1 An Overview of the Smart Grid

1.1 Introduction

The world population has been increased rapidly ever since the industrial revolution in the eighteenth century. Toward building a more affluent society, the development of many industries has led to significant increase in energy demand on a global scale. As a result, the increase in CO$_2$ (carbon dioxide) emissions has threatened the global environment and traditional fossil energy sources have reached their limits on the Earth. Compared to traditional fossil energy, nuclear energy began to be regarded as clean, safe, and reliable. However, in March 2011, this belief was shaken due to the Fukushima Daiichi Nuclear Power Plant accident in Japan. As a result, many countries and international bodies are now showing overwhelming interest in the use of renewable technologies for the production of clean and safe energy. However, maintaining a balance between the demand and supply of energy, fulfilling the national energy requirements through renewable energy, and abandoning energy production from fossil fuels pose many challenges. For example, energy supply which is based on the natural solar power, wind power, and hydroelectric power is unstable and cannot meet the strict requirements of electric systems. In order to make renewable energy into a stable energy resource, it is necessary to monitor power supply and demand in real time and to obtain a balance between supply and demand by integrating conventional electric grid with up-to-date information and communication technologies.

In December 2009, the United Nations organized the fifteenth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) (COP 15) and the fifth session of the Meeting of the Parties to the Kyoto Protocol (COP15/MOP5) in Copenhagen, Denmark. The industrial world reached an agreement with the long-term goal of preventing the global average temperature from rising more than 2 °C, that is, 3.6 °F, above preindustrial levels [1]. The first European Union (EU) Electricity Directive issued was Directive 96/62/EC whose primary objective was to liberalize the electric market in 1996 and this was then extended to the gas
market in 1998. The Directive was repealed and replaced by Directive 2003/54/EC as the second EU Electricity Directive in 2003, and was transposed by the EU Cogeneration Directive 2004/8/EC in 2004 [2]. In September 2007, the European Commission issued the third package of legislative proposals, which was then approved as Directive 2009/72/EC by the European Parliament and European Council in July 2009 [3]. Since March 2011, the Gas and Electricity Directives of the third package for an internal EU gas and electricity market have been transposed into a national law to introduce smart meters to the extent of around 80% by 2020 [4]. The European Parliament and European Council also established the Agency for the Cooperation of Energy Regulators (ACER) to promote the internal energy market for both electricity and natural gas in Europe [5].

The United States (US) has conducted a restructuring of electric power networks by issuing the American Recovery and Reinvestment Act (ARRA) in 2009 to enforce upgradation of the obsolete electric power networks. In January 2010, the National Institute of Standards Technology (NIST) of the US issued the NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0. NIST has initiated the Smart Grid Interoperability Panel (SGIP) under the Energy Independence and Security Act of 2007 (EISA 2007) to coordinate standards development for the Smart Grid with various organizations such as the Open Smart Grid User Group (OpenSG User Group), Institute of Electrical and Electronics Engineering (IEEE), Internet Engineering Task Force (IETF), Telecommunications Industry Association (TIA), and ZigBee Alliance.

Japan, an advanced industrial country, built a stable electric power network with nuclear power being considered as the main and stable source of power supply. However, this consideration underwent a total change after the accident at the Fukushima Daiichi nuclear power plant on March 11, 2011. After this accident, interest in promoting the research and development in setting out a policy for renewable energy technologies for the Smart Grid has grown rapidly.

The Smart Grid requires maintaining a balance between energy supply and demand through real-time monitoring enabled by bi-directional ICT. Since the cost of electric energy generation varies depending on not only the method of generating electric power but also the consumption time, location, and quantity, the purchased electricity price accordingly changes due to different situations of customers. Therefore, it is important for utilities and customers to exchange information about electricity supply and demand with each other. Furthermore, it is important to ensure not only the reliability of power generation, storage, and transmission systems but also the reliability of the information and communication systems. For example, many users use e-mail, Short Messaging Service (SMS), or Internet web pages through either a Computer or Personal Computer/Laptop or mobile phone for energy monitoring and management at home. However, transmitting critical data of electricity usage and customer privacy information through the Internet cannot meet the strict requirements of electricity systems such as latency and security. In particular, cyber security technologies will play an important role in the Smart Grid for ensuring reliable operations.
The challenges for realizing the next generation Smart Grid lies in the gaps between market needs and existing standards, and the lack of interoperability among standards. In order to bridge the gaps between future requirements and existing standards, various Standards Developing Organizations (SDOs) have been trying to promote a standardization process of the Smart Grid. The critical role of standards for the Smart Grid has already been realized worldwide by governments and industrial organizations, which advocates the development and adoption of standards to ensure that today’s investments in the Smart Grid remain valuable in the future; to ensure products from multiple manufacturers to interoperate seamlessly; to catalyze innovations; to support consumer choice; to create economies of scale to reduce costs; and to open global markets for Smart Grid devices and systems. As pointed out by the International Electrotechnical Commission (IEC), which is one of the major international standardization organizations for issuing standards related to the Smart Grid, a higher level of syntactic and semantic interoperability is required for the various products, solutions, technologies, and systems which build up the Smart Grid system [6]. Interoperability is necessary to ensure the smooth exchange and use of information between different systems or components. Two major domains of interoperability are syntactic interoperability and semantic interoperability. Syntactic interoperability ensures the ability of communication and exchange of information between different systems through standardized data formats and protocols, a typical domain where much of the work of IEC and other SDOs has focused on. Semantic interoperability is the next step of syntactic interoperability, which ensures the ability of different systems to interpret the exchanged information through standardized information exchange reference models. Besides SDOs, there are also many technical consortia, forums, and panels, which are actively involved in promoting the standardization process of the Smart Grid. This chapter will provide an overview of the current status of the Smart Grid in both developed and developing countries. The organization of this chapter is as follows: Section 1.2 provides an overview of major Smart Grid-related organizations, including SDOs, regulatory organizations, technical consortia, forums, and panels, and marketing/advocacy organizations; Section 1.3 introduces the development of the Smart Grid in the United States; Section 1.4 introduces the development of the Smart Grid in the European Union; Section 1.5 introduces the development of the Smart Grid in Japan; Section 1.6 introduces the development of the Smart Grid in South Korea; Section 1.7 introduces the development of the Smart Grid in China; and Section 1.8 gives the conclusion.

1.2 An Overview of Smart Grid-Related Organizations

In this subsection, we provide an overview of major Smart Grid-related organizations, including SDOs, regulatory organizations, technical consortia, forums and panels, and marketing/advocacy organizations [7]. In general, SDOs are the organizations that develop, revise, coordinate, and amend technical standards. SDOs not only deal with
different types of standards to address applications or sets of applications but also deal with specifications that lead to formal standards which are approved by law. Some of the standards are informal or voluntary as they are adopted by industries but not formally approved by law. Besides SDOs, there are various technical consortia, forums and panels, regulatory organizations, and marketing/advocacy organizations, which are also actively involved in developing or evaluating Smart Grid-related technical specifications and cooperating with SDOs in promoting the standardization process. It is noted that the classification of organizations in Figure 1 is just for illustration purpose as some organizations are active in a broad scope and it would been difficult to classify them into a single category.

1.2.1 SDOs Dealing with the Smart Grid

SDOs are classified according to their roles, positions, and domains of applications. SDOs can be local, regional, or international organizations, and might be governmental, semi-governmental, or non-governmental entities. Governmental SDOs are usually profitable organizations while semi and non-governmental organizations are usually non-profit organizations.

1.2.1.1 International Electrotechnical Commission (IEC)

IEC is among the most well-established and largest SDOs along with the International Organization for Standardization (ISO), and the International Telecommunication Union (ITU). It is a nongovernmental international SDO that prepares and publishes international standards for electrical, electronics, power generation, transmission, distribution, and associated technologies. Standards developed by IEC also cover home appliances and office equipment, semiconductors, fiber optics, batteries, nanotechnology, and renewable energy systems and equipments. The IEC also supervises conformity testing in order to certify whether an equipment, system, or component conforms to its international standard.

IEC issued the IEC Smart Grid Standardization Roadmap in 2010, which outlines the gaps between requirements for the Smart Grid and existing standards. In the roadmap, IEC has specified communication, security, and planning as three general requirements for all Smart Grid aspects. Besides these three general requirements, IEC has also specified 13 specific applications and requirements to cover the main areas and applications of the Smart Grid, which are the following: (i) smart transmission system and transmission level applications, (ii) blackout prevention/EMS (Energy Management System), (iii) advanced distribution management, (iv) distribution automation, (v) smart substation automation-process bus, (vi) Distributed Energy Resources (DERs), (vii) advanced metering for billing and network management,
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(viii) demand response/load management, (ix) smart home and building automation, (x) electric storage, (xi) E-mobility, (xii) condition monitoring, and (xiii) renewable energy generation. Other requirements which are necessary for implementing the Smart Grid but are not limited to Smart Grid applications and systems have also been specified, including Electromagnetic Compatibility (EMC), Low Voltage (LV) installation, object identification, product classification, properties, and documentation, and user cases.

