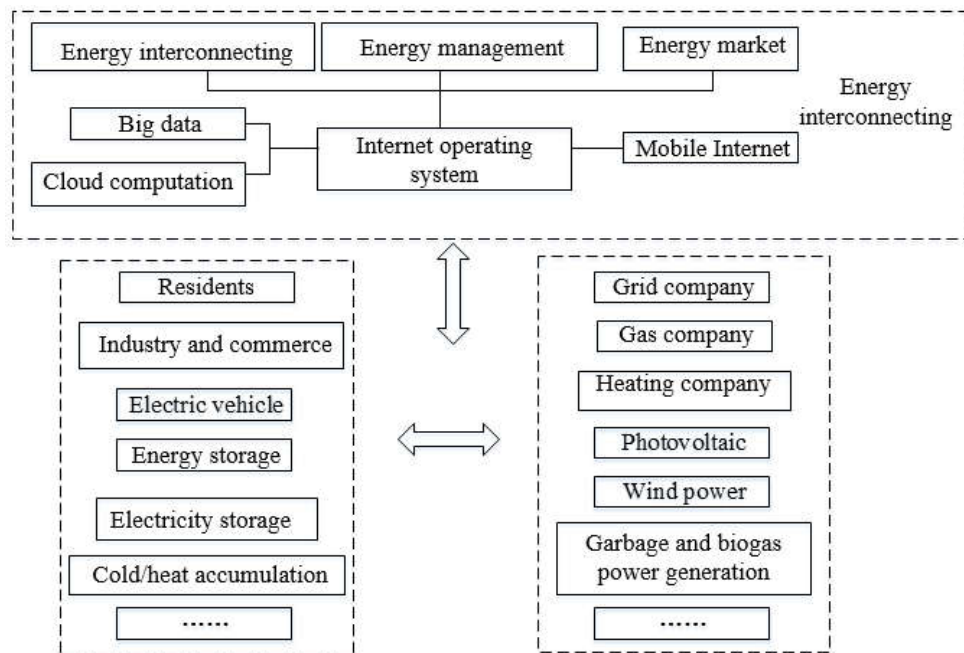
4) Concentration and distribution combined self-organization network architecture.

5) Support public funded energy Internet market and finance.

6) Support energy operation, maintenance, transaction, finance and other big data analysis.

### 2.5. Basic framework

Basic framework of Energy Internet facing smart city is as shown in Fig. 1, generally may be divided into the two layers of "class networking of energy system" and "Internet +": the former refers to energy system, is the transformation of present energy system by Internet thinking; the latter refers to information system, is the integration in energy system of information Internet.



**Figure 1.** Basic framework of Energy Internet facing smart city

### 3. Energy Internet technical framework analysis

#### 3.1. energy Internet composition

Smart city building mainly aims to create a scientific energy supply system, while the main purposes of building "energy Internet" are to optimize energy structure (using more new energy resources), improve energy efficiency (give play to different energy advantages and the technical advantage of new loads) so as to improve user experience. For optimizing Energy Internet resources, it is firstly required to confirm the components of Energy Internet and define optimal range.

Combining with smart power grid research result and contents shown in fig. 1, overall constitution of Energy Internet is as follows: electric, heating, cooling and other forms of energy inputs through organic integration with information, etc. support system form synergistic modern "comprehensive energy supply system". Various energy (fossil energy, renewable energy) in the system via coordinated dispatching supply among electric, cooling, heating and stored energy forms reach high use efficiency, meet various energy application requirements of users, improve social supply reliability, safety and other purposes; meanwhile, overall coordination of various energy system may also help eliminate energy supply choke point and improve different energy equipment use efficiency. Different energy has varying effect on environment, in traditional energy supply system, specific energy has generated relatively stable consumer market, for example, petroleum is mainly used in traffic, chemical engineering, power generation and other industries; while natural gas is mainly used in daily life, heat supply, electricity, traffic and other fields. Renewable energy at present is almost all used for power generation. For a long period, primary energy forms its own industrial chain, complementary space among different kinds of energy is limited. However, electric energy may act as the bridge of different energy. By far renewable energy sources are partly changed into electric energy. If through electricity replace high pollution primary energy with green renewable energy, the overall environment-friendly degree of energy consumption may be improved. The following are preconditions for optimized supply of this energy:

