# Survey of Smart Grid Concepts, Architectures, and Technological Demonstrations Worldwide

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***Abstract*--This paper describes various smart grid concepts, architectures, and details of associated technological demonstrations implemented worldwide. The survey is based on initiatives taken by EU and IEA (e.g. ETP, EEGI, EERA and IEA DSM) and description of projects conducted in Europe and US (e.g. FENIX, ADDRESS, EU-DEEP, ADINE, GridWise and SEESGEN-ICT). The report presents drivers, visions and roadmaps to develop smart grids worldwide including China and India. The survey encompasses various smart grid concepts, i.e. development of virtual power plant, active demand in consumer networks, DER aggregation business, active distribution network, and ICT applications to develop intelligent future grids. The comparison is carried out on the basis of commercial, technological, and regulatory aspects. In addition, the existing features of smart grid technology and challenges faced to implement it in Finnish environment are addressed. As a matter of fact, the implementation of smart grid is consisting of more than any one technology, therefore, this transition will not be so easy. In the end, a fully realized smart grid will be beneficial to all the stakeholders. Smart grid will be an outcome of an evolutionary development of the existing electricity networks towards an optimized and sustainable energy system.**

***Index Terms*--Smart grids, energy efficiency, distributed generation, renewable energy resources, demand response, distribution automation, smart metering, reliability.**

## I. Introduction

THE energy deficiency has been faced in many countries recently that has directly impacted economics, society, development of the country, and environment through greenhouse gas (GHG) emissions. Energy demand is exponentially increasing worldwide and energy saving has become a dire need of the times. The electric transmission and distribution (T&D) systems have continued to operate in the same way since last many decades. The lack of investment for new installations combined with aged network components (older than 40 years) has resulted in inefficient and increasingly unstable electric systems [1].

Climate change, rising fuel costs, outdated grid infrastructure and new generation technologies have changed the mindset of all stakeholders. It has been revealed that electric power causes approximately 25% of global GHG missions. The utilities are concerned about the future of electricity systems; it is hoped that renewable and distributed generation (DG) will play a significant role in reducing GHG emissions. From grid perspective, these new generation modes require improved control and monitoring of existing networks. Taking into account aforementioned challenges, the energy community has started thinking to integrate information and communications technology (ICT) with electricity infrastructure. Demand side management (DSM) seems promising to improve energy efficiency and reduce overall electricity consumption. The real-time monitoring will improve grid reliability and utilization by reducing blackouts. These changes on the demand and supply side may require a new, more intelligent smart grid system that can manage the increasingly complex electric grid efficiently. It will enable utilities to meet regulatory requirements and customer demands for reliable power flow from both conventional and renewable energy sources (RES) [2].

Efficient development and management of such smart grids is considered an important research topic currently in both academia and industry. There is a great deal of variation to what exactly should be included under the umbrella of a smart grid – it is not only the concept of developing smart meters or home automation, rather there is much more to consider. For instance, according to [3]–[6], the smart grid refers to a way of operating the power system using communications, power electronics, and storage technologies to balance production and consumption at all levels. Smart grid may be defined by its capabilities and operational characteristics rather than by the use of any particular technology. The definition of smart grid can also depend on local conditions; different countries can have very different starting points for the progress towards smart grid. Deployment of smart grid technologies will occur over a long period of time, adding successive layers of functionality and capability onto existing equipments and systems. Technology is the key consideration and it can be defined by certain technical characteristics (e.g. predictive, integrated, interactive, optimized, flexible, accessible, reliable, economic, and secure). Broadly speaking, three major components of the smart grids are distributed intelligence, communication technologies, and automated control systems.

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## II. Motivation To Build Future Intelligent Grids

The drivers for change in energy infrastructure are both external (low-carbon future) and internal (aging infrastructure). One of the main external drivers is the European Union (EU) Energy and Climate Package, which has set out targets (of reduction in GHG emissions, addition of RES, and energy savings) for year 2020 and beyond [7]. The existing electric grid is not performing at the same level as it was decades ago. Energy losses in the T&D system have nearly become doubled from 1970 to 2001. Generally speaking, up to 8% of the electric energy leaving a power plant is lost in the T&D network in most of the advanced power systems. Energy efficiency has now come to the force as another key issue. There is considerable security risk in the design of the grid with centralized generation plants serving remotely located loads over long transmission networks. Large scale development of RES, e.g., wind and photovoltaic (PV) power generation has got special attention because they are environmentally friendly. However, integration of RES into existing power network in future may bring many technical challenges associated with power quality (PQ), reliability, and security. The consumers are interested to get more information and better control over their energy usage, e.g. smart metering can allow utility customers to take advantage of time-of-use (ToU) pricing that was formerly available only to large commercial/industrial users. It has becomes apparent that the grid we know today is insufficient to serve in future and we may need an innovative grid to meet the requirements and challenges of the future energy infrastructure.

