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Review paper

Belt and Road Initiative with Global Energy Interconnection*

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Abstract: Belt and road initiative delivers an idea for Global Energy Interconnection (GEI) as globally interconnected strong and smart grid based on Ultra-High Voltage (UHV). Global Energy Interconnection is an infrastructure platform that can be used for clean energy production, transition and consumption worldwide. GEI facilitate efforts to meet global power demand with clean and green alternatives as low carbon energy. GEI is promoting integration of energy, information and transportation networks, enlarging global power trade, ensuring universal electricity service. GEI optimizes resource allocation and utilization by converting various energy sources including coal, oil, hydro, wind and solar into electricity and transmitting over long distance. It can achieve mutual support and free trade of clean energy from different regions, and maximize energy efficiency and economy by taking advantages of time-zone, seasonal and price difference. Actually, Global Energy Interconnection is a system that consist of "Smart Grid", "UHV Grid" and "Clean Energy". Smart Grid integrates modern smart technologies with respect to advanced power transmission, smart control, new energy integration and new energy storage. UHV Grid is mainly composed of 1000 kV (and above) AC and +-800 kV (and above) DC transmission lines, featuring long transmission distance, large capacity, high efficiency, low line loss, less land use and high security. The shaping up of GEI can be divided into three phase: domestic, intra-continental and intercontinental interconnection. UHV Grid result is visible in already tested in practice transmission lines of DC and AC voltage. Over 20 UHV networks have been built in China. There is one network longer than 2000 km in Brazil, and two networks of UHV in India.

Keywords: Belt and road initiative, Ultra-high voltage grid, Energy interconnection, Renewable energy resources.

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1. Introduction

Environmental issues, climate change, energy supply for sustainable socioeconomic development and other issues are currently faced by the international community affect, directly or indirectly, human's survival and development. The demand for energy transition is a challenge of the aforesaid issues.

In 2016, traditional energy and economy were severely impacted: fossil energy faced with resource depletion and price downturn; investment in the energy industry slowed down and grew sluggishly; energy trade protection and "anti-globalization" were intensified; climate change and environmental problems caused by the use of fossil energy worsened. The energy system dominated by fossil energy and the demand for socioeconomic development became acute. In this context, it is hard to continue the old energy structure.

Chinese President Xi Jinping proposed the initiative on establishing a Global Energy Interconnection (GEI), to facilitate efforts to meet global power demand with clean and green alternatives at the United Nations Sustainable Development Summit on September 26th, 2015. As a remarkable innovation in the traditional concept of energy development, this proposal indicates that the essence of establishing GEI is to build energy community which is characterized by green and low carbon energy, connectivity, co-construction and sharing. Suggested is a new blueprint for the global green and low-carbon energy development, which will break new grounds for combating climate change. This has been widely acknowledged and positively responded by the international community.

With the execution of the Paris Agreement, concepts including cleanness, low-carbon and international cooperation and development have taken root in people's mind, and GEI has been widely recognized by the international community. In March 2016, the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) was founded with 80 members from 14 countries scattering across the five continents, marking the beginning of GEI from a new prospect of discussion, construction, sharing and win-win globally.

The vision of GEI is to create a globally connected ultra-high voltage smart grid as the backbone of the transportation system. Such a system can serve as a platform for the extensive development, deployment and use of clean energy. It is based on the principle of accelerating the energy transition from fossil fuels to renewable energy sources. The paper gives an overview of electricity consumption in the world, explains the concept of global energy connectivity. The completed projects and the results they have achieved are presented.

2. Materials and methods – electricity in the world and conditions of global interconnections

Providing an affordable and stable price for energy supply and the need for energy itself to be sustainable and to reduce the negative impact on climate change is a fundamental goal of economic progress. Its fulfillment requires large investments in new energy infrastructure and technology, as well as the upgrade of existing energy supply systems. Global Energy Interconnection (GEI) is a globally interconnected robust and smart grid which takes Ultra-high voltage grid as its backbone. It serves as a global platform for extensive development, delivery and utilization of clean energy. In essence, GEI is "Smart Grid + UHV Grid + Clean Energy". Smart grid is the foundation, UHV grid is the key, and clean energy is the priority. Establishing GEI and implementing it could build a new energy structure dominated by clean energy, centered on electricity and allocated globally, realize global energy transition from fossil energy dominating to clean energy dominating.

