Smart Grids Research

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***Abstract*—Smart grids have been used to denote many technical operations. This technology is used to monitor and analyze electrical networks. The Smart Grid with certain modifications can be useful for solving various tasks. It is used to establish communication between various energy sources, to connect these energy sources to the power grids and to bring energy to consumers, combining the possibility of calculating the cost of production and its distribution in all countries of the world.**

***Keywords*— Distributed generation sources, renewable energy, Smart Meters, Smart Grid.**

I. INTRODUCTION

Smart Grid is a system of electricity transmission from the producer to the consumer, which monitors and distributes electricity flows to achieve the highest energy efficiency. Using modern information and communication technologies, smart networks have interacted all the equipment, the result is a single intelligent power supply system [1]. Network analyzes the information got from the equipment, and the results help to optimize energy consumption, reduce costs, and improve the reliability and efficiency of power systems. The word Smart Grid was applied by Massoud Amini and Bruce Vollenberg in the publication "To the Intelligent Network" back in 1998. They used it in the marketing names of specialized controllers, which should control the operation and synchronize independent wind turbines with the electrical network. Using Smart networks allows not only to reduce losses but also to more use the energy, to integrate and distribute energy from alternative sources [2].

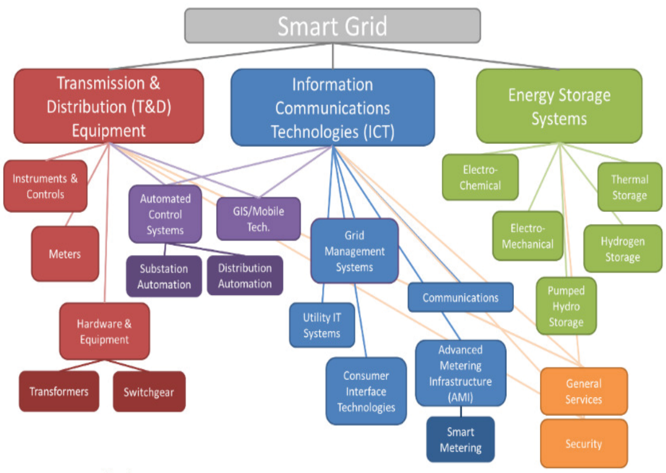

Fig. 1. Smart Grid Industry Taxonomy [3]

In the automatic mode, you can diagnose and fix problems that arise, supply electricity in the required amount, reduce energy costs, and reduce carbon dioxide emissions. Renewable energy sources transform centralized systems into a distributed system. Intelligent power management systems are a promising direction for energy development. This system comprising traditional energy sources of renewable energy sources. Optimization of the combined work of various energy sources, increasing energy efficiency and reliability of the system is an important issue in the modern energetic industry. Some innovative properties characterize Smart Grid technology [4]:

1. Active bidirectional model of interaction in real-time information exchange between all elements and participants of the network, from power generators to end devices of electrical consumers.
2. Coverage of the technological chain of the electric power system from energy producers (both main and independent) and electric distribution networks to final consumers
3. Ensuring an almost permanent controlled equilibrium between the demand and supply of electrical energy. Therefore, network elements should interact with each other with data on the parameters of electrical energy, consumption and generation modes, the amount of energy consumed and planned consumption, commercial information.
4. Smart Grid can defend itself and recover from major disruptions, natural disasters, and external factors.

II. SMART GRID IN EUROPE

Evolution of new generation networks began in Europe to include numerous renewable energy sources in the network because these countries have limited fuel resources. Since the use of solar and wind installations do not allow getting stable power, because weather influences their work, therefore it is necessary to use an intelligent system that performs the distribute energy between multiple sources and many consumers. In addition, a promising direction for solving the problems associated with generation is the use of accumulation equipment [5].

Over 540 research projects are being implemented in Europe. Moreover, the total number of projects in this direction is 950, they are implemented in 50 countries. The total budget is 360,413 million € [6].

