Architecture of A Mobile Energy Internet

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Abstract. With the development of mobile energy storage technology, it is possible to build a mobile energy internet for the business purpose of energy internet. Now the research work of mobile energy internet is non-holistic, so this paper propose a Architecture of Mobile Energy Internet (AMEI). Firstly, summarize the related work about electric power information, software defined grid and energy internet; then propose a architecture of mobile energy internet, aims to application of energy storage local area net and mobile energy storage; furthermore, discuss the key technology of AMEI, meanwhile give the analysis of ability and application value; finally give a example of prototype system to prove the feasibility of AMEI.

1. Introduction

Energy Internet [1] is a product of the deep integration of energy technology and information and communication technology, providing a more open, clean and sustainable mode of energy utilization. As a secondary energy source for easy transmission, electric energy has become a core form of energy in the energy Internet. With the integration of information, transportation and energy networks, the construction of mobile power Internet has become a necessary choice for the commercial operation of energy Internet, driven by the development of power electronics technology, location service technology and mobile power storage technology. It is worth noting that the concept of the three T networks [2] proposed by the Global Energy Internet Development Cooperation Organization puts Mitt, Bit and Watt into a framework of information physics system, and puts forward a clear demand for the proposal and construction of the mobile power Internet. The construction of mobile power Internet will further promote the commercialization and practicability of the global energy Internet.

At present, a number of commercial products have emerged in mobile power and mobile power sharing. For example, “small electricity” shared charging point, Mobike bicycle with Beidou GPS positioning and Hanergy thin-film solar module, “small bottle” electric bicycle shared battery, China Putian mobile new energy charging equipment. Triad has carried out a lot of practical work in the two-way integration of automotive charging network and new energy micro-grid, exploring the construction of new energy ecosystem. The maturity of hydrogen fuel cell technology and business model also provides a new form of energy support for mobile energy sharing. At present, fuel cell UPS has been put into operation. Didi and the Global Energy Internet Development Cooperation have set up a global new energy automotive service company and are developing a new charging and switching system called "Little Orange Charging". This is a useful practice for the integration of information, transportation and energy networks.

At present, the academic work in the field of mobile energy interconnection mainly concentrates on energy informatization, software definition of power grid, energy Internet control theory, power block chain and energy interconnection standards. With the integration and evolution of energy technology
and information and communication technology, a number of laboratory products with the characteristics of energy Internet have emerged. The most representative work includes: software-defined reconfigurable battery system proposed by Professor Ci Song of Tsinghua University [4], energy network card, battery cloud and energy big data service [5]. In addition, there are research work of the China Electric Power Research Institute's energy router [6] and various types of integrated energy buildings.

Section 1 summarizes the related research work. In section 2, mobile power Internet architecture is proposed, and the key technologies to implement the architecture are discussed. In section 3, the capability and application value of the architecture are analyzed, and an example of a prototype system of mobile power Internet is introduced. Section 4 summarizes the full text and discusses the next steps.

2. Related Work

2.1. Electric Energy Informatization
As a typical physical information system, the electric energy control system constantly puts forward new requirements for the informationization of electric energy. The modeling, acquisition, analysis and control of electric energy information have gone through three stages of development: traditional power grid, smart grid and energy Internet. In the traditional power grid stage, the electric energy informationization work mainly focuses on the establishment of basic information models, information collection, transmission and display, and various production monitoring systems such as SCADA and various management information systems such as MIS have emerged; In the smart grid phase, in order to cope with the demand for the use of electric energy information in the entire chain of generation, transmission, substation, distribution, scheduling, the work of electric energy informationization mainly focuses on the integration of information. SGERP platform of State Grid Corporation [7] can be used as a representative, and the literature [8] systematically studies the architecture of the smart grid information system. In the era of energy Internet, the work of electric energy informatization mainly focuses on two-way control and decentralization. The literature [9] deeply analyzes the informationization of electric energy in the energy Internet stage. In addition, Pasqualetti et al described the power information physical system as a dynamic linearized wave equation and so on [10]. Literature [11] proposed a multi-time scale microgrid energy management optimization scheduling scheme, and the literature [12] studied the mobile cloud computing energy saving measures under 5G.

2.2. Software Defined Grid
With the continuous maturity of SDN technology and the development of electric energy information technology, concepts such as software-defined energy and software-defined power grids have emerged and gradually realized. First, at the level of a single energy-using device, Huawei conducted early research work on bit management watts; at the data center level, Lianfang Yuntian United Shuguang has launched a distributed power system for software-defined energy; the software-defined energy platform developed by Virtual Power Systems of the United States implements information system-level energy scheduling; in terms of theoretical models, the literature [13] discusses the architecture of software-defined grids. There is also some research work in software-defined virtual power plants [14].

