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EFFECTS OF SOLAR PANELS ON ELECTRICAL NETWORKS

[1]*Péter Bencs*, [1]*Mohammed Al-Ktranee*, [2]*Károly Marcell Mészáros*

[1]University of Miskolc, Department of Fluid and Heat Engineering, Miskolc-Egyetemváros, HU-3515, Miskolc, Hungary,
[2]MAVIR Ltd., Secondary Service, Bába utca 1., HU-3599, Sajószöged, Hungary,
e-mail: arambp@uni-miskolc.hu

ABSTRACT

Today, the increasing use of solar energy contributes to the EU's energy policies. Increasing use of renewable energy sources reduces pollutant emissions, dependence on fossil fuels and improves air quality. Globally, installed photovoltaic capacity has reached 400 GW by the end of 2017, and is projected to reach 4,500 GW by 2050. In the context of this research, we would like to present a detailed presentation of the possibilities and effects of integrating solar systems into electricity networks. The integration of renewable energies into networks is of paramount importance to researchers because of current energy demand and the depletion of fossil fuel reserves and environmental impacts. In this study, we highlight the effects of solar network integration on both the solar system and the public utility service. We also report on the opportunities and impacts of integration in Hungary in connection with our research. Today, solar panels are the cornerstone of sustainable development.

Keywords: solar panel, PV, integration, electricity network

1. INTRODUCTION

In a brief historical review, we would like to highlight the importance of integrating solar systems into the electrical grid. Standardized integration of photovoltaic systems enables optimum use of photovoltaic (PV) systems. Optimized use improves the efficiency of the photovoltaic system, reduces operating costs and provides added value for both the consumer and the service provider. The integration of solar systems is a widespread practice in countries around the world as there is a growing need for alternative clean energy to fossil fuels. Integration uses smart network technology (smart systems), which senses and responds to different states of the network system. Intelligent technologies offer opportunities to increase network stability during integration and to operate solar systems more cost-effectively. The use of smart grid technology is essential if the integration of renewable energy sources into the electricity grid exceeds 30% [1]. Due to the predictability of renewable energy sources, there are many integration challenges. The various systems and measures provide opportunities to maintain the stability of the electricity network.

2. SOLAR PANEL PRODUCTION

Photovoltaic (PV) power generation is one of the most advanced technologies for renewable energy production. Solar technology is currently the world's third most important renewable energy source after water and wind. Solar energy produces low-carbon energy. Solar PV energy consumption has increased in the last few decades. 2017 was an outstanding year for the photovoltaic industry. Solar energy has delivered more new capacities than nuclear and fossil fuels (see Fig. 1) [2].

To reduce manufacturing costs, the production of large-area PV units is a new trend. In 2018, Saudi Arabia launched a bid for a 300 MW power plant to produce the world's lowest price ($ 0.0234 / kWh) [3]. Due to the development of solar technologies, the cost of production is constantly falling. China led the world in solar generation in 2017 and installed 50% of the world's new solar generation capacity. Solar production capacity in Europe has grown at a slower rate, which was only 30% higher than a year earlier. By the end of 2022, global solar power generation capacity may increase to 1270.5 GW, and solar power will exceed 1 TW (TWh).

In 2017, the Asia-Pacific region became the leading region in solar energy as it increased its capacity by 73.7 GW to reach 221.3 GW of total installed capacity.