## III. Initiatives Taken By EU And IEA

The energy challenges that Europe is now facing are changing the electricity generation landscape. More customer-centric networks are the way ahead, but these fundamental changes will impact significantly on network design and control. In this context, following initiatives have been taken:

### *A. European Technology Platform (ETP)*

The ETP SmartGrids was established in 2005 to create a joint vision for the European networks of 2020 and beyond. SmartGrids mission is to create a shared vision which enables Europe's electricity grids to meet the challenges and opportunities of the 21st century to fulfil the expectations of society. SmartGrids is a necessary response to the environmental, social and political demands placed on energy supply. SmartGrids will use revolutionary new technologies, products and services to create a strongly user-centric approach for all customers. The SmartGrids vision is about a bold program of research, development, and demonstration (RD&D) that will reduce peaks in power usage, reduce waste, encourage manufacturers to produce smart appliances to reduce energy use, and sense and prevent power blackouts by isolating disturbances in the grid [8]. Seeking at European level to balance power might be economically efficient. The huge amount of fast-controllable hydro power e.g. in the Nordic countries of Europe could be used as real-time balancing power for those areas in central Europe, where a large part of electricity generation could be provided by non-controllable primary energy. It has been envisaged that distribution networks become more active and share many of the responsibilities of transmission.

### *B. European Electricity Grid Initiative (EEGI)*

The EEGI proposes a nine year European RD&D program initiated by electricity T&D network operators to accelerate innovation and the development of the electricity networks of future in Europe. Its deployment will start progressively over the period from years 2010–30 and result in benefits such as increased hosting capacity for renewable and DG, integration of national networks into market-based networks, increased PQ, active participation of users in markets and energy efficiency, and opening of business opportunities and markets for new players in the smart grids area [9]. The Initiative will also promote solutions that support European standardization and interoperability. The proposed RD&D program focuses on system innovation rather than on technology innovation, addresses the challenge of integrating new technologies under real-life working conditions and validating the results. The focus of EEGI has been on defining the major smart grid functionalities rather than on definition. To meet this goal, a smart grid model has been developed where level 0 covers centralized generation technologies, level 1 covers transmission issues, level 2 covers the issues that are the exclusive responsibilities of the distribution system operators (DSOs), and levels 3 to 5 cover issues that require the involvement of DSOs, grid users connected to the distribution network (as generators and customers) and free market players (as retailers and aggregators).

### *C. European Energy Research Alliance (EERA)*

The objective of EERA joint program is to lower investments in electricity grid by introducing intermittent resources (wind, PV), load management by electric vehicles (EVs), grid stability, and power management. The balance between demand and supply will be obtained by considering market share production options e.g., PV, micro-combined heat and power (CHP), wind, and market share demand options e.g., heat pumps, intelligent appliances, and EVs. Smart grids are also required because the capacity of electricity grid varies throughout Europe as well as there are major differences between countries energy markets [10]. EERA program will investigate the consequences of DG, new types of electric appliances and higher network loads on the grid stability and PQ such as increasing voltage fluctuations, reactive power shortage, frequency instability, and harmonics.

### *D. IEA DSM Task XVII*

The main objective of IEA DSM Task XVII is the integration of DSM, DG, RES, energy storages, and investigating how to achieve a better integration of flexible demand with DG, energy storages, and smart grids [11]. Renewable sources are producing large amounts of variable generation which are not fully forecastable and it may cause increasing problems in electrical networks (both in local T&D networks). One solution is to add energy storages into the systems (centralised or distributed energy storages). Another way is to use flexibility in electricity consumption, e.g. using demand response (DR). In this sense DG, distributed energy storages, and DR can be seen as an integrated distributed energy resources (DER). In future system, a proportion of the electricity generated by large conventional power plants will be displaced by RES and DER.

Three conceptual models can be mentioned as microgrids, active networks supported by ICT, and an internet model; all of which could find applications, depending on geographical constraints and market evolution.