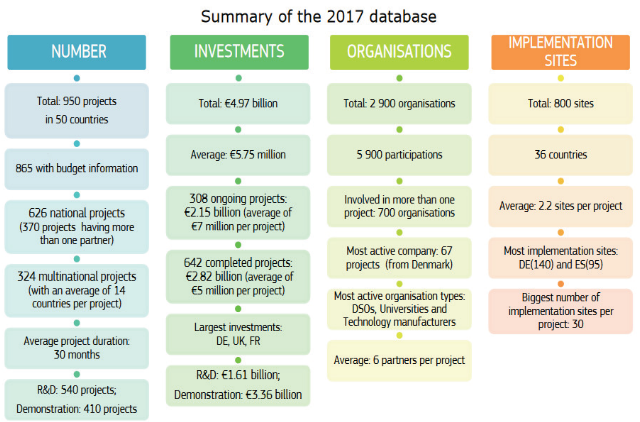

Fig. 2. Summary of the database of 2017 on implemented projects, allocated investments. [6]

As one of the most successful can be a result of the project in Denmark on the Jutland peninsula. In this area, there were a few electricity consumers, 12 electrical substations, 47 wind power plants, and 5 cogeneration plants, which combine into a virtual power plant. The introduction of Smart Grid elements in the region allowed us to ensure not only work in the offgrid mode, but also to export electricity to neighboring areas

III. SMART GRID IN USA

In the US, The Smart grid is an automated system that combines the power capacities of the entire country. The US government approved a program of development Smart Grid American Recovery and Reinvestment Act of 2009 in 2009 [7]. Energy companies will implement over 407 projects worth about \$338–476 billion in 44 states. It will allocate \$7 billion to pilot projects. We assume the distribution of investment [8]:

1. Modernization of power plants and power lines by 19-24%
2. Development of retail chains 69-71%
3. Client System 7-10%

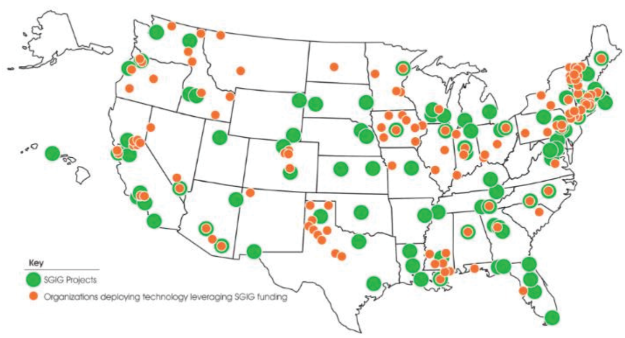

Fig. 3. Map with projects in the USA [7]

One of the first pilot projects implemented in the city of Boulder, USA, Colorado. US government chose this city because it has a suitable infrastructure, a convenient geographical position; the population is 50 thousand people, most of whom are users of web resources [9]. To carry out the experiment, key components were chosen, such as a real-time high-speed two-way communication system, automated substations, sensors, distributed generation sources, and household power management devices. The project cost is 44.5 million dollars [10]. As a result, the project brought a workable system, but the specialists the population did not teach the population how to work with the new equipment.

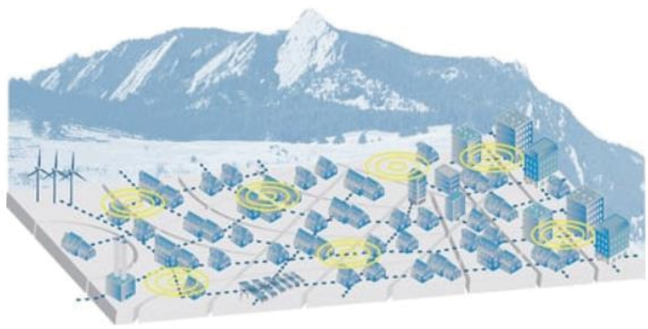

Fig. 4. Smart Grid City Boulder [11]

As a result, many residents did not know about all the capabilities of the equipment installed in their homes and did not use it, which reduced the result.