The existing IEC core standards are shown in Figure 1.1, and summarized as follows:

- **IEC 61850**: substation automation and beyond.
- **IEC 61970**: EMS, Common Information Model (CIM), and Generic Interface Definitions (GIDs).
- **IEC 61968**: Distribution Management System (DMS), CIM, and Component Interface Specification (CIS).
- **IEC 62351**: security.

IEC has focused on new areas such as Advanced Metering Infrastructure (AMI), which is specified by IEC 62051–62059 and IEC/TR 61334; DER, which is specified by IEC 61850-7-410: -420, and Electric Vehicles (EVs) which is specified by IEC

Figure 1.1  IEC 61850 models and the Common Information Model (CIM). Reproduced from IEC Smart Grid Standardization Roadmap ed. 1.0 Copyright © 2010 IEC Geneva, Switzerland. www.iec.ch [6] with permissions from International Electrotechnical Commission (IEC)
These areas are not traditional standardization topics and pose new requirements for IEC standards. In order to promote the standardization of the Smart Grid, IEC has outlined the following general recommendations [6]:

**Recommendation G-1**
The Smart Grid can have multiple shapes and concepts and the concepts are not unified. Furthermore, legacy systems and existing mature domain communication systems must be incorporated and used. The IEC should avoid standardizing applications and business models and focus in standardizing necessary interfaces and product requirements.

**Recommendation G-2**
The potential of Smart Grid standardization and in particular the potential of IEC/TR 62357 should be promoted by the IEC. Stakeholders should be informed through numerous ways about the possible applications developed by TC 57.

**Recommendation G-3**
The IEC should not focus on the harmonization of various technical connection criteria, which are subject to different standards, regulations, and specifications. TC 8 could be responsible for specifying general minimum requirements, but the detailed standardization of these issues is out of the scope of IEC standardization.

**Recommendation G-4**
The IEC should cooperate closely with stakeholders, organizations, and other important regulatory authorities and trade associations in the domain “markets.” The IEC should perform an investigation of the market data systems.

**Recommendation G-5**
The IEC should cooperate with NIST in the prioritized action fields and offer consultation for local or regional standards, and acknowledge the works of the NIST roadmap.

**Recommendation G-6**
Production control should be integrated with the enterprise management using the achievement of technology and innovation of management. A new model rather than the original CIM model should be built to solve this problem.

### 1.2.1.2 International Organization for Standardization (ISO)
The ISO, was founded in 1947, with its headquarters in Geneva, Switzerland. It is composed of representatives from various local standard bodies. The ISO publishes worldwide proprietary, industrial, and commercial standards [8]. The Organization has English, French, and Russian as its three official languages [9]. It manages the specific projects or sends experts to participate in the technical work, subscriptions from local member bodies, and publishes standards once developed and approved.
1.2.1.3 **International Telecommunication Union (ITU)**

The ITU, which is located in Geneva, Switzerland, was originally founded in May 1865 as the International Telegraph Union. ITU is a specialized body of the United Nations that is responsible for issues that concern ICT [10, 11]. Its responsibilities include promoting international cooperation in assigning satellite orbits, coordinating the shared global use of the radio spectrum, improving telecommunication infrastructure in the developing world, and promoting the development of international standards. The ITU is active in various diverse applications and domains such as wired and wireless communication technologies, 2G/3G mobile communication network services, broadband Internet, aeronautical engineering and maritime navigation, radio astronomy, satellite-based meteorology, triple play services (voice, video, and data), TV broadcasting, and Next Generation Networks (NGN).

1.2.1.4 **SAE International**

The Society of Automotive Engineers (SAE) International is a global association for engineering professionals and researchers in the aerospace, automotive, and commercial-vehicle industries [18]. SAE International creates and manages more aerospace and ground vehicle standards than any other entity in the world. It has more than 128,000 members globally and the membership is granted to individuals. In the field of EVs, SAE International has published numerous standards to provide references for performance rating of EV batteries, battery system safety, determination of the maximum available power from a rechargeable energy storage system, packaging of EV batteries, communications between EVs and utility grid and Electric Vehicle Service Equipment (EVSE), communications between EVs and customers, interoperability with EVSE, and so on. Many standards issued by SAE International such as SAE J2847, SAE J1772, and SAE J2836 have been identified by the NIST as critical standards for the development of the Smart Grid.

1.2.1.5 **Institute of Electrical and Electronics Engineers (IEEE)**

The IEEE was founded in 1884 as the American Institute of Electrical Engineers (AIEE). Its headquarters is in New York City. The IEEE is a professional body with more than 400,000 electrical and electronics engineers, among whom around 51% are living in the United States [12, 13]. It has dedicated itself to advancing technological innovation and excellence. Basically, it is incorporated under the Not-for-Profit Corporation Law of New York [14]. By the early 21st century, a total of 38 societies had been formed within the IEEE, and more than 900 active standards had been developed by IEEE members and related stakeholders. In January 2010, the IEEE launched the IEEE Smart Grid Web Portal to bring together a broad array of sources within it, including education, news, and intelligence. The IEEE Smart Grid Web Portal is the
first phase of the IEEE Smart Grid, which is an initiative launched by the IEEE to provide expertise and guidance for those involved in the Smart Grid worldwide. The IEEE has developed numerous standards related to the Smart Grid, including IEEE P2030, IEEE 802 series, IEEE SCC 21 1457, IEEE 1159, IEEE 762, and IEEE SCC 31. Some of these standards are covered and introduced in detail in this book.

1.2.1.6 European Committee for Standardization (CEN)

The European Committee for Standardization (CEN) is a nonprofit organization, which was founded in 1961. CEN is a regional organization, which is officially recognized by European Union as a European standard body. The CEN aims to promote the European economy in global trading and the welfare of European citizens and the European environment. Its objectives are to provide an efficient infrastructure to various stakeholders for the development, maintenance, and distribution of coherent sets of standards and specifications. It has 30 national members who are working together to develop Standards for European internal market in various sectors.

1.2.1.7 European Committee for Electrotechnical Standardization (CENELEC)

The European Committee for Electrotechnical Standardization (CENELEC) was founded in 1973. As a European SDO, CENELEC is responsible for European standardization in the area of electrical engineering. Based in Brussels, CENELEC is a nonprofit organization under Belgian law. Its members are the national electrotechnical standardization bodies from most European countries. CENELEC, the European Telecommunications Standards Institute (ETSI), and CEN have formed a Joint Working Group (JWG) on standards for the Smart Grid. Standards coordinated by these agencies are regularly adopted in many countries outside Europe, which also follow European technical standards. Before the CENELEC, the other two European organizations that were responsible for electrotechnical standardization are the CENELCOM (European Committee for the Coordination of Electrotechnical Standards in the Common Market) and CENEL (European Electrical Standards Coordinating Committee) [15].

1.2.1.8 Telecommunications Industry Association (TIA)

The TIA is an association that develops consensus-based industry standards for a wide variety of ICT products. It is accredited by the American National Standards Institute (ANSI). Currently, it represents nearly 400 member companies, with 12 engineering committees under its standard and development department that develop guidelines for satellites, telephone terminal equipment, accessibility, private radio equipment,
cellular towers, data terminals, VoIP devices, structured cabling, data centers, mobile communications, multimedia multicast, vehicular telemetric, healthcare ICT, M2M communication, and smart networks [16].

1.2.1.9 Internet Engineering Task Force (IETF)

The Internet Engineering Task Force (IETF) is a large open international community of network operators, vendors, designers, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It is open to any interested individual. The IETF has its working groups where its actual technical work is performed. The working groups are organized into several areas according to specific topics such as routing, transport, and security [17].

1.2.1.10 Alliance for Telecommunications Industry Solutions (ATIS)

The Alliance for Telecommunications Industry Solutions (ATIS), which is located in Washington, D.C., has developed numerous standards for the telecommunications industry. ATIS has more than 250 member companies, including broadband providers, commercial mobile radio service providers, competitive local exchange carriers, cable providers, consumer electronics companies, digital rights management companies, equipment manufacturers, Internet service providers, and so on. ATIS is accredited by the ANSI, and is one of the six organizational partners for the 3rd Generation Partnership Project (3GPP), and is a founding partner of oneM2M, which is a common M2M service layer for various hardware and software.