## IV. Various Smart Grid Concepts And Architectures

Many smart grid concepts and architectures have been developed based on the projects initiated in Europe and US. The descriptions of some of the major concepts are given as:

### *A. Development of VPP*

In practice, current policy of connecting DER units is generally based on a so-called 'fit and forget' approach. With large-scale deployment, we are now entering an era where this approach is beginning to adversely impact the deployment rates of DER/RES and increasing the costs of investment and operation of the electric power system as well as having impact on the integrity and security of the system [12].

In order to address these problems, DER units must take over the responsibilities from large conventional power plants and provide the flexibility and controllability necessary to support secure system operation. With integration of DER units, DSOs also need to operate their network actively using local resources. This represents a shift from traditional central control philosophy to a new distributed control paradigm. DER units are too small and too numerous to be visible or manageable on an individual basis. The concept of virtual power plant (VPP) counteracts this problem by aggregating DER units into a portfolio that has similar characteristics to transmission connected generation today. A VPP is a multi-fuel, multi-location and multi-owned power station.

In late 2005, a consortium of 20 different partners from research and industry launched the four-year FENIX (Flexible Electricity Network to Integrate the eXpected energy evolution) research project. The objective of FENIX was to conceptualize, design, and demonstrate a technical architecture and commercial and regulatory framework that would enable DER units to become the solution for the future. To facilitate this solution, the VPP concept was further developed and tested in FENIX project.

### *B. Development of Active Demand in Consumer Networks*

The existing transmission networks are active and distribution networks are behaving passively. The development of active networks by introducing active demand (AD) in consumer networks is a new concept of future smart grids. The ADDRESS (Active Distribution network with full integration of Demand and distributed energy RESourceS) project is an example of this concept. The ADDRESS aims to deliver a comprehensive commercial and technical framework for the development of AD in the smart grids of the future. Specifically, ADDRESS is investigating how to effectively develop the participation of domestic and small commercial consumers in the power system markets and in the provision of services to the different power system participants. In ADDRESS architecture, the aggregators are a central concept. The aggregators are the key mediators between the consumers, the markets, and the other participants. The aggregators collect the requests and signals for AD-based services coming from the markets and the different participants. They gather the flexibilities and the contributions provided by consumers to form AD-based services and they offer them to the different power system participants through various markets [13], [14]. At the consumer level, the energy box is the interface between the consumer and an aggregator. It is located at the consumer side and it consists of hardware and software (with a certain level of intelligence) [15].

The DSOs play an important role because AD concerns consumers connected to distribution networks. DSOs still continue to ensure secure and efficient network operations. They do so mainly through interactions with the other power system participants and, in particular, with aggregators via markets. Also, they maintain direct interactions with TSOs to ensure secure network operation. The markets consist of all kinds of commercial agreements between power system participants (such as bilateral contracts, forward markets, real-time markets and power exchanges).

### *C. Developing DER Aggregation Business*

Aggregation is the process of linking small groups of industrial, commercial, or residential customers into a larger power unit to make them visible from the electric system point of view. Aggregation can involve DR and/or DG. Thus, load or generation profiles of individual consumers and/or small generators appear as a single unit to the electric system. Building up a large and flexible portfolio enables aggregators to operate DER and to provide services to the power system, e.g. system balancing. Aggregation helps implementing smart grids concepts by reaping some of its benefits to integrate DER units more efficiently. It is by combining these features (more flexibility, lower operating costs) that aggregation will reduce the gap to profitability of DER units [16].

The main goal of EU-DEEP (The birth of EUropean Distributed EnErgy Partnership) project was to design, develop, and validate an innovative methodology, based on future energy market requirements, and able to produce innovative business solutions for enhanced DER deployment in Europe by the year 2010. The project objectives were therefore to address the removal of the barriers by providing solutions based on a demand-pull approach like, innovative business options to favor DER integration, equipment and electric system specifications to connect safely more DER units to existing grids.

EU-DEEP investigated three business models to exploit different types of value possibly unveiled when aggregating DG and/or individual loads within the given energy and regulation context. Business model I described aggregating commercial and industrial DR to balance intermittent generation, business model II described integrating residential scale flexible micro-CHP into electricity markets, and business model III explained leveraging on the flexibility of aggregated CHP units and DR to extend the conventional energy service company business.

### *D. Developing Active Distribution Network*

The traditional passive network management or "fit and forget" principle in DG connection needs to be changed into active network management (ANM). DG provides a good potential as a controllable resource for the active networks. Other existing controllable resources are direct load control, reactive power compensation, and DSM. ANM method adds value by increasing the potential for renewable energy, by improving efficient utilization of distribution network assets and by supporting distribution network by ancillary services from customer- owned resources [17].