IV. SMART GRID IN JAPAN

The uniqueness of the Japanese power grid is that it comprises two separate networks operating at different frequencies and interconnected by three stations on which have current transducers. Eastern network has German equipment, and it operates at a frequency of 50 Hertz, while the western one uses American equipment and operates at a frequency of 60 Hertz. Japan power grid covers 10 zones; zones are served by one company, which is a monopolist in this territory. Smart grid technology in Japan is evolving because [12]:

1. There exists a large amount of solar energy;
2. Large consumers stimulate energy savings;
3. Power companies develop the power grid.

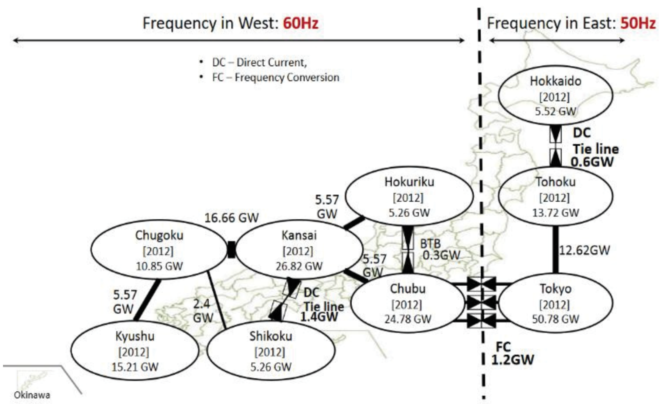

Fig. 5. Transmission system of Japan [13]

Japan is one of the leaders in investment in Smart Grid technology. Japan invest more than a billion dollars in its development. The first practical experiment was in the city of Yokohama. In this experiment, the new Smart Grid unites the power systems of several large buildings. They installed to combine electricity from a common network and distributed sources to support an optimal level of energy consumption by enterprises, small generators, and batteries [14].

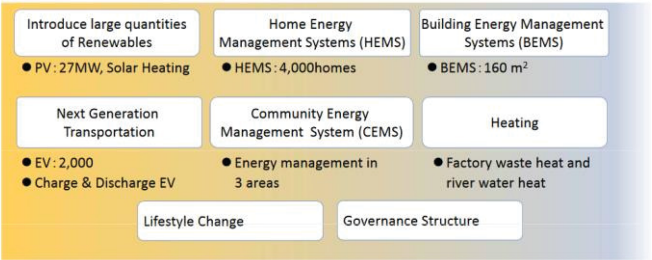

Fig. 6. Data of project Smart Grid city of Yokohama [14]

Near the factories. Some houses installed equipment based on the principle of energy saving with the use of an optimal energy efficient lighting, heating, and air conditioning system. In addition, they installed solar energy-generating systems, batteries, which were the basis of "smart" power supplies.

V. Smart Grid in China

Smart grid technology has been introduced in China since the 19th 90s. The main stop has done on power electronics and digital intelligent substations. The main objectives to introduce new technologies of reliability and security [15].

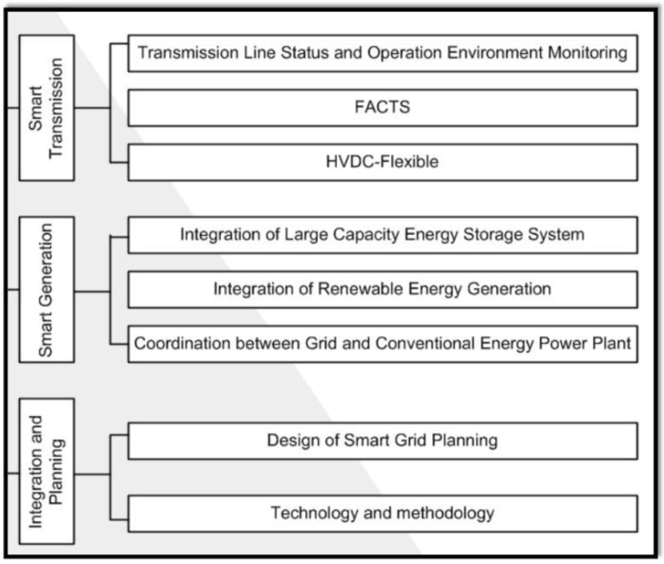

Fig. 7. The main objectives of SGCC's Smart Grid Strategy [16]