Renewable energy sources are largely limited by time and space. The largest sources of wind and solar energy are often located far from the centers of their demand (e.g., wind energy in northern China or solar energy in the southwestern United States). Technological advances in the use of wind and solar energy allow their power plants to be built in hard-to-reach areas (for example, in deep seas, deserts, high altitudes), so it is necessary to enable the successful transfer of that energy to the place of use. The construction of hydropower plants, as today's largest sources of clean energy, is limited by the geographical location of suitable natural resources, and the same applies to less used renewable energy sources such as geothermal, wave or tidal wave energy. In order to meet the demand for electricity in larger areas, it is necessary to interconnect energy systems. To increase the overall efficiency of the energy system, it is desirable to keep energy consumption constant. For example, linking the winter energy consumption of one region with the summer consumption of another region can lead to a reduction in the peak network load. The same effect would occur in networked regions in different time zones. Such an idea of global energy interconnection was first presented by the Chinese State Grid Corporation of China [1].

The concept of global energy interconnection is built on three principles [2]:

1) transmission of energy over long distances, which requires ultra-high voltage technology,

2) distribution of large-scale clean energy, especially renewable energy sources, together with a high level of electrification,

3) smart grid solutions that enable intelligent use of monitoring and control at all voltage levels.

3. Results and discussion – Ultra-high voltage and smart grid

The first studies on the feasibility of ultra-high AC voltage were initiated as early as 1986 [3]. In the period from 1990 to 1995, the first demonstrations of the method of long-distance energy transmission and voltage classes were carried out. China has achieved several results in a study of ultra-high voltage AC transmission by 2006. The key problems related to the construction of the demonstration project of ultra-high voltage were solved and the basic characteristics of ultra-high voltage transmission of alternating current and network were better understood. Preliminary results were obtained for key technologies such as the limit value of the ultrahigh voltage electromagnetic environment, surge level, reactive configuration, insulation coordination and lightning protection. These parameters were the basis of the feasibility study on ultra-high voltage energy transmission and provided a large amount of reliable and accurate data for making the first designs. There are more and more ultra-high voltage AC and DC power transmission projects in the world. China is currently the first country in the world in the number of such projects. The project of developing a system for transmission of ultra-high voltage direct current (± 1100 kV) on the route Zhungdong - Wannan was completed in 2019. In 2020, this network has the highest voltage in the world, the largest transport capacity and the largest energy transmission distance (3324 km) [3]. China has become a pioneer in the development of ultra-high voltage power transmission for direct and alternating current due to large investments in the development of technology and construction of ultra-high voltage network. By 2016, it had contributed to the introduction of 33 national standards and as many as 41 industry standards.

Ultra-high voltage in China

By the end of 2017, China has totally 22 UHV transmission projects in total. 13 lines under operation, developed by State Grid Corporation of China (SGCC) (6 AC and 7 DC). In addition, there are 9 lines (2 AC and 7 DC) under construction (Figure 1). Developing clean energy based on large power grid, SGCC may expect an integration capacity of 220 GW clean energy and become the grid that enjoys the largest wind integration scale and the fastest solar power generation growth.

Fig. 1 - *UHV grid projects in China [4].*

Over 20 ultra-high voltage networks have been built in China by the end of 2019. Five more networks are currently under construction, three for alternating current and two for direct current. This development of power grid construction largely allows the use of large amounts of renewable hydropower from the *Yalong*, *Yangtze* and *Mekong rivers*, wind energy from *Zhundong* and *Jiuquan* cities and solar energy from *Hami* city. The State Grid Corporation of China expects further development of clean energy based on a large electricity grid, whose capacity is planned to expand to 220 GW [4].

Ultra-high voltage in Brazil

The first phase of construction of a project called *Belo Monte* was signed in January 2016 in Brazil. This marked the beginning of the construction of a transmission line for the transport of energy with an ultra-high voltage of ± 800 kV. In the first phase of the project, 2,084 kilometers of transmission lines, one *Xingu* converter station (capacity 4 GVA) and one *Instanredu* converter station (capacity 3.85 GVA) were built (Figure 2).

The second phase of the project is the construction of a transmission line on the route *Xingu - Rio*, the distance of which should be 2518 km. These two ultra-high voltage lines should be used to transport the energy obtained from the *Belo Monte* hydropower plant. This hydropower plant is the fourth largest in the world with an installed capacity of 11.3 GW and should supply energy to the south of Brazil [4].