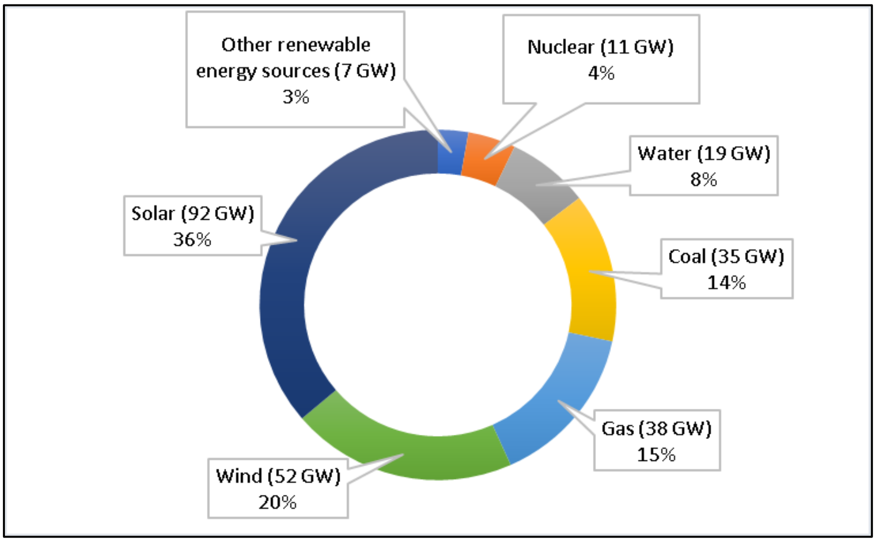

Figure 1. Installed power generation capacity in 2017

Meanwhile, European nations were pioneers in solar energy and continue to collectively rank second in the world in terms of capacity with 114 GW of total PV capacity, with their share falling to just 28%. The United States ranks third with a total installed capacity of 59.2 GW, or about 15% [3]. The share of Africa and the Middle East decreased in 2017. Even after the addition of 2.1 GW, the total solar capacity of 6.9 GW was only 1.7% of the world's total capacity. Nearly one third of the world's solar generation capacity has been operated by China, based on significant growth since 2016 (Fig. 2).

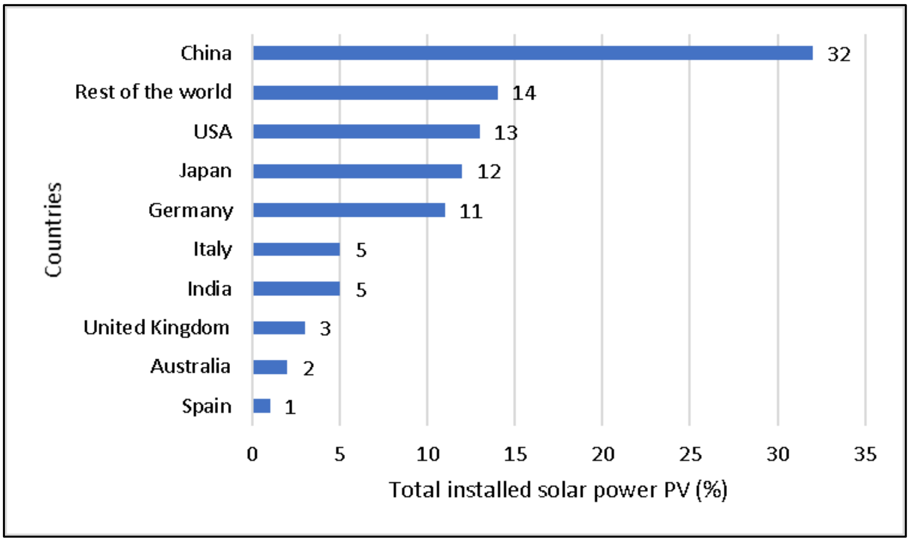

Figure 2. Top 10 countries based on total installed PV capacity at end of 2017 [2]

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As can be seen in Fig. 3, in Hungary, as a result of existing policy measures, the installed capacity of renewable electricity generation units will exceed 7200 MW by 2030, of which more than 6600 MW will be generated by solar panels. Renewable electricity is expected to exceed 6500 GWh in 2030, with nearly 70% covered by solar panels. The share of renewable energy use is projected to be 12.8% of gross final electricity consumption in 2030.