ADINE (Active DIstribution NEtwork) project developed new methods for the electric distribution network management including DER. To make ANM possible, a set of technical solutions are developed and demonstrated in real-life environment. The distribution network management concept of ADINE project is based on existing systems like supervisory control and data acquisition (SCADA), distribution management system (DMS), substation and distribution automation, and advanced metering infrastructure (AMI). The ANM concept includes local voltage, PQ, frequency control, load shedding, and production curtailment features at decentralized control system level. Many new features are also added for the area control level like coordinated voltage control, power flow, fault location schemes, automatic network restoration, and island operation. According to ANM concept, all hardware devices (e.g. protection relays, regulators and controllers) are working in decentralized way. On the top of the decentralized control system, there also exists a centralized system for distribution network management.

### *E. ICT Applications to Develop Intelligent Grid*

Energy efficiency, demand side control, and RES are considered as some of the effective solutions to counteract climate change effects. The reorganization of distribution network is necessary to implement envisaged solutions. This renovation has already begun and distribution systems are moving towards smart DG grids. The operation of smart grid is complex and it requires novel ICT-based applications for real-time process control and communications, adaptive protection, and portfolio management.

The focus of IntelliGrid program is on the communications and information infrastructure that will become the foundation of many smart grid applications including security of this infrastructure. When this enabling infrastructure is matched with smart grid applications in transmission, distribution, or at a customer interface, then the resulting smart grid can reach significant gains in reliability, capacity, and DR. The main objective of this program as to achieve power delivery system of the future by integrating two infrastructures, i.e., electrical and intelligence infrastructures [18]–[20].

The purpose of the Olympic Peninsula project was to create and observe a futuristic energy-pricing experiment that illustrates several values of grid transformation that align with the GridWise concept. The stem of the GridWise concept is that inserting intelligence into electric-grid components at the end-use, distribution, transmission, and generation levels will significantly improve both the electrical and economic efficiencies. This project tested whether automated two-way communication between the grid and distributed resources will enable resources to be dispatched based on the energy and demand price signals that they receive. The project tested possibility to decrease the stress on the distribution system at times of peak demand by more actively engaging typically passive resources-end user loads and idle DG [21].

The main objectives of SEESGEN-ICT (Supporting Energy Efficiency in Smart GEneration grids through ICT) consist in producing a harmonized set of priorities to accelerate introduction of ICT into smart DG grids, investigating requirements, barriers, and proposing solutions. The project will produce policy recommendations, identify best practices, and draw scenarios and roadmaps for the next generation distribution network. ICT applications have been implemented for multiple purposes in this project e.g. for management of smart grids with DER, energy efficiency monitoring in smart grids, demand side integration, business models management and for environmental protection in smart grids [22].

## V. Smart Grid Visions, Roadmaps, And Developments

Most of the technologies required to create a smart grid are available today. Utility companies looking forward for business enhancement are already offering DR technologies. Many utility companies are also implementing large numbers of smart meters to offer variable pricing to consumers and to reduce manual meter-reading costs [1]. Major building automation companies have smart building solutions that integrate their various heating, ventilation, and air-conditioning systems. Many public and private organizations have implemented energy-consumption dashboards which are custom-designed or provided by small software integrators. However, so far, nobody has been able to define an industry architecture that spans the entire smart grid from high voltage (HV) transformers to the wall sockets in homes and offices.

### *A. Smart Grid Development in US*

Electric Power Research Institute (EPRI) has estimated the market for smart grid-related projects in the United States of America (US) to be around $13 billion per year over the next 20 years. That comes in addition to an estimated $20 billion per year spent on T&D projects generally. The US is home to several consortia working on smart grid issues. EPRI's IntelliGrid program and department of energy (DoE's) GridWise Alliance are just two examples. Likewise, the nation's utilities are actively involved with approximately 80% of investor-owned utilities developing some form of smart grid, e.g. by participating in pilot studies of wide area monitoring systems (WAMS).

A recent Pacific Northwest National Laboratory (PNNL) study provided homeowners with smart grid technologies to monitor and adjust the energy consumption at their homes. The average household reduced its annual electric bill by 10%. This could save up to $200 billion in capital expenditures on new plant and grid investments and take the equivalent of 30 million autos off the road [1], [23].

### *B. Smart Grid Development in China*

Electricity consumption in China has been growing at an unprecedented rate since the year 2004 due to the rapid growth of industrial sectors. In addition to increase generation capacity, it is equally important to improve distribution networks and utilization. In the last few years, the country has focused to expand T&D capacity and reduce line losses by uplifting transmission voltage and installing high efficiency distribution transformers.