1.2.2 Technical Consortia, Forums, and Panels Dealing with the Smart Grid

1.2.2.1 Wi-Fi Alliance

The Wi-Fi Alliance is a global nonprofit organization founded in 1999 with the goal of driving adoption of high-speed wireless local area networking technologies. The key sponsors of the Wi-Fi Alliance include Cisco, Dell, Apple, Huawei, Broadcom, Intel, Motorola, Samsung Electronics, and Texas Instruments. The Wi-Fi Alliance has developed the Wi-Fi Certified, which is a program for testing products to conform to the IEEE 802.11 standard in terms of interoperability, security, reliability, and so on. Wi-Fi Certified devices will carry a Wi-Fi Certified logo, which ensures interoperability among different manufactures. The Wi-Fi technology is widely used at home around the world and the adoption rate continues to grow. The goals of the Wi-Fi Alliance are to provide a highly effective collaboration forum, to promote the development of the Wi-Fi industry with new technology specifications and programs, and to realize seamless product connectivity through testing and certification.
1.2.2.2 ZigBee Alliance

The ZigBee Alliance was established in 2002 as an open, nonprofit association. Its members include companies, universities, and government agencies worldwide. The ZigBee Alliance has focused on developing green, low-power, and short-range wireless networking standards for monitoring, control, and sensor applications. The two specifications which have been developed by the ZigBee Alliance are the ZigBee Specification, which includes the ZigBee PRO and ZigBee feature sets, and the ZigBee RF4CE Specification, which was designed for simple, two-way device-to-device control applications. Furthermore, the ZigBee Alliance has also developed numerous leading standards for building automation, health care, home automation, input device, light link, network devices, remote control, retail services, smart energy, and telecommunication services. Similar to the Wi-Fi Certified program, the ZigBee Certified program certifies ZigBee products from different manufactures to ensure interoperability and quality.

1.2.2.3 WiMAX Forum

The Worldwide Interoperability for Microwave Access (WiMAX) Forum is a worldwide consortium established in 2001 to promote and accelerate the introduction of WiMAX-based services into the marketplace. WiMAX is based on the IEEE 802.16-2004, and IEEE 802.16e-2005 standards. IEEE 802.16-2004 is also called the fixed WiMAX and was developed as a wireless backhaul technology, while IEEE 802.16e-2005 is called the mobile WiMAX and was developed as a replacement for cellular phone technologies such as Global System for Mobile communication (GSM) and Code Division Multiple Access (CDMA). Similar to the Wi-Fi Alliance and the ZigBee Alliance, the WiMAX Forum has established the WiMAX Forum Certification Program to certify the interoperability of IEEE 802.16e products though conformance and interoperability tests. Devices or products which pass the tests can carry the WiMAX Forum Certified logo.

1.2.2.4 UCA International Users Group

The UCA International Users Group (UCAIug) is a nonprofit corporation established to promote the integration and interoperability of electric/gas/water utility systems through the use of international standards-based technology. The UCAIug consists of both utility users and supplier companies, and it provides a forum in which various stakeholders in the utility industry can work in collaboration to deploy standards for real-time applications. The UCAIug works closely with various SDOs as a User Group of many international standards such as IEC 61850, the CIM, advanced metering, and demand response via the Open Automated Demand Response (OpenADR).
1.2.2.5 National Electrical Manufactures Association (NEMA)

The National Electrical Manufactures Association (NEMA) was founded in 1926 to provide a forum for the standardization of electrical equipment. It consists of more than 400 member companies which manufacture electrical equipment used in power generation, transmission, distribution, factory automation, control, and medical systems. The annual sale of NEMA-scoped products has exceeded $120 billion [19]. NEMA has focused on the development of standards and providing solutions for emerging technical, regulatory, and economic issues. It has published over 600 standards and technical papers in building systems, electronics, industrial automations, insulating materials, lighting systems, medical imaging, power equipment, security imaging, wires, and cables. Furthermore, it has helped launch the Electrical Safety Foundation International (ESFI) to increase electrical safety awareness and promote the safe use of electrical equipment.

1.2.2.6 Organization for the Advancement of Structured Information Standards (OASIS)

The Organization for the Advancement of Structured Information Standards (OASIS) is a nonprofit consortium founded in 1993 to promote the development, convergence, and adoption of open standards for security, cloud computing, SOA, web services, Smart Grid, emergency management, and other areas [20]. It consists of more than 5000 members in 10 member sections: OASIS AMQP (Advanced Message Queuing Protocol), OASIS CGM (Computer Graphics Metafile), OASIS eGov, OASIS Emergency, OASIS IDtrust, OASIS LegalXML, OASIS Open CSA (Composite Services Architecture), and OASIS Web Service Interoperability (WS-I). Each member section is formed to meet the needs of a specific group and maintains its own identity as a distinct organization. The advantage is that each member section can focus on its own interest while having access to OASIS infrastructures, resources, and expertise.

1.2.2.7 HomePlug Power line Alliance

The HomePlug Power line Alliance is a trade association organization that promotes the adoption and implementation of cost-effective and standard-based home power line networks and products. It has developed several home power line technologies, including HomePlug AV/AV2 for broadband networks applications such as HDTV (High-definition Television) and VOIP (Voice Over Internet Protocol). It has also developed HomePlug Green PHY (Physical Layer) for low-cost and low-power applications such as demand response, load control, and home and building automation. Furthermore, it has cooperated with the IEEE 1901.2 working group to develop a low-frequency, narrowband Power Line Communication (PLC) certification and marketing program, named Netricity PLC, which can be used for narrowband low-frequency communications such as Smart Grid to meter applications.
1.2.2.8 **HomeGrid Forum (HGF)**

The HomeGrid Forum (HGF) is an industry alliance, which has been formed to promote the development and adoption of the International Telecommunication Union-Telecommunication Standardization Sector, Gigabit Home Networking (ITU-T G.hn) standard. ITU-T G.hn is the first standard to define a single standard for all major wired communication media including power lines, phone lines, and coaxial cables. In order to ensure compliance and interoperability, HGF has launched certification programs based on plugfests, compliance, and interoperability testing technology. Products that pass the HGF test will carry a HomeGrid logo.

1.2.2.9 **GridWise Architecture Council (GWAC)**

The GridWise Architecture Council (GWAC) was formed by the US Department of Energy (DoE) to help identify areas for standardization which ensures interoperability among different electric system components. Its members represent the many constituencies of the electricity supply chain and users. GWAC has made efforts to promote the move from control-based interactions toward transaction-oriented interactions, which requires significant information exchange between electric system devices and electricity consumers. The term “transactive energy” means that the decisions of how to consume the energy are made on the basis of economic or market constructs while considering grid reliability constraints. Examples of transactive energy applications are the GridWise Olympic Peninsula Project [21], TeMIX [22], and the Pacific Northwest Smart Grid Demonstration Project [23]. GWAC has also cooperated with NIST to form the Domain Expert Working Groups (DEWGs) to assist NIST with addressing Smart Grid interoperability issues.

1.2.3 **Other Political, Market, and Trade Organizations, Forums, and Alliances**

Besides various SDOs and technical consortia, forums, and panels, there are also many other political, market, trade, and regulatory organizations, forums, and alliances, which are actively involved in promoting the development of the Smart Grid. In this section, we briefly introduce some of these organizations, forums, and alliances.

1.2.3.1 **International Energy Agency (IEA)**

The International Energy Agency (IEA) was founded in response to the 1973 oil crisis with the role to coordinate response to major disruptions in oil supply by releasing emergency oil stocks [25]. Its current work is to ensure reliable, affordable, and clean energy. The four core areas of IEA’s works are energy security, economic development, environmental awareness, and engagement worldwide. The IEA consists of 28 member countries including Australia, Canada, the Czech Republic, Denmark, Finland, Germany, Hungary, Italy, Japan, Luxembourg, New Zealand,
Norway, the Slovak Republic, Spain, Turkey, United Kingdom, United States, and so on. Besides member countries, the IEA has also developed close relationships with nonmember countries such as China, India, Brazil, Russia, and Thailand.