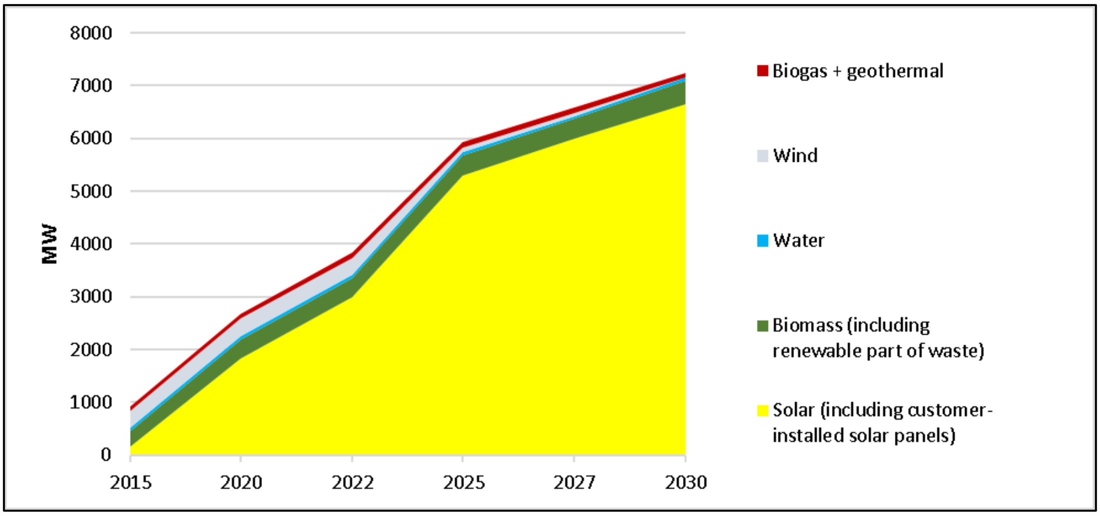

Figure 3. Installed electricity generation capacities for renewable energy use broken down by technology (installed capacity - Hungary) [4]

3. STABILITY OF ELECTRICITY NETWORKS

Fluctuating supply of renewable energy sources posed risks to the stability of the grid and the security of energy supply.

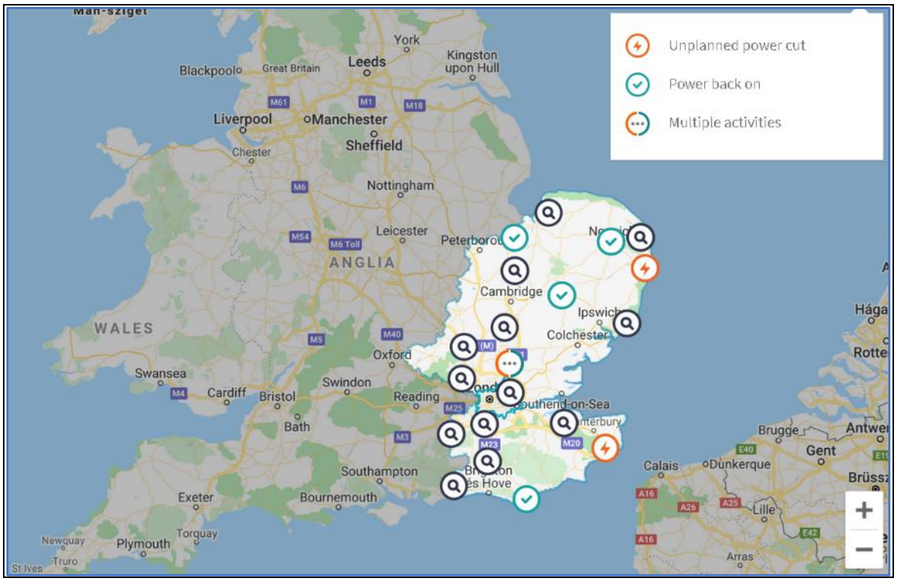

Figure 4. United Kingdom live power cuts [13]

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Previously, only hydropower and biogas from power plants could be used to feed the network safely. Nowadays, intelligent grid technologies provide an opportunity to supply energy from other renewable sources as well. Fig. 4 illustrates the stability of power grid systems in the United Kingdom. Fig. 5 illustrates the stability of power grid systems in the European countries.