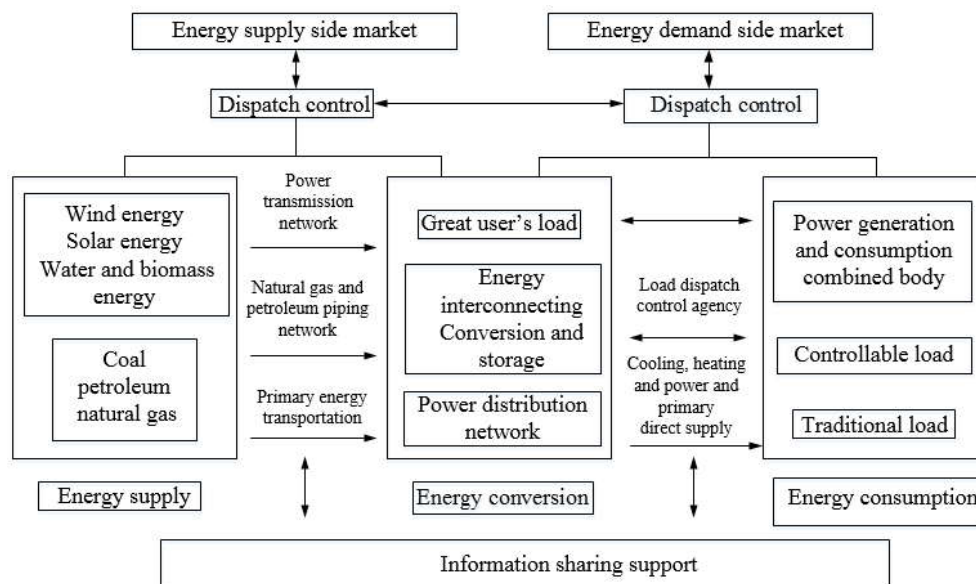
- ① have (supply-demand relationship) information interconnecting among different types of energy;
- ② have necessary technical means for interchangeable energy output, i.e., electricity may meet the demands of the consuming subject of the replaced energy;



③ have the ability to give energy consumers clear and timely pilot signal so as to attract energy consuming subject to participate in optimal configuration of energy use. When the said conditions are provided, the overall optimal use of social energy may be realized by combining with necessary technological means. After reaching this target, "Energy Internet" may be constructed using technological means.

### 3.2. Energy Internet technology framework

To achieve the said overall optimization objectives, define energy experience. For optimizing Energy Internet resources, it is firstly required to, based on defined energy "interconnecting" scope, further study proper Energy Internet technology framework, and to use advanced technologies to give play to the overall advantage of various energy and user interconnection and interaction. The purpose of such Energy Internet technology framework design is to give play to technical advantages and improve energy use efficiency from a technical point of view. Under the precondition that there is no policy, market and technology condition limit, Energy Internet technology frame model of which design meets above conditions is as shown in Fig 2.



**Figure 2.** Technology framework model of Energy Internet facing smart city

"Technology framework model of Energy Internet facing smart city" shown in fig. 2 includes the 4 parts of "market environment", "energy supply, transformation and consumption", "information support" and "dispatching control". Market environment includes energy supply side market and energy demand side market. Wherein, energy supply side market is responsible for releasing market price signal of different types of energy and regulating market energy supply structure (price signal or subsidy may be used in this step to encourage use of clean energy and reduce environment pollution); energy demand side market is responsible for releasing the price for attracting controllable load and "power generation and consuming combined body" with reverse power transmission (or other energy form) to participate in demand side dispatching control or other excitation signals to encourage load to take part in the demand side response. Energy supply, transformation and consumption are the energy flow in Energy Internet, the final optimization and coordination target of the whole technical framework. Electricity, heating, cooling and other energy forms given by multiple energy through transmission grid, pipe network or transport corridor finally reach user side and meet user's energy use demands. On the said basis, Energy Internet framework reinforces support to distributed power supply

and micro-grid, uses different stored energy, electricity-gas transformation and other technologies, and combines with information sharing and cost comparison of various energy to achieve electric energy-centered targeted replacement and transformation among various energy (optimizing or reducing pollution and improving clean energy ratio, etc.).