Fig. 2 - *Belo Monte ±800 kV UHVDC Transmission Project [5].*

Ultra-high voltage in India

The Indian Power Grid Corporation of India (State Electricity Corporation) is in the implementation phase of the construction of a transmission line for the transport of ultra-high voltage ± 800 kV. The goal is to connect the cities of *Assam* in northeastern India and *Agra* in northern

India. It is 1728 km long, and its transmission capacity is 6 GW. The first phase was completed on August 2015, which connects *Agra* Convertor Station and *Biswanath Chariali* convertor Station, creating a transmission capacity of 1.5 GW. Since 2016, the second convertor station at the transmission side, *Alipurduar*, started to be built, which will operate with three AC terminals that integrate two rectifier stations and one inverter station (Figure 3). When completed, the project may become the first UHV MTDC project in the world, delivering surplus electricity in eight northeastern states to the northern region which is short of power and playing an important role in transmitting potential hydropower in the northeastern region.

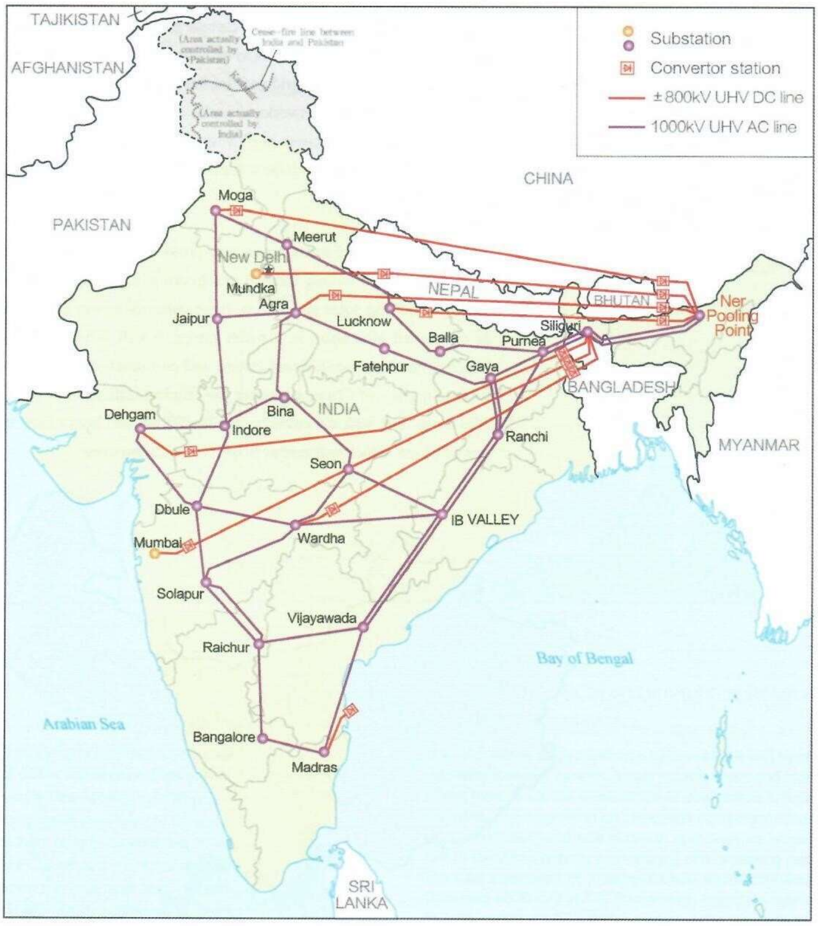

Fig. 3 - *UHV projects in India [4].*

3.1. Clean energy

Renewable energy resources are inexhaustible and have great development potential. The energy revolution with water, wind and solar energy should become a driver of economic and technological development in the world, especially if the goals set by the Paris Agreement on Climate Change are to be achieved. The global installed capacity of renewable energy sources is estimated at 2400 GW. Due to high safety risks and potential environmental pollution by nuclear waste, it is very likely that the share of nuclear energy will decrease in the future. Solar energy has the largest increase in capacity with an annual increase of as much as 30% [4]. Investments in renewable energy sources are currently leading the economic development of the countries that invest in them. This trend is shifting from developed economies in Europe and North America to developing economies such as China and India. Clean energy investment projects are capital intensive and take longer to return to investment. Nevertheless, the concept of clean low-carbon development, good market mechanisms and strong infrastructure in Europe and North America are a strong factor for continued investment.

With the development of technology in the world and the reduction of prices, Asian countries are expected to be leaders in the future development of clean energy. This is seen by the rapid increase in the share of world investment. The cost of generating electricity from solar or wind power plants is declining worldwide due to technological advances. The price of an onshore wind farm decreased by 18% in the first half of 2016. A similar decline can be observed with solar energy, with the largest decline observed for offshore wind farms. The market price of clean energy production compared to conventional energy sources varies considerably in different regions. There is great potential for further reductions in clean energy costs in the near future [6].