In parallel to economic growth aspect, the environmental problems associated with heavy industries are well known. China's heavy industrial sector is one of the biggest sources of $CO_2$ and $SO_2$ in the world [24]. The problem is further aggravated by the fact that generation resources and load centers in the country are located far apart; majority of hydropower resources are located in west, coal in northwest, but huge loadings are prevailing in east and south. It has been estimated that 100–200 GW transmission capacity will be required to deliver electricity over long distance from west to east and from north to south in coming 15 years. The existing grid structure in China (primarily based on 500 kV AC and ±500 kV DC backbones) is not sufficient to meet the existing demand [25]. Furthermore, overall T&D loss consideration is also critical [26]. The government has approved a number of transmission line construction projects using UHVAC (refers to 1,000 kV) and UHVDC (refers to ±800 kV) technologies [26], [27]. It has been revealed that the losses due to distribution transformer can be over 40% of the total T&D losses in a typical modern grid, or about 3% of the total electricity generated [28], [29]. In a general sense, efficient distribution transformers can reduce the transformer no-load losses by about 70% with respect to conventional transformer [30]. The Jiangsu experiment has successfully verified the technology performance of amorphous metals distribution transformers [31].

After US's Unified Smart Grid and Europe's SuperSmart Grid, China has also announced the Strengthened Smart Grid plan in May 2009. At present in China, the smart grid is focusing more on the transmission networks rather than the distribution networks. According to State Grid Corporation of China, smart grid plan in China can be divided into three stages, i.e., planning and testing (2009-10), construction and development (2011-15) and upgrading (2016-20) [32], [33].

### *C. Smart Grid Development in India*

According to statistics given by ministry of power, the T&D losses are among the highest in the world, averaging 26% of total electricity production. When non-technical losses such as energy theft are included in the total, average losses are as high as 50%. The financial loss has been estimated at 1.5% of the national gross domestic product (GDP) and is growing steadily. As India keeps one of the weakest electric grids in the world, the opportunities for building smart grids are high. India's grid is in need of major improvements because of variety of system failures, e.g., poorly planned distribution networks, overloading of system components, lack of reactive power support and regulation services, low metering efficiency and bill collection, and power theft. Recently, discussion has been raised that using DSM to selectively curtail electricity use for delinquent customers while improving PQ for consistently paying customers. It might not sound like a desirable program to most American utilities, however, it may make sense in India's constrained power grid where high levels of delinquency have increased system load without revenue returns. Another motivation to build smart grid is its trend towards energy efficiency and increased use of renewables. India would greatly benefit from intelligent energy efficiency in the form of DR and grid-responsive appliances. [34].

## VI. Comparison Of Smart Grid Concepts Based On Geographical Locations

The definition of smart grid is global; however, from the operation and control perspective, smart grid technologies are varying from country to country. Taking US into consideration, while the user-end discussions are comprehensive, analysis about transmission is relatively light. US system is more mature and the design orientation focuses more heavily on users and services integration (metering, renewables, electric transportation, etc.). On the other hand, the end-users and distribution networks in China are not as mature as most developed countries, and the penetration rate of small-scale renewables are relatively low at the moment. It is expected that initial stages of the Chinese smart grid plan will focus on the ability of controlling bulk electricity transfer efficiently, and then moves towards end-users and services integration in the next stages when the users are becoming more ready. As a matter of fact, Europe is relatively deficient in traditional fossil energy resources and therefore has high reliance on import. When political conflicts or instabilities arise from time to time, energy supply in Europe could be seriously disturbed. In order to reduce the risk, Europe has a specific need to develop complementary energy supply. This partially explains why Europe has been running ahead of the world in terms of renewable energy deployment.

It is interesting and worthy to note that visions of the smart grids in Europe and China have many similarities, e.g., a large capacity, highly interconnected backbone as reliable carrier, added on with decentralized interactive blocks that could conveniently serve users. However, due to differences in historical developments, the sequence of deployment is varying. As a matter of fact, Europe has already installed with large capacity of renewable generation today, whereas China is starting off with both UHVAC and UHVDC. Nevertheless, differences are there, it is clear that there are many areas of common interest [32]. The Indian national grid was not designed for high capacity, long-distance power transfer as is the case in the rest of the world. India needs to interconnect regional grids as has already been practiced in US.