### 1.2.3.2 Clean Energy Ministerial (CEM)

The Clean Energy Ministerial (CEM) is a high-level global forum for clean energy technologies first hosted by the then US Secretary of Energy Steven Chu at the UN Framework Convention on Climate Change conference of parties in December 2009 [26]. Since then, it has attracted worldwide participation from governments, taking into account 80% of global greenhouse gas emissions and 90% of global clean energy investment. The three core focus areas of the CEM are energy efficiency, clean energy supply, and clean energy access. It has developed 13 action-driven, transformative clean energy initiatives [27]: Electric Vehicles Initiative (EVI), Global Superior Energy Performance Partnership (GSEP) Initiative, Super-Efficient Equipment and Appliance Development (SEAD) Initiative, Bioenergy Working Group Initiative, Carbon Capture, Use, and Storage Action Group (CCUS) Initiative, Multilateral Solar and Wind Working Group Initiative, Sustainable Development of Hydropower Initiative, twenty-first century Power Partnership Initiative, Clean Energy Education and Empowerment (C3E) Women’s Initiative, Clean Energy Solutions Center Initiative, Global Lighting and Energy Access Partnership (Global LEAP) Initiative, Global Sustainable Cities Network (GSCN) Initiative, and International Smart Grid Action Network (ISGAN) Initiative. Among these 13 initiatives, ISGAN enables multilateral collaborations among governments to improve the understanding of Smart Grid technologies, practices, policies, and so on. Currently, ISGAN has involved 22 member countries: Australia, Austria, Belgium, Canada, China, Finland, France, Germany, India, Ireland, Italy, Japan, Korea, Mexico, Norway, the Netherlands, Russia, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

### 1.2.3.3 Demand Response and Smart Grid Coalition (DRSG)

Demand Response and Smart Grid Coalition (DRSG) is a trade association that consists of various companies in the areas of demand response, smart meters, and the smart grid technologies. DRSG consists of executive-level members and associate-level members, who provide demand response and Smart Grid technologies and services. The member companies are working together to promote the development and adoption of demand response and Smart Grid technologies.

### 1.2.3.4 China Electricity Council (CEC)

The China Electricity Council (CEC), which was founded in December 1988, is a joint organization of China’s power enterprises and institutions. The CEC consists of 1188 members, among which the State Grid Corporation of China (SGCC) is the
president member. The CEC functions as a bridge between government and its member companies and institutions by forwarding their requests to the government and protecting the legal rights of its members.

### 1.2.3.5 Global Smart Grid Federation

The Global Smart Grid Federation was founded in April 2010 to facilitate collaboration among various stakeholders to promote development and research of Smart Grid technologies. It consists of the following members:

- **GridWise Alliance (USA):** a forum found in 2003 in which various stakeholders of the energy supply chain work cooperatively to promote the transformation of the industrial-age electric grid into the information age.
- **India Smart Grid Forum (ISGF) (India):** a Public Private Partnership (PPP) initiated by the Ministry of Power, Government of India, to promote the development of Smart Grid technologies in India.
- **Japan Smart Community Alliance (JSCA) (Japan):** an alliance established by the New Energy and Industrial Technology Development Organization (NEDO) to promote collaboration of various stakeholders from electric power, gas, automobile, information and communications, electric machinery, construction and trading industries, public sector, academia, and so on.
- **Smart Grid Flanders (Belgium), Smart Grid Canada (Canada), Danish Intelligent Energy Alliance (Denmark), EDSO, European Distribution System Operator, for Smart Grids (EU), Smart Grid Great Britain (UK), Norwegian Smartgrid Centre (Norway), Smart Grid Ireland (Ireland), Israel Smart Energy Association (Israel), Industrial Technology Research Institute (ITRI), Korea Smart Grid Association (Korea), Smart Grid Australia (Australia).**

### 1.2.3.6 National Institute of Science and Technology and Smart Grid Interoperability Panel

NIST was found in 1901 as a nonregulatory federal agency and is one of the nation’s oldest physical science laboratories. Currently, NIST is part of the US Department of Commerce, with a mission to promote US innovation and industrial competitiveness by advancing measurement science, standards, and technologies through the NIST laboratories, the Hollings Manufacturing Extension Partnership, the Baldrige Performance Excellence Program, and the Technology Innovation Program. The SGIP was initiated by NIST in 2009 to promote the development of a SmartGrid framework for interoperability standards. Therefore, SGIP was called the “best vehicle for developing Smart Grid interoperability standards” by the Federal Energy Regulatory Commission (FERC) [24]. SGIP has assisted NIST with its fulfillment of the EISA 2007. SGIP has focused on seven core domains of Smart Grid: operations, markets,
service providers, bulk generation, transmission, distribution, and customer. These seven core domains are represented by 22 stakeholder categories that are working closely and cooperating with each other to promote the development and adoption of interoperability standards for the Smart Grid.

### 1.3 Status of the United States (US)

In the United States, FERC is responsible for regulating the interstate transmission of electricity, natural gas, and oil. However, the regulation of retail electricity and natural gas sales to consumers is outside of the FERC’s responsibility. FECS issued the FERC Energy Policy Act in 1992 to take a step forward toward electric deregulation, and issued the FERC Orders 888 and 889 in 1996, which led to the creation of the Open Access Same-Time Information System (OASIS, formerly Real-Time Information Networks). The effects of partial deregulation in retail markets was promoted as a means of increasing competition. However, in the 2000–2001 California electricity crisis, only the wholesale prices were deregulated but retail prices were still regulated by the government. As a result, major utilities such as PG&E and SoCal Edition experienced financial deficit that is caused by paying more to the electricity wholesalers than the revenue charged from the customers. Investment in new power plants and distribution infrastructures dropped sharply. Aging, outdated electrical equipment and overloaded distribution lines were becoming a major problem in the United States. In the 2003 Northeast blackout, a software bug in the alarm system caused the second most widespread blackout in history, which affected an estimated 10 million people in Ontario and 45 million people in eight other states [28]. Therefore, in order to upgrade the aging electric infrastructures and power grid, and to stimulate the economy, the Obama government has regarded the Smart Grid as one of the core components of the economy stimulus package. The development of the Smart Grid in the United States can be divided into three domains as shown in Figure 1.2: strategy development and planning, policy and law enforcement, and government and company pilot projects.

#### 1.3.1 Strategy Development and Planning

In the strategy development and planning domain, the DoE has issued the DoE National Transmission Grid Study in 2002, in which the following six topics are reviewed [29]: transmission system operation and interconnection, reliability management and oversight, alternative business models for transmission ownership and operation, transmission planning and the need for new capacity, transmission siting and permitting, and advanced transmission technologies. The study has specified 51 recommendations to ensure a robust and reliable transmission grid for the twenty-first century. On 2 and 3 April 2003, 65 senior executives representing various stakeholders held a meeting to discuss the future of North America’s electric system. In July 2003, DoE issued the “Grid 2030 – A National Vision for Electricity’s Second 100 Years,” to help implement
the 51 recommendations and to modernize the electricity delivery system in the United States [30]. Also in 2003, the Electric Power Research Institute (EPRI) issued the Electricity Technology Roadmap – Meeting the Critical Challenges of the twenty-first century. The roadmap has specified five destinations for realizing a sustainable global energy economy by 2050 [31]: (i) strengthening the power delivery infrastructure, (ii) enabling the digital society, (iii) boosting the economic productivity and prosperity, (iv) resolving the energy/environment conflict, and (v) managing the global sustainability challenge.

In January 2004, the DOE issued the National Electric Delivery Technologies Roadmap Version 1.0, which suggests paths to build America’s future electric delivery system and outlines challenges faced by various stakeholders. In January 2006, the DOE issued the Roadmap to Secure Control Systems in the Energy Sector, which has outlined a strategic framework to achieve the vision that by 2015 US energy sector would be able to survive an intentional cyber assault without large impacts on critical
applications [32]. In March 2007, the National Energy Technology Laboratory (NETL) issued A Vision for the Modern Grid V1.0, which defined seven characteristics for the Modern Grid [33]: (i) self-heals, (ii) motivates and includes the customer, (iii) resists attack, (iv) meets twenty-first century power quality requirements, (v) accommodates all generation and storage options, (vi) enables markets, and (vii) optimizes assets and operates efficiently. It is noted that in June, 2009, NETL issued A Vision for the Smart Grid, in which the word “Modern Grid” has been changed to “Smart Grid” compared to the document issued in 2007 [34].