In addition to traditional users, the consumption link also includes intelligent controlled user and power production and consumption combined body with reverse energy supply function, etc. Information sharing support is the information flow within the whole technology framework. "Fast, reliable and safe" future information network technology is the basic condition for large quantity data acquisition, transmission, analysis and optimization calculation under Energy Internet technology framework. Under the support of information technology, to guarantee the safe and optimized operation of the whole energy framework, necessary operation management organization is required to centrally dispatch and manage energy, such dispatching and management may use commercial operation pattern adaptive to outside market environment and hierarchical design based on energy management scope. Meanwhile, user side controllable loads and "power generation and consumption combined body" with power generation and other energy supply (heating, cooling, etc.) abilities may under the precondition of voluntary directly take part in, or through "load dispatching and control agency" use "virtual power plant" to take part in, the dispatching and control of Energy Internet. Such overall optimal use of energy based on information sharing and enabled by energy overall dispatching and control is the core of Energy Internet technology framework.

### 3.3. Conceptual model of Energy Internet optimal control

Energy consumption within the Energy Internet technology framework used for smart city building shall have the following characteristics.

(1) Energy supply may be "interconnected". Under Energy Internet technology framework, different energy may support each other and realize certain degree of substitution and transformation. Such interconnection may via control system or directly through transition and replacement of different energy realize "application conversion" facing users' final demand.

(2) Energy interconnection has no effect on user consumption. To facilitate safe and high efficiency use by consumers, originally intersected energy supply upon "interconnection" improves users' experience without affecting the normal use by users.

(3) Optimization is possible after energy interconnection. Energy supply under Energy Internet technology framework shall have higher efficiency than before "interconnection".

As you see, Energy Internet is one complex energy supply system which aims to provide energy with overall optimization, to achieve such purpose, the corresponding optimization model shall be built. To sum up, the consumption cost changes with energy type, meanwhile, different energy supply have varying effect on environment. Considering controllability of new load Energy Internet optimization model as below is established.

Equality constraint, when  $t=0, 1, 2, \dots, T$ , equality:

$$\sum_{i=0}^n P_i(t) = \sum_{j=0}^m L_j(t) \quad (1)$$

Optimization target:

$$\min \sum_{t=0}^T \sum_{i=0}^n F_i(P) \quad (2)$$

Where,  $t$  refers to time frame,  $T$  refers to time horizon;  $j$  refers to load type in Energy Internet,  $i$  refers to energy input type within Energy Internet;  $L$  refers to load characteristic function;  $P$  refers to output characteristic function of certain energy;  $F$  refers to characteristic function of certain energy; other constraint conditions:  $P_{yi}(t)$  is the supply constraint of different energy;  $L_{yj}(t)$  is the application constraint of different energy.

Physical significance of above model is under the precondition of meeting energy supply-demand balance and supply consumption constraints to pursue minimum total energy supply cost or minimum pollutant discharge and another optimization goal. Energy Internet optimization model based on different market operation rules will be different in detail, optimization model discussed in this paper is one purpose description of Energy Internet technology framework, to solve this model requires determining cost functions of different energy and other constraint conditions closely associated with concrete Energy Internet operation rules and physical environment.

#### 4. Conclusion and Prospect

The rise of smart city initiates new city development concept and pattern, Energy Internet, as one of the main technology means to realize smart city, is the new energy system formed by energy and Internet deep integration and has become the new focus for present international academic circle and industrial circle, and is another frontier development direction and important issue after smart grid of the energy industry. This paper from a new angle summarizes the main targets, concepts, characteristics and basic framework of the Energy Internet and expects possible frontier problems. As the technical means and hand grab, Energy Internet may contribute to facilitate energy marketization, high efficiency and environment protection. As an interdisciplinary new direction, development of Energy Internet cannot be separated from multi-disciplines crossing and industry-university-research cooperation and will display new open development characteristic and cause new form and mode. Through joint efforts of domestic and foreign scholars and all sectors of society, Energy Internet will enjoy a better future.

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