2.3. Energy Internet
Futurist Jeremy Rifkin put forward the concept of energy internet in the book "The Third Industrial Revolution" and discussed the application prospect of energy interconnection [15]. Energy Internet is a new generation of intelligent network with power as the core, energy and information deep integration and interconnection, and realizes “horizontal multi-energy complementary, vertical source network storage and coordination” [16]. An important feature of the energy Internet is the fusion of energy flow and information flow. Sun Qiuye from Northeastern University conducted an in-depth study on the energy Internet and its key control issues [17]. Literature [18] systematically discusses the concept, connotation and system framework of intelligent energy systems, pointing out that the core of energy 5.0 is to build a virtual artificial energy system that is isomorphic with the actual energy system.
At present, the business model of energy interconnection mainly focuses on the production, exchange and use of energy. Energy Internet enterprises have obtained a large amount of energy interconnection information. The main focus of work is still on the acquisition, transmission and secure storage of information. The fusion of energy flow and location flow and value mining need to be further improved.

Through the analysis of relevant research work, the author believes that similar to the emergence of data center SAN network, energy storage local area network will become an important component of energy Internet. With the development of energy storage batteries, fuel cells and electric vehicle technology, the integration of mobile energy storage and energy storage local area networks have matured, and the integration of energy flow, information flow and location flow, decentralized mobile energy Internet research is bound to become a meaningful job.

3. A Mobile Energy Internet Architecture

This section presents mobile energy Internet architecture, as shown in Figure 1. The mobile energy Internet is divided into four layers: information model layer, mobile energy interconnection layer, local energy storage layer and application layer.

The information model layer unifies the three key elements of energy, location, and information into one model. Specifically, a unified syntax and semantics are used to represent the energy extension and location expansion of the Internet. The mobile energy interconnection layer adds mobile energy network cards to existing mobile energy storage devices, and interconnects information and energy in remote public channels and on-site trusted channels. The local energy storage layer adds energy network cards to existing fixed energy storage devices, and increases energy storage local area network switches to interconnect mobile energy storage devices and fixed energy storage devices. The application layer is responsible for the monitoring, analysis and control functions of the entire mobile energy Internet. In Figure 1, the positional flow is indicated by a virtual connecting line, the solid connecting line represents an information flow, and the hollow connecting line represents an energy flow, and the following figures are the same.

By connecting the real-time energy information of these mobile energy storage devices with the mobile energy network card, a decentralized mobile energy Internet can be established. Moreover, through location information, trusted operation information interconnection and energy interconnection can be established.

3.1. Theoretical Model

In terms of location modeling, the literature [19] extends spatial location and time and scale in the traditional RBAC model, and proposes a spatial database access control method. Literature [20] proposed trusted LBS by defining location-time--ticket. Literature [21] studied the privacy protection technology of Internet of Things, and the literature [22] reviewed the research status and progress of LBS privacy protection. Literature [23] proposed a geospatial constrained business process modeling method and used advanced Petri nets as modeling tools. We also noticed that the literature [24] used the automaton to establish the system energy consumption model, and there are more research results in the power grid fault diagnosis in Petri net [25] [26]. Literature [27] uses the extension of time Petri nets to model the software architecture of information physics systems. A Petri net that effectively extends energy and position information may be a modeling tool for the mobile energy Internet.

With the development of computing technology, energy modeling in the new computing environment has also evolved [28] [29]. Literature [30] analyzed the intelligent distributed power energy system operating on the block chain. Based on the theoretical model, the researchers also developed some simulation software [31]. For example, Ganglia, developed by the University of California at Berkeley, and Joulemeter, developed by Microsoft.

3.2. Mobile Energy Network Card and Energy Storage LAN Switch

According to the definition of the energy network card by Professor Ci Song of Tsinghua University, the energy transmission port should be fixed in the information system to form a standard. This is the meaning of the information physics system [32]. This paper designs a mobile energy network card,
which can insert a mobile energy network card into the existing electric energy storage battery, fuel cell and other equipment to realize the decentralization and mobilization of energy information collection, and change the current traditional mode of centralized use of electricity information collection is more in line with the application needs of energy integrated service providers. The structure of the mobile energy network card is shown in Figure 2. The difference between a mobile energy network card and an energy network card is: 1. The positioning module and the location communication interface are added, and the location service can be used to establish the trusted energy interconnection; 2. Energy operation information such as energy pricing, energy metering and energy type in intelligent control and storage module can be updated through operation communication interface.