In the United States, NIST is the central institute to promote the standardization of the Smart Grid. The EISA 2007 has directed NIST to coordinate the development of specifications, protocols, models, and standards to achieve interoperability. NIST will submit standards to FERC, which will adopt these standards through the rule-making process. There are various agencies and institutions working cooperatively with NIST in developing standards related to the Smart Grid. NIST has released the final version of NIST Framework and Roadmap for Smart Grid Interoperability Standards 2.0 on February 28, 2012, which has specified the following 15 Priority Action Plans (PAPs) [35]:

- PAP00 Meter Upgradeability Standard
- PAP01 Role of Internet Protocol (IP) in the Smart Grid
- PAP02 Wireless Communications for the Smart Grid
- PAP03 Common Price Communication Model
- PAP04 Common Schedule Communication Mechanism
- PAP05 Standard Meter Data Profiles
- PAP06 Common Semantic Model for Meter Data Tables
- PAP07 Energy Storage Interconnection Guidelines
- PAP08 CIM for Distribution Grid Management
- PAP09 Standard DR and DER Signals
- PAP10 Standard Energy Usage Information
- PAP11 Common Object Models for Electric Transportation
- PAP12 Mapping IEEE 1815 (DNP3) to IEC 61850 Objects
- PAP13 Harmonization of IEEE C37.118 with IEC 61850 and Precision Time Synchronization
- PAP14 Transmission and Distribution Power Systems Model Mapping
- PAP15 Harmonization of Power Line Carrier Standards for Appliance Communications in the Home
- PAP16 Wind Plant Communications
- PAP17 Facility Smart Grid Information Standard
- PAP 18 Smart Energy Profile (SEP) 1.X to 2.0 Transition and Coexistence

More details about the NIST Framework and Roadmap for Smart Grid Interoperability Standards can be found in Chapter 8 and references therein. NIST has positioned the Internet as the core network for the realization of smart grid. In Internet, there
already exists a set of protocols which define how information is packaged, transmitted, and shared across the Internet users. Similar to that concept, a working group of NIST has been developing core set of protocols that can be used to build a new network for the Smart Grid. A core set which consists of more than 150 individual Request for the Comments (RFCs) protocols has been developed for communications and cybersecurity. In the field of energy, NIST has set up six subject areas: alternative energy, electric power metrology, energy conservation, storage and transport, fossil fuels, and sustainability. Within each subject area, numerous programs and projects have been launched to promote the development and research of Smart Grid standards.

Since the study of the Smart Grid in the United States has mainly focused on the integration of ICT technologies, there are many information and networking companies such as IBM, Accenture, Oracle, SAP, and Cisco participating in the development of the Smart Grid. In order to operate safely and reliably, it is necessary for the Smart Grid to adopt practical countermeasures against cyber threats. Therefore, NIST has formed the Smart Grid Interoperability Panel–Cyber Security Working Group (SGIP-CSWG). SGIP-CSWG has worked since June 2009 to develop a cyber security strategy for the Smart Grid that addresses prevention, detection, response, and recovery issues. The cybersecurity strategy should ensure interoperability of solutions across different domains and components of the Smart Grid. As a result, the SGIP-CSWG has issued the National Institute of Standards Technology Interagency Report (NISTIR) 7628 Guidelines for Smart Grid Cybersecurity in 2010. It is a report for individuals and organizations, including vendors, manufacturers, utilities, system operators, researchers, and so on, who will be addressing cybersecurity for Smart Grid systems. The guideline is comprised of three volumes: Volume 1-Smart Grid Cybersecurity Strategy, Architecture, and High-Level Requirements; Volume 2-Privacy and the Smart Grid; and Volume 3-Supportive Analyses and References. One hundred and eighty-nine high-level security requirements and 137 interfaces have been identified in the guideline. Multiple levels of security implementations are recommended to countermeasure the diverse and evolving cyber security threats.

In 2011, the DoE issued the Roadmap to Achieve Energy Delivery Systems Cybersecurity, which was developed as a replacement to the 2006 Roadmap to Secure Control Systems in the Energy Sector. In this report, a strategic framework has been developed to ensure that energy delivery systems are capable of surviving cyber incidents without large impacts on critical functions.

1.3.2 Policy and Law Enforcement

In order to guarantee energy production in the United States, the US Congress passed the Energy Policy Act of 2005 (EPAct 2005) on 29 July 2005. The EPAct 2005 has specified energy management requirements in the following areas: metering and
reporting, energy-efficient product procurement, energy savings performance contract, building performance standards, renewable energy requirement, and alternative fuel use [36].

Later, the United States enforced the EISA 2007, which was originally named the Clean Energy Act of 2007. One of the major goals of the EISA 2007 is to move the United States toward greater energy independence and security. Under EISA 2007, NIST has been given the key role for coordinating development of a framework for interoperable Smart Grid standards. NIST has launched a three-phase plan to promote the development and adoption of Smart Grid interoperability standards. When the Obama administration was born, he put the Smart Grid at the center of a Green New Deal, an economic stimulus package through which he plans to create three million jobs in energy, education, healthcare, and infrastructure. On 13 February 2009, President Obama signed the ARRA into law, under which there is a total of $4.5 billion US energy grant for developing Smart Grid technologies [37]. On 27 April 2009, Obama announced the launch of the Advanced Research Projects Agency-Energy (ARPA-E), which was established to fund energy technology projects.

1.3.3 Government and Company Pilot Projects

Both government agencies and energy companies have also launched numerous Smart Grid projects. In 2004, the Austin Energy Corporation launched the Austin Energy Smart Grid program, with plans to offer real-time meter information by phone or Internet, management of smart appliances through the Web, and remote turn-on and turn-off service [38]. In 2006, the Pacific Gas and Electric (PG&E) initiated the SmartMeter™ project, in which more than nine million gas and electric meters were installed by 31 July 2012 [39]. With the SmartMeter system, residential electric usage data are recorded every hour, while commercial electric usage data are recorded every 15 min. The gas usage data are recorded once a time per day. Both the electric and gas usage recorders are transmitted using wireless communication networks. The SmartMeter system is expected to provide services to all customers.

In 2008, the Xcel Energy Corporation launched the “SmartGridCity project” in Boulder, Colorado to promote the development and adoption of Smart Grid technologies such as the SmartMeter and Home Automation Network (HAN). The SmartGridCity consists of four main components: Smart Grid infrastructure, smart meters, My Account website, and in-home smart devices. A user can log into the My Account website to track electricity use on daily, hourly, or 15-min intervals.

In October 2009, Dominion Virginia Power launched the $20 million SmartGrid Charlottesville project. In this project, more than 46 500 smart meters were installed. This project aims to test battery storage systems, develop automatic reporting of outages, allow for quicker restoration of service, increase customer convenience through remote turn-on and turn-off services, enable remote meter readings, and develop a demonstration program for light-emitting diode (LED) street lights [40].
In 2010, the PG&E and EPRI initiated an innovative Plug-in Electric Vehicle (PEV) pilot program, aimed to test and validate the security, scalability, and functionality of smart charging technology integrated with the Smart Grid [41]. Two leading companies in Smart Grid and PEV charging infrastructure, namely, Silver Spring Networks and ClipperCreek, Inc., joined the pilot program to promote the integration of PEV charging stations with the electricity grid.

In 2012, the US and Japan Smart Grid Collaborative Demonstration Project was conducted for verifying microgrid demonstration in Los Alamos, smart house in Los Alamos, microgrid demonstration in commercial areas of Albuquerque, and collective research on the overall project. Companies including Shimizu Corporation, Toshiba Corporation, Sharp Corporation, Meidensha Corporation, Tokyo Gas Co., Ltd, Mitsubishi Heavy Industries, Ltd, Fuji Electric Co., Ltd, Furukawa Electric Co., Ltd, Furukawa Battery Co., Ltd, Public Service Company of New Mexico, Sandia National Laboratories (SNL), the University of New Mexico, and regional US utility firms are currently working on it. In this project, a microgrid which is comprised of a 50 kW photovoltaic (PV) power generation system, a 240 kW gas-engine generator, an 80 kW fuel cell system, and a 90 kW battery storage system have been deployed to provide power on the demand side [42].

1.4 Status of the European Union (EU)

1.4.1 Activities of the European Union

Toward the establishment of common rules for the internal electricity market in Europe, the European Union issued the First EU Electricity Directive in December 1996. In the First Directive, the European Union obligates the liberalization of the retail market, accounting separation of power transmission and distribution businesses of vertical-type electric power companies, and obligates the approval of constructing new electric power generation infrastructures for the purpose of opening the market for new companies within the EU power market.

The European Union issued the Second EU Electricity Directive in 2004. The primary purpose of the Second Directive is to ensure the energy supply based on principles of consumer protection. The second purpose is to introduce competition in the energy markets. The third purpose is to introduce competition in the supply market. The fourth purpose is to guarantee the transmission and distribution network connection. The fifth purpose is to separate electric power generation, electricity sales business, and power transmission and distribution business from each other. The final purpose is to issue an annual report on the electricity and gas market.