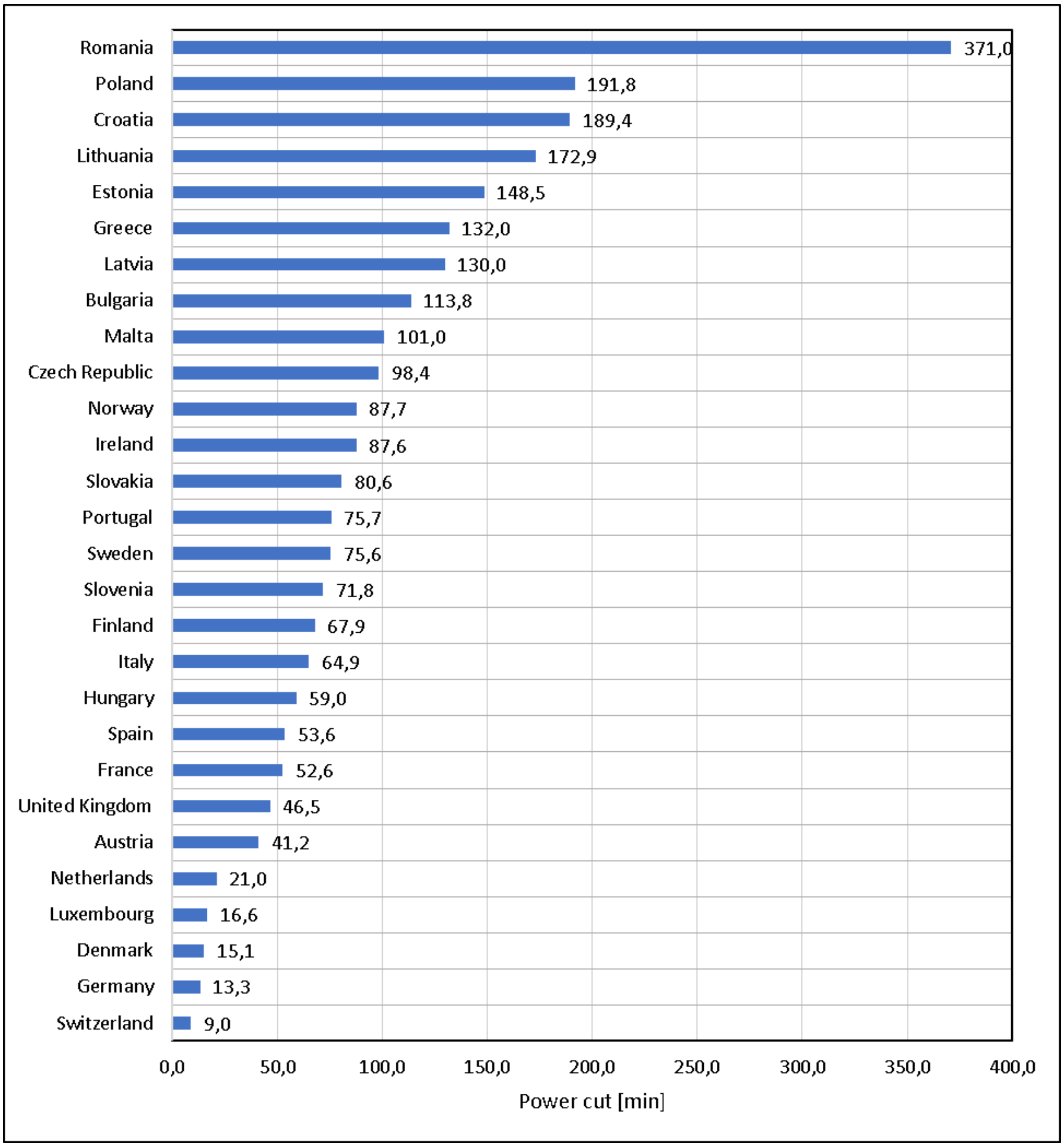

Figure 5. Average annual blackout in European countries in 2016 (including unexpected events) [5]

The increasing share of decentralized production capacity from renewable sources of energy will continue to have a negative impact on the quality of supply [5]. We saw a typical example of system outages in

Germany in 2017. Losses due to extreme weather events such as storms, floods and snow have nearly doubled from a year earlier. In Germany, the average power failure in 2016 was 13.3 minutes.
The design of the power grid system determines further development opportunities. The integration of energy from renewable sources into the electricity grid requires new grid systems and modifications. The general electric network model is shown in Fig. 6 (consumer: large (industry) and small consumers (households)).

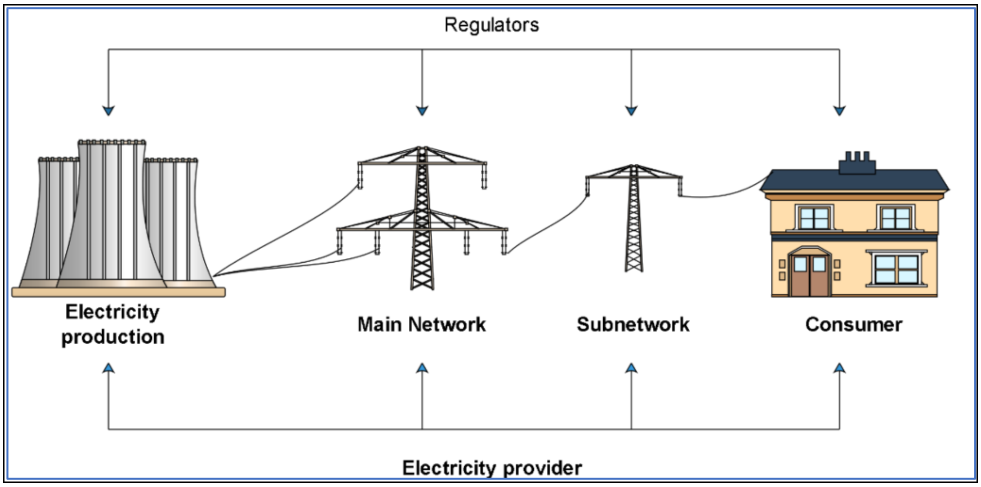

Figure 6. General layout of the electricity network

It is the responsibility of the network operators to ensure the stability of the grid in the event of a large influx of renewable energy sources and the organization of cooperation between transmission (main) and distribution (sub) grids.
Using renewable energy sources, power systems become dynamic and require a new strategy to modify traditional control algorithms. Systems using renewable energy sources are connected to the grid using intelligent grid technology, thereby reducing the overall inertia of the grid (Fig. 7).