Another key device for implementing the mobile energy Internet is the energy storage LAN switch. The difference between energy storage LAN switches and energy Internet routers is: 1. A location management module is added to the energy storage LAN switch. The control module needs to obtain location information from the location management module and generate location authentication and location authorization information, thereby improving the security of the energy interconnection; 2. An operational communication module is added to the energy storage LAN switch. The monitoring control bus needs to obtain price information from the operational communication module and generate charging information and credit information, and provides an energy interconnection operation means; 3. The hydrogen storage module is added to the energy storage LAN switch. In addition to the electrical energy storage module of the energy storage LAN switch body, a mobile energy storage means is provided, which greatly improves the reliability of the energy storage of the energy storage LAN switch. The structure of the energy storage LAN switch is shown in Figure 3.

![Figure 1. Architecture of Mobile Energy Internet](image-url)
3.3. Typical Application

In the "mobile-fixed" C2B application mode, the electrical energy storage and hydrogen storage vehicles can be interconnected with the UPS as a typical application scenario, and the energy storage of the vehicle is used as the UPS emergency backup power supply. In the "mobile-to-mobile" C2C application mode, energy sharing of electric energy storage and hydrogen storage vehicles can be used as a typical application scenario, including sharing of power, starting energy. For example, the user can see information such as the location, available power, and credit of other shared power users. According to the relative position and moving speed of users, the energy network card can calculate the time, location, power consumption of two users and display them. In terms of management and monitoring, the power mobile Internet does not need data sharing at the data center level. It only needs real-time energy, location and user information collected by the energy network card to form a flow chart of mobile energy storage, which is very helpful to the public management of mobile energy interconnection.

4. Capability and Value Analysis

Considering that the mobile energy Internet has the characteristics of de-centralized Internet of Things, this paper analyzes the capability and application value of the mobile energy Internet architecture by referring to the capability analysis of the information model of the Internet of Things in reference [33].
4.1. Relational Capability Analysis
An important feature of the mobile Internet is the integration of energy, information and location. Therefore, the information network, service provision, service use and other operations of the mobile power Internet have the ability to correlate the energy elements and location elements of the physical world. For example, various energy storage devices can make their own electricity, interfaces and so on into data products, open to nearby energy storage devices, and combine the energy surplus of energy storage devices, road conditions and other comprehensive plans for energy interconnection.

4.2. Autonomous Operational Capability Analysis
Decentralization is another important feature of the Internet of Things mobile Internet. The energy storage devices equipped with mobile energy network cards have the capability of autonomous networking, service provision, service invocation and so on. For example, an energy storage device equipped with a mobile energy network card can also be regarded as a mobile energy matching server, which can provide energy interconnection services for nearby mobile power network access devices without using a centralized server.

4.3. Privacy Protection Capability Analysis
Because the mobile power Internet is suitable for the application of local energy exchange, it is necessary to control the security operation of relevant physical information systems based on physical location, so all operations have the ability of privacy protection accordingly. For example, public matching information (residual energy, credibility, etc.) can be transmitted over the open carrier channel, and private information such as energy, cost can be transmitted over the location-site encryption channel.

4.4. Application Value Analysis and Prototype System Development
At present, there are many B2C commercialization apps in the shared charging point. The C2C application scenario based on the mobile energy Internet provides a new application mode for sharing charging point, which helps to promote the social development of energy sharing. Just as Didi windmill is essentially a social platform, the C2C model based on the mobile energy Internet could be a huge boost to the commercialization of the energy Internet. On the basis of information interconnection, mobile energy interconnection also brings reliable and high-quality energy data services, which is also the core application value of mobile energy Internet.

Based on the research on Petri Net [34], position sensitive data [35], GIS service [36], and trusted cloud computing [37], the author is implementing the development of mobile energy Internet prototype system. The prototype system includes the main functions of mobile energy user management, mobile energy user matching, mobile energy operation, mobile energy user monitoring and so on. The project is progressing smoothly.

5. Summary and Future Work
This paper proposes a mobile energy Internet architecture, discusses the key technologies to realize the architecture; then analyzes the capability and application value of the architecture, and introduces a research and development example of a mobile power Internet prototype system to prove the feasibility of the mobile power Internet architecture. In the next step, based on the research on the energy and price (overhead) expansion of Petri nets, the energy and position expansion of Petri nets will be studied. After the prototype system is completed, typical demonstration applications will be carried out.

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