In 2006, the European Union issued the European Smart Grids Technology Platform-Vision and Strategy for Europe’s Electricity Networks of the Future, with the aim to create a joint vision for the European electricity networks of 2020 and beyond. The Vision should ensure that the future electricity networks of Europe have the following four features: flexibility, accessibility, reliability, and economy.
of operation. The key elements of the Vision include a toolbox of proven technical solutions, a harmonized regulatory and commercial framework, shared technical standards and protocols, information and communication systems, and interfaces for both new and old designs [43]. In 2007, the European Union issued the Strategic Research Agenda (SRA) for Europe’s Electricity Networks of the Future, which defines and promotes research themes and projects to address the key elements of the Vision. The research agenda has identified 5 research areas, and 19 research tasks, which are necessary to realize the Vision.

In 2009, the Gas and Electricity Directives of the Third Package for an Internal EU Gas and Electricity Market was adopted and it was introduced into force by the European Commission Directorate General for Energy and Transport, and was transposed into national law by Member States in 2011. The purpose was to create a genuine internal energy market in which European consumers could choose gas and electricity supplying services from different companies at reasonable prices, and to enable all energy suppliers including small companies be able to access the market. The European Union established a task force in November 2009 for this purpose. The third legislative package obligates Ownership Unbending (OU), Independent System Operator (ISO), and Independent Transmission Operator (ITO) for the purpose of separating electric power generation and transmission systems. The ACER was established in 2010 as a successor to the European Regulators’ Group for Electricity and Gas (ERGEG) to regulate the third legislative package. In addition, the third legislative package gives priority to investment in new renewable energy generation infrastructures, and to strengthen the protection of consumers.

Toward the end of 2009, the European Commission set up the Smart Grid Task Force (SGTF) to provide policy and regulatory directions for the deployment of the Smart Grid. In March 2010, the European standardization organizations CEN and CENELEC held an informal meeting to discuss the standardization problems of Smart Grid technology in Europe. This meeting set up a working group to actively promote the development and research work of the Smart Grid standards. In 2011, the CEN/CENELEC/ETSI Joint Working Group (JWG) issued the final report of the CEN/CENELEC/ETSI Joint Working Group on Standards for Smart Grid, which outlines the standardization requirements for implementing the European vision of the Smart Grid [44]. The report provides an overview of current standards and activities and identifies the necessary steps to be taken to realize the vision.

In March 2012, the European Union issued the Smart Grid SRA 2035 SRA Update of the Smart Grid SRA 2007 for needs by the year 2035 [45]. The SRA 2035 describes the research topics and priorities that will be necessary for further development of the electricity system from 2020 to 2035 and beyond. The European Union promotes low-carbon related technology, bio energy, carbon capture and storage, power grid, hydrogen and fuel cells, nuclear power, smart city, solar power, and wind power based on the European Strategic Energy Technologies (SETs) Plan.

In June 2012, the European Union founded the European Network of Transmission System Operators for Electricity (ENTSO-E) to represent all electric Transmission
System Operators (TSOs) in the European Union. In ENTSO-E, the TSOs cooperate with each other regionally or on the European scale, and activities were organized through three committees: the System Development Committee, the System Operations Committee, and the Market Committee. The climate and energy policy of the European Union sets the following targets for 2020: cutting greenhouse gases by at least 20% of 1990 levels and increasing use of renewable energy sources (wind, solar, biomass, etc.) to 20% of total energy consumption. In order to increase energy efficiency by 20%. The ENTSO-E issued the scenarios A and B (corresponding the conservative case and best estimate case respectively). In July, 2012, the ENTSO-E published the final Ten-Year Network Development Plan (TYNDP) package. The TYNDP package comprises of six regional investment plans (RgIps): Baltic Sea, Continental South East, Continental Central East, Continental South West, Continental Central South, and North Sea [46]. The TYNDP package has also specified the Scenario Outlook and Adequacy Forecast (SO&AF) 2012–2030. In SO&AF 2012–2030, four visions for 2030 have been specified: Slow Progress, Money Rules, Green Transitions, and Green Revolution. These four visions are different enough from each other to capture realistic future pathways and challenges. There will be more than 100 transmission projects of pan-European significance, which total about 52 300 km of Extra High Voltage Routes, and require a total investment of more than €100 billion [46]. These projects will result in a 170 million tons reduction of CO$_2$, of which 150 million tons CO$_2$ is due to the deployment of renewable energy resources, and the other 20 million tons CO$_2$ is due to the effect of market integration.

The European Union has actively promoted the use of wind power and the use of solar energy as renewable energy, and has established some priority electricity corridors. In order to integrate the offshore wind capacities in the Northern Seas, the European Union has established the North Seas Countries’ Offshore Grid Initiative (NSCOGI). Further, in order to integrate new renewable generation of Western Europe with other consumption centers, the European Union has launched the South Western Electricity Interconnections to increase interconnections between Member States in Western Europe. Other priority electricity corridors include the North–South electricity interconnections in central Eastern and South Eastern Europe and the Baltic Energy Market Interconnection Plan. The European Union has initiated the Framework Programme (FP) to provide funding for research, technological development, and demonstration. In the field of DER, several projects have been launched, including the FP5 (1998–2002) DISPOWER project, MICROGRIDS project, the FP6 (2002–2006) EU-DEEP project, IRED project, FENIX project, and the FP7 (2007–2013) iGREEN-Grid project, and ADDRESS project. More details about DER can be found in Chapter 4 and references therein.

1.4.2 Activities of EU Member Countries

EU member countries have also been actively involved in the research and development of the Smart Grid. Germany amended the Energy Industry Act in 1998 and
started liberalization of the electricity market based on the first EU Electricity Directive. The restructuring of the electric power industry has occurred consequent to this. Following the Japanese Fukushima Daiichi nuclear power plant accident in March 2011, Germany determined to withdraw from nuclear power in June 2011, and to close all nuclear power plants in Germany by 2022. Companies such as E.ON which invested heavily in nuclear power plants had to cut jobs and switch to other energy generation technologies such as renewables. At present in Germany, there are four electric power generation companies: E.ON, RWE, EnBW, and Vattenfall Europe. The electricity transmission companies are TenneT TSO GmbH, 50 Hz Transmission, Amprion, and TransnetBW. In the distribution business, there are more than 800 distribution companies in the country following the liberalization of the electricity retail market.

Germany turned aggressive in developing solar energy and began the Feed-in Tariff (FiT) in 2000. Using FiT, each energy technology is given a different price from other energy technologies, on the basis of the particular cost of generation of that energy. Solar PV is offered a higher price than cheap wind power, and the tariff rates also depend on the size and location of the PV systems. PV manufacturers such as Q-Cells continued to grow but have suffered recently because of competition from cheap solar products from China. Owing to a net loss of more than €8 million, Q-Cells was acquired by Hanwha Korea as Hanwha Q. Cells, and continue to manufacture solar cells and panels. Solar PV installations in Germany have increased dramatically in the past, and are expected to continue to grow in the future. Germany has founded a consortium with 12 founders, including nine Germany companies: Deutsche Bank, Munich Re, HSH Nordbank, Siemens, Solar Millennium, Schott Solar, E.ON, RWE, and M+W Zander. The consortium will build a giant solar plant in the Moroccan desert, the first of many renewable energy power stations which would together cover 15% of Europe’s electricity demand by 2050 [47].

The German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) and Federal Ministry of Economics and Technology (BMWi) jointly launched the “E-Energy” demonstration project plan in 2008 [48]. The E-Energy project includes six E-Energy demonstration projects, and seven electricity mobility projects. More than €140 million of funding have been provided by both government and private companies. One example is the Cuxhaven demonstration project. The Cuxhaven demonstration project (e-Telligence) is carried out in Cuxhaven, which has a high percentage of renewable energies, for example, wind power, and a high percentage of electric storage systems, for example, cold stores and indoor swimming pools. A complex control system using Smart Grid technologies has been developed to balance the fluctuations of renewable energies, and to establish a renewable energy market.

The Cuxhaven demonstration project uses the modern ICT to improve the energy supply system and realize the integration of renewable energies, including wind power, solar power, and biomass. Consumers, DER systems, and electric storage systems, are integrated by establishing Virtual Power Plants (VPPs) to improve...
energy use efficiency. Smart meters have been installed for more than 2000 families, and on-line visualization of electricity usage has been provided. In order to ensure the interoperability among different devices, a distributed information processing platform was established on the basis of the IEC 61850 and IEC 61970/IEC 61968 standards. The communications of the electricity market information and the control and status information are based on the CIM and the IEC 61850, respectively.