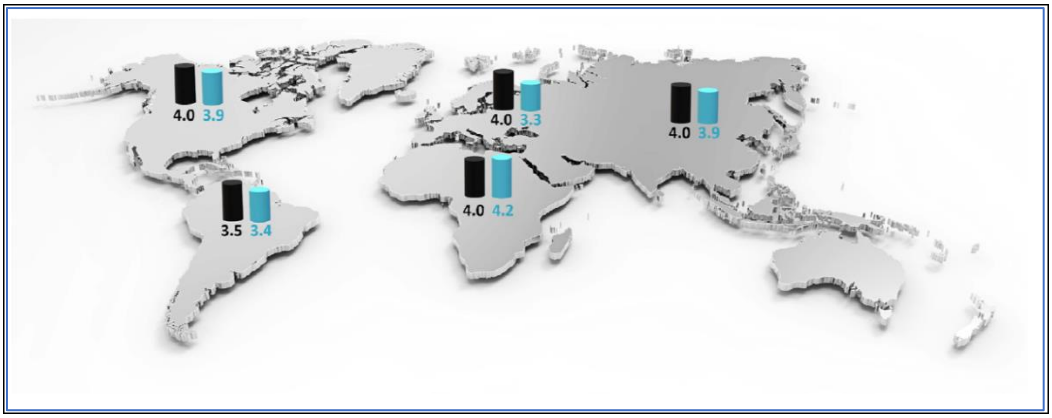

Figure 7. Equivalent inertia constants are estimated worldwide for each continent. Change between 1996 and 2016 [6]

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4. ELECTRICITY NETWORK OPERATION

The various challenges of operating networks are illustrated by examples. In the context of this study, we are presenting network operational improvements for Germany and Hungary.
In 2017, 33.3% of German energy production came from renewable sources (13.5% of which were offshore wind, 2.7% offshore wind and 6.1% photovoltaic). More than two-thirds of Germany's mainland wind is installed in the northern and north-eastern provinces of Schleswig-Holstein, Lower Saxony, Mecklenburg-Vorpommern, Brandenburg and Saxony-Anhalt. Meanwhile, metropolitan areas and energy-intensive industries are largely located in the south and west of the country (Fig. 8). During one year, the northern state of Schleswig-Holstein produces more energy than it can use, while the Bavarian government has indicated that it will have to account for 3 GW of capacity shortfall after the last nuclear power plant is shut down in 2023.

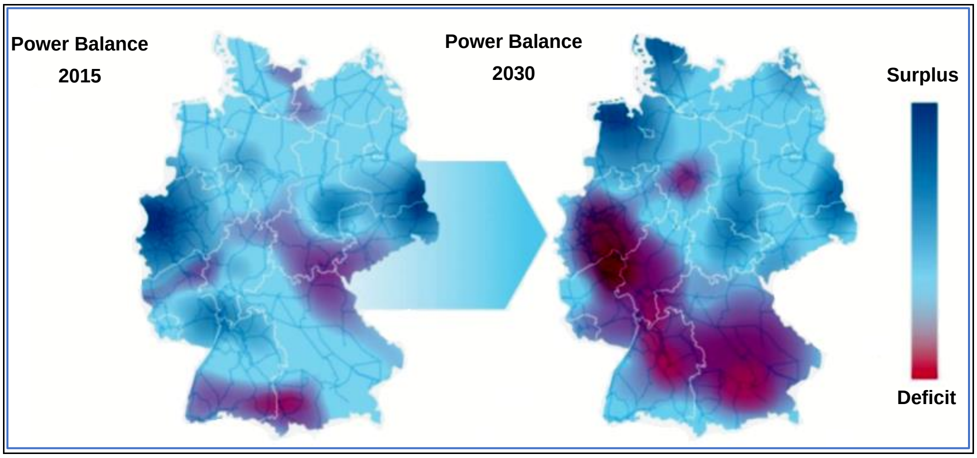

Figure 8. Northern Germany has excess wind power surplus, while southern electricity shortage (operator of Amprion transmission network) [7]