In China, thermal power plants produce the most electrical energy. To reduce carbon dioxide emissions, clean energy is being increased, including water, nuclear, wind and solar sources. The increase in the number of stations that are not used fossil fuels is happening. It is necessary to introduce an effective system that will allow the use of distributed sources in the overall energy system. The main problem is that the most powerful stations situated off the east coast, which is the most populated. Government prompted to design and construct three main electron transmission lines, each of which the 2020 year should transmit 20 gigawatts transmit power. The main goal is to create a system of wide integration of renewable energy sources [16].

VI. Smart Grid in Canada

Canada is the world leader in the development of intelligent networks. Alberta and Ontario are planning many billions of investments to upgrade distribution networks. The total capacity for the production of electricity in Canada is 133 GW, the hydroelectric power plant produces about 77 GW. Renewable resources generate about 5 GW. In the next 10-15 years, energy companies are planning to upgrade 80% of generating capacity. According to Natural Resources Canada, investment in intelligent networks in the country will increase from $ 520 million in 2011 to $ 2.1 billion in 2020, there are currently 72 projects, and their number will increase [17].

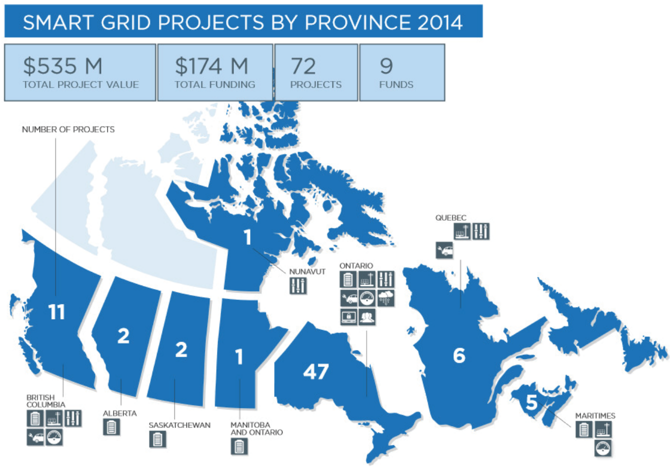

Fig. 8. Map with projects in Canada [17]

VII. Progress

There are positive implementations of local projects of lighting systems, electricity metering, and the use of distributed energy sources. Using smart meters makes it possible to increase the accuracy of settlements with the public and reduce the possibility of electricity theft, introducing automation systems has reduced the time of power failure [18].

VIII. Problems

The common challenges of implementing a smart system. Energy sector needs fundamental changes since there are difficulties in integrating equipment from different manufacturers into a single system. The main problem of renewable energy sources is the difficulty of predicting the quantity of electricity. Significant investment costs for infrastructure. Consumers need to be explained the possibility of reducing cash costs when upgrading equipment [19].

The main problems of implementation technology Smart Grid in the world are [20]:

1. Huge financial investments in Smart Grid;
2. A significant number of consumers with different conditions for the quality of electrical energy;
3. Lack of reliable energy storage devices;
4. Lack of standards and regulations;
5. The lack of motivation among monopolists of the market, because their profits depend on the volume of electricity sold, and introducing new technologies, it can reduce revenues.

IX. Conclusion

The most active technologies of Smart Grid are used in Europe, China, USA, and Japan. Many projects are being implemented. Not all results of implemented projects are positive. Nevertheless, we can use even negative results in further research. To identify and eliminate weaknesses. To create an intelligent network, you must use numerous new technologies. The widespread lack of communication technologies and smart metering systems is the most important now. These technologies are the basis for the next stage of replacing old networks with new ones. To introduce technology Smart grid had a successful implementation, we must implement the following conditions [20]:

1. Government support and control of investments in this area;
2. Development of the regulatory framework;
3. An explanation for the final consumers of their rights and opportunities.

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