France amended the municipal law in 1999 according to the First EU Electricity Directive, for the purpose of enacting electricity deregulation in 2000. The EDF (Électricité de France), a monopoly company in the electricity market, used to produce 22% of the EU’s electricity through nuclear power plants. The dependence on nuclear power of France has jumped to as high as 85%, which is the highest in the world. Besides EDF, other power generation companies are GDF Sües (Gaz de France) and SNET (Société nationale d’électricité et de thermique), whose market shares are weaker compared to EDF. In the transmission and distribution business, both the transmission company RTE (Réseau de Transport électrique) and the distribution company ERDF (Electricité Réseau Distribution France) are 100% subsidiary companies of EDF. Therefore, the separation of electrical power generation from power transmission makes very slow progress.

In order to reform the French electricity market, the Nouvelle Organization du Marché de l’Électricité (NOME) law was passed in 2010 to require EDF to sell its nuclear outputs to competitors at a rate specified by the CRE (Commission de régulation de l ‘énergie/Energy Regulatory Commission). Under the NOME law, EDF has to sell 100 TWh per year to other electricity suppliers, which ensures that other electricity suppliers can offer competitive prices to customers [49].

In the United Kingdom (UK), after the liberalization of the electric market by enforcing the new Electricity Act 1989, the Distributed Generation Co-ordination Group (DGCG) was established to conduct a purchase obligation of renewable energy by introducing Renewable Obligation Certificates (ROCs) in 2002. A ROC is a green certificated issued by the authority to energy suppliers. ROC can be traded with other suppliers and each supplier needs a sufficient number of ROCs to meet its obligation. When the ROCs are not sufficient, the supplier has to pay an equivalent amount as fee, which can be distributed back to other green renewable energy suppliers.

In 2003, the Department of Trade and Industry (DTI) issued the Energy White Paper to define a goal with 60% reduction of GHG (greenhouse gas) emissions by 2050. In 2005, the Electricity Networks Strategy Group (ENS) was launched as the organization’s activities to DGCG continue [50]. The UK regulator Office of the Gas and Electricity Markets (Ofgem) and the government agency, that is, the Department of Energy and Climate Change (DECC), have initiated the DECC/Ofgem Smart Grid Forum, which provides a platform for various electricity network companies to cooperate closely to address significant challenges faced by the implementation of the Smart Grid. The ENSG, which is jointly chaired by both DECC and Ofgem, published the A Smart Grid Vision in November 2009, and A Smart Grid Routemap in
February 2010. In July 2010, DECC, Ofgem, and the Gas and Electricity Markets Authority (GEMA) jointly published a prospectus to propose the installation of electricity and gas smart metering in Great Britain. It is expected that from 2012 to 2019, more than 50 million smart meters will be installed in 30 million homes and smaller businesses in Britain [51].

In Denmark, the EDISON demonstration project has been launched to work out how the Smart Grid would integrate electric power system to meet the needs of most distributed wind power integration and the development of new energy vehicles. The Danish grid company Energinet, has invested in this project. IBM and Siemens are also involved in the construction of this project. More details of the Edison Project can be found in Chapter 4.

In Italy, Enel has already deployed a large number of smart meters and the electricity consumption data are transmitted to the utilities by GSM/GPRS (General Packet Radio Service), PSTN (Public Switched Telephone Network), KNX, and so on. Spain launched numerous Smart Grid projects such as the STAR project (Spanish acronym for Remote Grid Management and Automation System), Substation to Grid (S2G) wireless substation monitoring project, Movele project, and the Smart Community project. Spain has also cooperated with Japan to launch the Japan–Spain Innovation Program (JSIP) in 2010.

1.5 Status of Japan

The overall utilization efficiency and power supply reliability of the Japanese power system are in the leading position globally. In April 2009, the Japanese Prime Minister Taro Aso gave a speech, “Japan’s Future Development Strategy and Growth Initiative toward Doubling the Size of Asia’s Economy.” One of the future development strategies is to enable Japan to become the leading country in the field of low-carbon emission, which includes becoming the number one solar power nation in the world, and the first nation to popularize eco-cars [52]. In July 2009, the Federation of Electric Power Companies (FEPCs) of Japan started to discuss how to develop the Japanese version of the the Smart Grid and incorporate solar power generation. In November 2009, the Japanese Ministry of Economy, Trade, and Industry (METI), launched the conference on next generation energy and social system, to discuss how to build a low-carbon society.

In April 2010, METI selected Yokohama City, Toyota City, Kansai Science City, and Kitakyushu City as areas for demonstration projects [53]. The Yokohama project in Kanagawa Prefecture was promoted by Yokohama, Accenture, Nissan, Toshiba, Meidensha, Panasonic, Tokyo Electric Power Company, and Tokyo Gas, to deploy large-scale renewable energy (27 000 kW PV system), to introduce smart home and building technologies for 4000 households, to deploy 2000 next-generation vehicles, and to reduce CO₂ emissions by 30% by 2025 compared to the level of 2004.
The project in Toyota City, Aichi Prefecture, was promoted by Toyota, Denso, Sharp, Chubu Electric, Toho Gas Co., Fujitsu, Toshiba, KDDI, Mitsubishi Motors, Circle K, Lawson, Home Toyota, and Mitsubishi, and so on. The goals are to deploy 3100 next-generation vehicles, to improve energy efficiency by using a mix of different energy sources (electricity, heat, and unused energy), and to reduce CO$_2$ emissions by 20% in households and 40% in transport. The project in the Kansai Science City, Kyoto, is supported by Kyoto city, Keihanna Science City, Kyoto University, Kansai Electric Power Co, and Kyoto City Gas. The goals are to install PV systems in 1000 households, to build “nano-grids” in homes and buildings for the purpose of controlling power generation systems and electric storage systems, to propose an energy economy model based on “Kyoto eco-points,” and to reduce CO$_2$ emissions by 20% in households and 40% in transport by 2030, compared to the level of 2005.

The project in the Kitakyushu City, Fukuoka Prefecture, is supported by Kitakyushu City government, Nippon Steel, Fuji Electric Systems, IBM Japan, and so on. The goals are to create a city block where new energy (including wind power, solar power, waste heat, etc.) supports 10% of the total energy consumption, to deploy smart meters in 70 companies and 200 households, and to reduce CO$_2$ emissions by 50% in the residential/commercial and transport sectors by 2030, and 80% by 2050.

METI has issued 25 Smart Grid core research subjects: (i) monitoring and control of systems for wide area transmission system; (ii) optimal control of storage battery system; (iii) optimal control of the battery for power distribution; (iv) optimal control of cells in the region; (v) billing the contents of the theme standardization; (vi) power conditioners for a high efficiency battery and distribution automation system; (vii) power conditioners for distributed power; (viii) equipment power electronics for power distribution; (ix) demand response network; (x) HEMS (Home Energy Management System); (xi) BEMS (Building Energy Management System); (xii) FEMS (Factory Energy Management System); (xiii) CEMS (Cluster/Community Energy Management System); (xiv) stationary storage system; (xv) battery modules; (xvi) evaluation method of the residual value for automotive storage battery; (xvii) EV rapid charger for Electric Vehicles; and so on. In 2010, METI announced the Next Generation Vehicle Strategy 2010, which specifies the strategy for developing new-generation vehicles. It sets the diffusion target that the next generation vehicles will account for up to 50% in 2020. In order to attain this goal, each Japanese automobile company should develop 17 EVs and 38 hybrid-power vehicles at the latest by 2020.

In Japan, the electricity generation and distribution businesses are not separated. Following the Fukushima Daiichi accident in March 2011 caused by the earthquake in East Japan, development and research interests have shifted away from nuclear power to EVs, LED lamps, and smart home and building automation systems. NEDO under METI has launched several projects to promote the development of the Japanese Smart Grid. One example is the Japan-US collaborative Smart Grid project in Los Alamos, New Mexico, which was launched in 2009 with an investment of $10 billion. NEDO has established the JSCA to promote cooperation among various stakeholders.
to accelerate Smart Grid-related activities in Japan. In order for Japanese companies to participate in Smart Grid-related activities, Japan has become actively involved in expanding the Asian Smart Grid market. NEDO has conducted an investigation of the Smart Grid-related technology requirements in the industrial areas surrounding Jakarta, Indonesia in 2010. This is the first time that Japan launched investigations of the Smart Grid in Southeast Asia. NEDO has investigated the current situation of Java Island Power Company in Jakarta, electricity supply and demand, electricity quality, number of factories, conditions of power stations, and so on. On the basis of the investigation results, the Japanese government has cooperated with the Indonesian government for the development of a smart community in Indonesia. NEDO has commissioned the Sumitomo Corporation, jointly with Fuji Electric Co., Ltd., Mitsubishi Electric Corporation, and NTT Communications Corporation, to implement the Smart Industrial Park project in the Indonesian Island of Java from 2013 to 2016.