At present, 35,000 km of power lines linking north and south of Germany are overloaded and there is a period in power generation where they are unable to transmit all the power generated in the north. On windy days, enormous amounts of renewable energy are flowing into the electricity market, depressing wholesale prices and encouraging consumers in the southern part of the country to consume excess power. At present, the grid is not capable of handling the high volumes of energy transported during the high wind days, and thus, in the south, it is able to meet the increasing power requirements by producing additional power plants. The excess energy produced by power plants is sold at higher prices in the south. In the northern part of the country, renewable energy production must be restricted during the same period. This problem entails additional costs for electricity grid operators, as wind power producers have to be compensated for wind turbine downsizing or shut down [7].
In Germany, too, there is continuous development of modern and high-performance infrastructure. To solve this, the power lines need to be better constructed and the overall system resilience increased. New high-power electricity highways will be developed from northern and eastern Germany to southern areas. Another major driver of network development in Germany is the single European energy market. In order to have unrestricted electricity flow across Europe and to make electricity cheaper for consumers, there is also a need for significant infrastructure development in European countries. European electricity network operators therefore submit a joint network development plan every two years, which includes all German needs and intentions [8].

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When developing distribution networks, account should be taken of the flexibility required by renewable energy sources. The solution is to provide the right flexibility for smart networks (with proper communication at all levels). Electricity generation and use can thus be more easily harmonized and adjusted in the short term (Fig. 9).

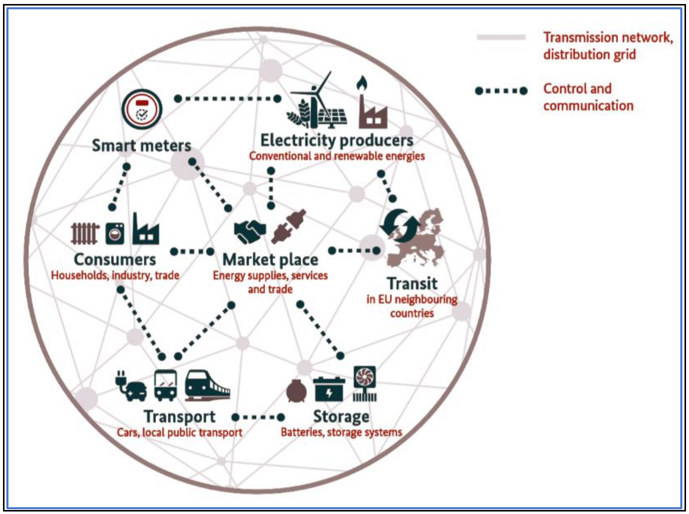

Figure 9. Schematic diagram of a smart network [8]

The transformation of the electricity market is a major challenge. Germany has already initiated a reform process to this end and has already taken the first steps. An important feature of this is flexibility [8]. All actors in the electricity market should respond as much as possible to fluctuations in the supply of wind and solar energy (Fig. 10).

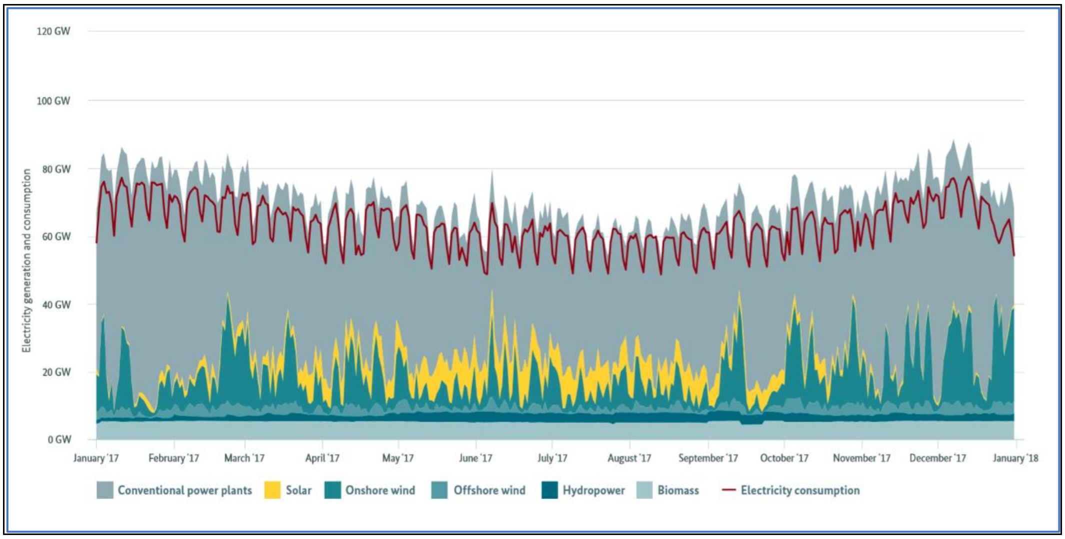

Figure 10. Total electricity generation and electricity consumption in Germany in 2017 [8]