## VII. Smart Grid Technology And Associated Challenges In Finland

Developing the energy infrastructure towards smart grids is a longer term national objective, with smart meter rollout being one of the first steps. Considerable amounts of both public and private funding are allocated to smart grids research and development. Energy security improvement through energy efficiency is an acknowledged goal, but generally the discussion and policy measures on energy security seem to be more emphasized in the production side issues, i.e. nuclear power and renewables. Utility companies are already implementing smart devices in various ways. Smart meters allow utility customers to participate in ToU pricing programs and have greater control over their energy usage and costs (smart metering regulation in Finland only covers electricity so far and new electricity market act has come into effect which requires all over 3x63 A connection points must have remotely readable hourly metering by 2011).

Different surveys have been conducted to estimate the readiness of the industry and energy consumers for the smart grids [35]. One-half of the utilities surveyed in the recent Pacific Crest Mosaic smart grid survey named cost as the strongest barrier to smart grid projects within their organization. Selecting an appropriate communication technology is centered on three groups of competing technologies. The first group is the current set of technologies (RF, PLC and broadband) that are constantly improving in terms of bandwidth, latency and internet protocol (IP) capabilities. The second group is the advanced communication technologies (3G, GPRS and WiMax). The future of these technologies is a highly debated issue. However, the GPRS standard is favored in Nordic countries. The third group of technologies focuses on customer interaction and service provision through an existing internet connection, i.e. provision of home area network (HAN) [36].

The regulatory push is strong for smart metering in Finland and its impact will be high in the year 2014 when smart meters are required to be installed at all end-users. While the technology side seems to be growing because of the regulation, the service side is still ambiguous from the technical, market model and regulation point of view. The huge amount of metering data coming from end-users (now stored by DSOs) will be available to all relevant actors who can make end-user services (and energy savings) with it. In recent years, there have been a few automated meter reading (AMR) solution providers, mostly to industry, commercial and service sectors and now some ready service applications have emerged also to the consumer sector. Rather than in-home displays, the Finnish AMR and smart metering end-user services are more leaning towards web-based applications [36].

Some automation functions can already be introduced to current distribution grids without significant changes, e.g. fault diagnosis, fault location, and service restoration. However, there is dire need to develop new automation functions e.g. distribution state estimation, voltage and reactive power control, and network reconfiguration for improving hosting capacity of DG and its efficient control [37], [38]. In order to take massive penetration into current grids, energy storage technologies must become cheaper. There are about 500 DSOs in Nordic countries, out of which the larger DSOs are supplying about 50% of the customers. It might be a bit challenging for small DSOs to handle smart grid issues and implementing new technology, especially due to the complexity of rules and regulation of the present electricity market. To overcome the future risk concerning small DSOs attitudes, the national energy /electricity associations should have to play a very important role.

## VIII. Conclusions

Smart grid is a new idea for electricity networks across the Europe. The major objectives of smart power networks are to increase the efficiency and to maintain safety and reliability of the European electricity networks by transforming the current electricity grids into an interactive (customers/operators) service network and to remove the technical obstacles to the large-scale installation and fully integration of RES. As Smart grid ideas are promoting quickly, manufactures must become more comfortable with taking risks and applying their technologies to new applications. Rather than wait for the perfect ICT solution or comprehensive standard to be developed, companies should expedite taking their solutions to market for testing and vetting.

Europe and China should work closely together to synergize from the knowledge and experiences in HV or UHV transmission, technological breakthrough, and economy of scale could be achieved much faster. The recent movements towards sustainable energy systems in Europe, China, and US are opening up a new horizon for energy conservation and climate change mitigation. Nevertheless, the extensive international cooperation is mandatory in order to make this bold evolution successful.

It is worthy to note that network operator business is traditionally conservative. The technology needs to be mature enough when taken into use. Taking incompletely matured smart grid technologies to use and resulting in PQ problems or major blackouts would mean a step backwards for smart grid deployment. The network companies are responsible for their network and customers and they would like to see tested and piloted solutions before they are willing to take new techniques to their network.

The implementation of smart grid is consisting of more than any one technology and the benefits of making it a reality extend far beyond the power system area itself. As a matter of fact, this transition will not be so easy and quick. Realizing smart grids' potential will require a new level of cooperation between industry players, advocacy groups, the public and especially the regulatory bodies that have such immediate influence over the direction the process will take. Smart grid is an evolution towards an optimized and sustainable energy system which is more intelligent, efficient and reliable and it has positive influence on the climate change.

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## X. Biographies

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