1.6 Status of South Korea

In 2008, South Korea enacted the Green Growth Basic Law, established the Green Growth Institute, and founded the Global Green Growth Institute (GGGI). The law explicitly states that the green growth development is the first priority among national issues, and lays the foundation for other relevant laws.

On 15 August 2008, the South Korea government has established the Presidential Committee on Green Growth, which is an organization directly responsible to the President for reducing CO$_2$ emissions and promote green growth. Its vision is to enable South Korea to become the seventh Green Power by 2020, and fifth Green Power by 2050 [54]. In 2009, the Presidential Committee on Green Growth issued the guideline, Building an Advanced Green Country, which specifies the contents of the South Korea Smart Grid. In August 2009, the Korea Smart Grid Institute (KSGI) was launched to promote the development of the Smart Grid in South Korea. KSGI issued Korea’s Smart Grid Roadmap, which specifies five sectors for implementing the Smart Grid: smart power grid, smart consumer, smart transportation, smart renewable, and smart electricity service [55]. In the first stage (2010–2012), the implementation direction was to construct and operate the Smart Grid test bed in pilot projects. In the second stage (2012–2020), the implementation direction is to expand the Smart Grid into metropolitan areas. In the final stage (2021–2030), the implementation direction is to complete a nationwide intelligent power grid.

In order to ensure smooth implementation of smart grid, the South Korean Government developed several supporting policies. For instance, it supports research, development, and industrialization, propagates successful modes, builds infrastructures, and establishes related policies and regulations. More details are shown in Table 1.1.

In January 2010, the South Korea Ministry of Knowledge Economy (MKE) issued the Korea Smart Grid Development Directions 2030, which predicted a 27.5 trillion
Table 1.1  Policy directions and implementation plans

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<tr>
<th>Policy direction</th>
<th>Implementation plans</th>
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<tr>
<td>Support research, development, and industrialization</td>
<td>Support activities in technology development, standardization, and commercialization, and reward companies and individuals for voluntary participation in the construction of the Smart Grid</td>
</tr>
<tr>
<td>Promote successful modes</td>
<td>Explore successful development modes and share the experience of the Jeju Smart Grid test bed</td>
</tr>
<tr>
<td>Build infrastructure</td>
<td>Make incentive plans for infrastructure constructions</td>
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<tr>
<td>Establish related policies and regulations</td>
<td>Refine and revise the Smart Grid-related laws and regulations</td>
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won investment in Smart Grid, from which 24.8 trillion won would be invested for private sectors [56]. In April 2011, the National Assembly passed the Smart Grid Stimulus Law, which specifies how to develop the Smart Grid and promote infrastructure construction, how to get returns on the investment and tax protection, and how to promote technology research and improve information supervision and security.

Among the pilot Smart Grid projects launched by the South Korea Government, the Jeju Smart Grid test bed is of the most successful. The Jeju Smart Grid test bed was launched in June 2009. The project started from 2009 to 2013, with a total investment of 2.4 trillion won. Its objective is to set up the world largest Smart Grid test bed at the initial stage. The whole project is divided into two phases. In the first phase (December 2009 to May 2011), the Smart Grid demonstration infrastructures were constructed, and the key areas were smart power grid, smart place, and intelligent transportation. In the second phase (June 2011 to May 2013), new Smart Grid services would be integrated with the existing infrastructures, and the key areas were renewable energies, and electricity services.

1.7  Status of China

China has achieved rapid economic growth, and at the same time, the electric demand has also increased dramatically. China has enough coal reserves to cover domestic needs. However, the self-sufficiency in crude oil is lower than 50%, and China is the second largest oil user after the United States. In addition, as the gap in economic development between eastern coastal areas and middle, western China expands, the Chinese Government has launched several projects to transmit the energy resources from the western region to the eastern region, due to the higher demand in the latter. Environmental pollution has already become a severe problem, that is, China is the world’s second largest CO₂ emitting country after the United States.

China has separated the electricity generation and transmission businesses since 2002, in order to introduce competition in the electricity market. As a result, the assets
of the State Electric Power Corporation were divided into 11 companies, including two transmission companies and five generation companies. Among them, the SGCC, the monopoly position in the electricity transmission and distribution market, and is the leading company to develop Smart Grid-related projects and standards.

On 7 June 2010, the Former President Hu Jintao gave a speech at the fifteenth Academician Conference of Chinese Academy of Sciences, in which he pointed out that China should build a smart, highly efficient, and reliable Smart Grid to cover both urban and rural areas. In July 2010, SGCC issued the SGCC Framework and Roadmap for Strong and Smart Grid Standards, which specifies that China would build a world-leading Strong and Smart Grid with Ultra High Voltage (UHV) grid as its backbone. Since 2009, SGCC has launched 228 projects of 21 categories in 26 provinces and cities [57]. The UHV transmission technology has been specified as one of the key technologies in the Outline of the National Long and Medium Term Program for Scientific and Technical Development (2006–2020), which was issued by the State Council. UHV demonstration projects were listed in the Key Projects List Of 2005–2006 National Energy Work Outline. SGCC specified three stages to realize the Strong and Smart Grid [59]:

- **2009–2010 Phase I Pilot Study**: issue technical and operational standards of the Smart Grid, develop technologies and equipment, and perform trial tests.
- **2011–2015 Phase II Construction and Development**: construct UHV urban/rural grids, establish the fundamental framework for Strong and Smart Grid operation control and interoperation, and achieve advancements in Smart Grid technologies and equipment productions.
- **2016–2020 year Phase III Upgrade**: enhance technologies and equipment development for the Strong and Smart Grids.

Furthermore, SGCC is actively involved in the standard development activities. China Electric Power Research Institute (CEPRI), which is a comprehensive research institute and subsidiary of SGCC, has been leading the development of specifications for IEC PC 118 Smart Grid User Interface. The goal of the IEC PC118 is to develop a standard and unified interface for information exchange between the demand-side equipment and/or systems and the Smart Grid. The simultaneous achievement of maintaining a stable power supply and reducing CO₂ emissions is an important issue in China’s energy policy. The Chinese Government has launched numerous demonstration projects to develop the Smart Grid technologies. Among them, the Sino-Singapore Tianjin Eco-city is an international project launched by both China and Singapore Government in 2007. The Sino-Singapore Tianjin Eco-city has a total land area of 30 km², and is expected to be completed in around 2020. The science and technology project is promoted with focus on clean water, ecology, clean environment, green transport, clean energy, green building, and city management [58]. Experts from both countries gathered together and formulated the Key Performance Indicators (KPIs), which are used to guide the planning and development of the
Eco-city. Currently, there are 22 quantitative and four qualitative KPIs. It is expected that the Eco-city will have an estimated 350,000 residents in around 2020.

1.8 Conclusions

This chapter provided an introduction to various Smart Grid-related SDOs, Technical Consortia, Forums, and Panels, Political, Market, Trade, and Regulatory Organizations, Forums, and Alliances. It also provided an overview of the development of the Smart Grid in both developed and developing countries, such as the United States, the European Union, Japan, South Korea, and China. Through the NIST, the United States have been actively involved in promoting open and interoperable standards for the Smart Grid. Other SDOs such as IEEE, IEC, ISO, CEN, CENELEC, and IETF are cooperating closely with NIST to achieve interoperability among Smart Grid-related standards. Crude oil, natural gas, coal, and other natural resources, have a finite supply, and the world might run out of these natural resources in the future. Therefore, the use of renewable energy resources, including solar power, wind power, hydroelectric power, and geothermal power, is required for sustainable development. However, the renewable energy resources have some sort of seasonal and diurnal profile, which has been discussed in more detail in Chapter 9, and might cause the supply of energy to be unstable. Smart Grid technologies should be used to adapt energy production to energy consumption, to lower the total cost of energy production, and to increase the energy use efficiency. Bi-directional communication and information technologies should be integrated with the Smart Grid to enable customers to exchange information with electricity service providers or with each other. It is necessary to standardize all interfaces to ensure interoperability among different Smart Grid systems. It is also required for the Smart Grid to control a lot of energy information while ensuring the security and reliability at the same time. In conclusion, it is important to promote the development of international standards for the Smart Grid as early as possible.

References


An Overview of the Smart Grid