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Hungary's transmission network is controlled by MAVIR Ltd. (Hungarian Electricity Transmission System Operator Limited Liability Company. It is a member of the ENTSO-E European Electricity Transmission Network, which connects the national systems at the continental level. countries except Russia, Ukraine, Belarus, Albania and Turkey. Part of Ukraine, Albania, Moldova, Maghreb and Turkey are synchronously linked to the system. (Fig. 11) MAVIR joined the XBID project on November 19, 2019 to implement the intraday market interconnection model. Electricity from renewable energy would be used immediately by interconnected networks, thus relieving the environment.

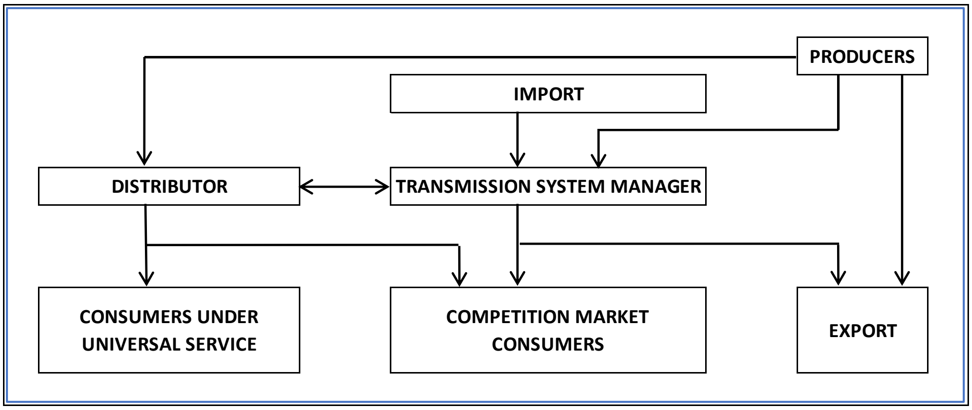

Figure 11. Operation of the domestic electricity market [10]

In addition, the Hungarian system is part of UCTE's European High Voltage Transmission System, which is the largest synchronous system in the world. From this large system, we can buy (import) and sell (export) electricity. Unfortunately, Hungary has a negative balance, i.e. we need imports.
As shown in Fig. 3, in Hungary, as a result of existing policy measures, the installed capacity of renewable electricity generation units will increase by 2030. Fig. 12 shows the distribution of installed capacity of power plants currently operating in Hungary.

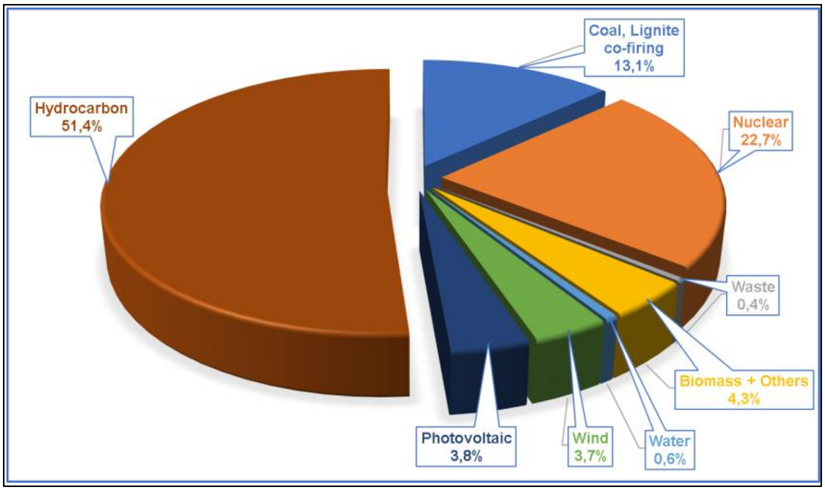

Figure 12. Distribution of installed capacity of all Hungarian power plants by primary source as at 31 December 2018 [10]

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In the case of the Hungarian electricity system, we distinguish between primary, secondary and tertiary control. If there is a power shortage that causes the frequency to start to fall, the power output of the power generators will begin to increase, fixed from the previous operating point to a new operating point, this primary control. During secondary control, the power plant generators start to increase the speed to return the reduced frequency to normal. For this purpose, quick-start power plants are used, located in Litér, Lőrinci and Sajószöged. In tertiary control, we want to restore the original power distribution, which requires that a power producer be included in the system at a point near the occurrence of the shortage.