3.2. Smart grid

The smart grid includes everything that is used to deliver electricity from the power plant to the consumer (for example, the electricity grid, the transmission line network, substations, transformers). The increasing complexity and power needs of the 21st century must be automated and managed. What makes a smart grid exceptional is its ability to perform two-way communication between the utility and its customers, and its ability to collect data on its own use along transport lines (Figure 4). It consists of new technologies and equipment that work within the electricity grid, and is needed to meet the demands for rapidly changing consumer needs for electricity. The application of smart grids is an opportunity to move the energy industry into a new era of reliability, availability and efficiency. The main benefits of improving the network are [7]:

- more efficient transmission of electricity,
- faster return of electricity to function after a disturbance,
- reduced operating and management costs of utilities, with lower electricity costs for end consumers,
- peak energy consumption is reduced, which also reduces the price of electricity,
- increased integration of large renewable energy systems,
- improved security.

Fig. 4 - *Concept of Smart Grid [4].*

Power outages can cause a number of failures that can affect banking, communications, traffic and security. This is a special danger in winter when homeowners may be left without heating. The smart grid adds a security factor to the power system and is better prepared to deal with emergencies (storms, earthquakes, and terrorist attacks). It allows automatic redirection in case of equipment failure or interruption thanks to two-way interactive capacity. New technologies help the recovery of electricity continue quickly and strategically after unforeseen situations. For example, it will first direct electricity to emergency services. Smart grid technology can also be used to address the aging of energy infrastructure that needs to be upgraded or replaced. It is a way to highlight energy efficiency by educating end users to contribute to the preservation of the environment. South Korea's Ministry of Trade, Industry and Energy promoted the idea of an energy-independent island using a smart grid [8]. This idea served as a demonstration of business opportunities in the energy industry. The island of Gaza in the province of South Jeolla has achieved energy independence through the use of renewable energy sources. This includes the operation of four wind farms with a capacity of 100 kW and a solar power plant with a capacity of 314 kW, as well as a storage capacity of 3 MWh. The smart grid limits the supply of electricity depending on the amount of energy consumed in real time. All excess electricity is stored in storage capacity (up to 24 hours) from which it is released for a period of reducing the amount of available energy.

3.3. Results of global energy interconnection planning

One of the main goals of global energy interconnection is to increase the production of electricity from renewable energy sources and to deliver it using ultra-high voltage to the place where it will be used. Such an approach should meet the future growth of global electricity demand and replace part of the energy obtained from fossil fuels. The Chinese State Grid Corporation of China presented its plan for what the global energy interconnection should look like by 2050 [9].

Europe is one of the most important hubs of electricity consumption. The plan is to design an electricity grid to enable the use of wind energy from the Arctic and North Sea, solar energy from southern Europe and northern Africa (Figure 5). It is desirable to combine the activities of hydropower and other energy sources in Europe to balance peak energy demand. Asia is the world's largest consumer of electricity in the world with abundant renewable energy potential. It is planned to build an intercontinental network that would connect the largest places of electricity use and the base of renewable energy sources. The electricity produced from the Arctic and the area around the equator should be able to be received into the electricity grid, distributed as needed using the smart grid and used. The interconnection of the electricity grid in Africa should enable the operation of solar and wind power plants in North Africa with the hydroelectric power plants of Central Africa. The electricity grid in Africa needs to be connected to Europe and West Asia to enable the use of different energy sources and to export electricity to the most needed regions. Better electricity grid connectivity in North America can harness the potential of wind farms in the central and western parts of the continent, solar energy bases from the southwest region, and hydropower potential in Canada. The obtained electricity can be used in industrial zones in the west and east of the continent. In addition to the above energy sources, electricity obtained from wind farms in the Arctic can be imported. By connecting to Asia's energy network through Alaska, transcontinental relocation of large amounts of energy can be accomplished to make efficient use of renewable energy sources within North America as well as Asia. South America has great potential for the use of renewable energy sources. The interconnection of the electricity network on the continent is planned in order to achieve the connection of energy use between north and south on the west and east coast of the continent, as well as for the transmission of energy from west to east in the central part of the continent.

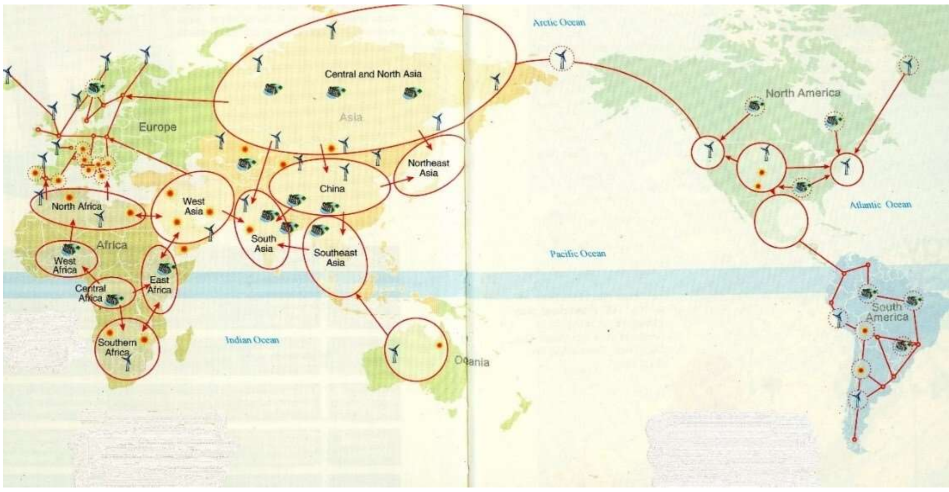

Fig. 5 - *Overall structure of global energy interconnection [10-12].*

4. Conclusion

The main goal of the Paris Agreement on Climate Change is to reduce carbon dioxide emissions in the atmosphere and prevent the rise of the average global temperature. In order to ensure sufficient amounts of energy to continue economic growth and to gradually reduce the use of fossil fuels, it is necessary to use energy that has a beneficial impact on the environment. Renewable energy sources are one of the possible solutions that can provide sufficient amounts of energy with significantly less negative impact on the environment. Their main drawback is that they are largely limited by time and space. The largest sources of wind and solar energy are often located far from the centers of their demand. Technological advances in the use of renewable energy sources allow power plants to be built in hard-to-reach areas (for example, in deep seas, deserts, high altitudes). Therefore, it is necessary to enable the successful transfer of this energy to the place of use.

One of the concepts that can overcome these obstacles is the global energy interconnection. The idea was first presented by the Chinese State Grid Corporation of China. Ultra-high voltage, smart grid and clean energy technologies have already been recognized and applied in various regions of the world. Increasing the level of their application and willingness to invest can lead to an increase in the share of energy obtained from renewable sources. This can ensure the further sustainable development of the world economy with the synergy of nature and humanity.

References

[1] White Paper on Global Energy interconnection – Development Strategy, GEIDCO, 2016.

[2] Global energy interconnection, International Electrotechnical Commission, Geneva, 2016.

[3] Z. Liu, Ultra-High Voltage AC/DC Grids, 2015. https://doi.org/10.1016/C2014-0-01327-5

[4] L. Zhenya, Global Energy Interconnection Development and Outlook, Global Energy Interconnection Development and Cooperation Organization, 2017.

[5] M. Leal, China Dialogue, 2016. https://www.chinadialogue.net/article/show/single/en/9266-Belo-Monte-power-line-passes-through-Brazil-s-Amazon-and-Cerrado-Savannah (accessed 14.04.2020).

[6] V. Lei, The age of „Grid Parity“ Starts for Wind Power, CFFC China Energy Journal, 2017, Issue 26, pp.43-44.

[7] US Department of Energy, https://www.smartgrid.gov/the_smart_grid/smart_grid.html (accessed 11.04.2020).

[8] S.-Y. Kim and J. A. Mathews, Korea’s Greening Strategy: The role of smart microgrids, The Asia-Pacific Journal, 2016, vol. 14, no. 24.

[9] M. Billington, African Agenda, 2018. http://africanagenda.net/china-goes-global-with-ultra-high-voltage-power-transmission (accessed 09.04.2020).

[10] B. Yiu, Dialogue on Energy Interconnection, Economic and Social Council – Dialogue concerning Energy Interconnection, New York, 2019.

[11] C. Cameron, InHabitat, 2015. https://inhabitat.com/v3solars-photovoltaic-spin-cell-cones-capture-sunlight-all-day-long/ (accessed 15.04.2020).

[12] K. Teranishi, Higashi-Matsushima City Disaster-Ready Smart Eco-Town, Construction 21 International, 2018, https://www.construction21.org/infrastructure/h/higashi-matsushima-city-disaster-ready-smart-eco-town.html (accessed 11.04.2020).

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