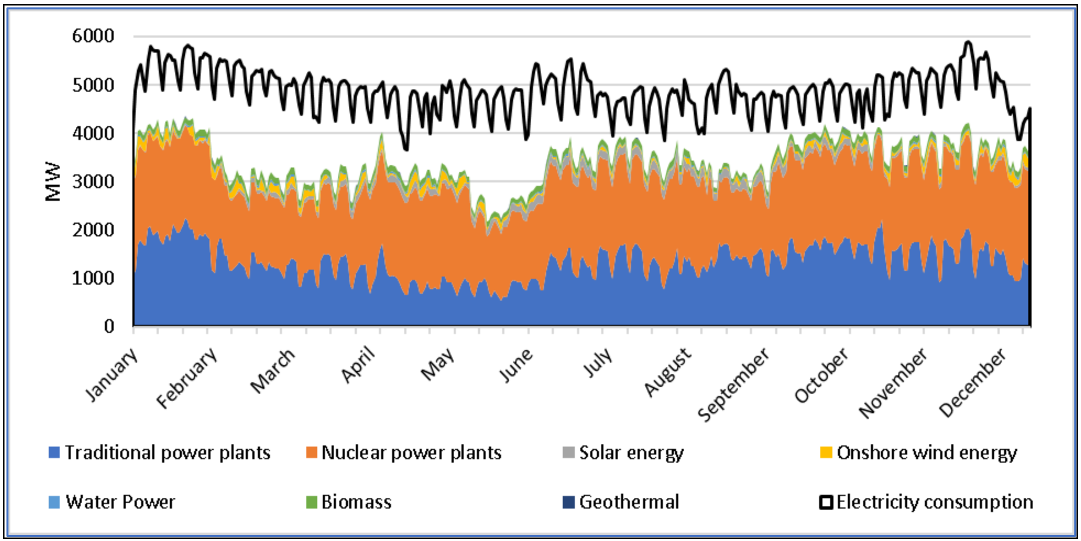

Figure 13. Total electricity generation and electricity use (net) in Hungary in 2019 [11]

It can also be clearly seen from Figure 12 that Hungary currently has a very high net import ratio (vacant area under electricity use), averaging around 30%. In Europe, only Lithuania, Luxembourg, Albania and Croatia have higher rates [12]. However, the high net import ratio is accompanied by a very strong network connection: the import capacity equals 55% of the total installed domestic power plant capacity. Only Croatia (80%), Luxembourg (58%) and Slovenia (75%) have higher values in the EU. Between 2015 and 2018, 21.5% of the domestic installed power plant capacity was physically unable to meet domestic demand due to their low availability, i.e. we were forced to import.

Capacity mechanisms, as regulatory interventions for security of supply in Europe, are perceived as twofold: the European Commission firmly rejects their necessity and imposes strict conditions on their use; Twelve Member States currently use some form of capacity mechanism, although in six of them ENTSO-E has not anticipated any security of supply problem [12].

Practice shows that there is currently no "clean" energy market that is proven to be able to guarantee security of supply without interference in the long term, especially at the level expected by policy makers. Each of the known markets employs some form of administrative intervention in the operation of the market, not infrequently drawing on theoretical literature. These range of instruments range from market organization measures to promote market integration (and "market" operation) of renewables, to interventions aimed at strengthening price signals (e.g. scarcity pricing) and to the organization of capacity markets [12].

The REKK (Regional Centre for Energy Economics Research) examines the future of the domestic wholesale electricity market, including the development of wholesale prices and import rates and the cost of renewable subsidies. In the current measures' scenario, net imports will fall very sharply between 2029 and 2032, and in 2030 Hungary will become a net exporter thanks to the production of new Paks blocks. However, in the early 1930s, net imports rose again as natural gas producers continued to close and no new capacity was being built or old Paks blocks were exiting the system. Renewables will be close to 20% in 2030 due to relatively modest wind power and lower biomass production compared to other scenarios [12].

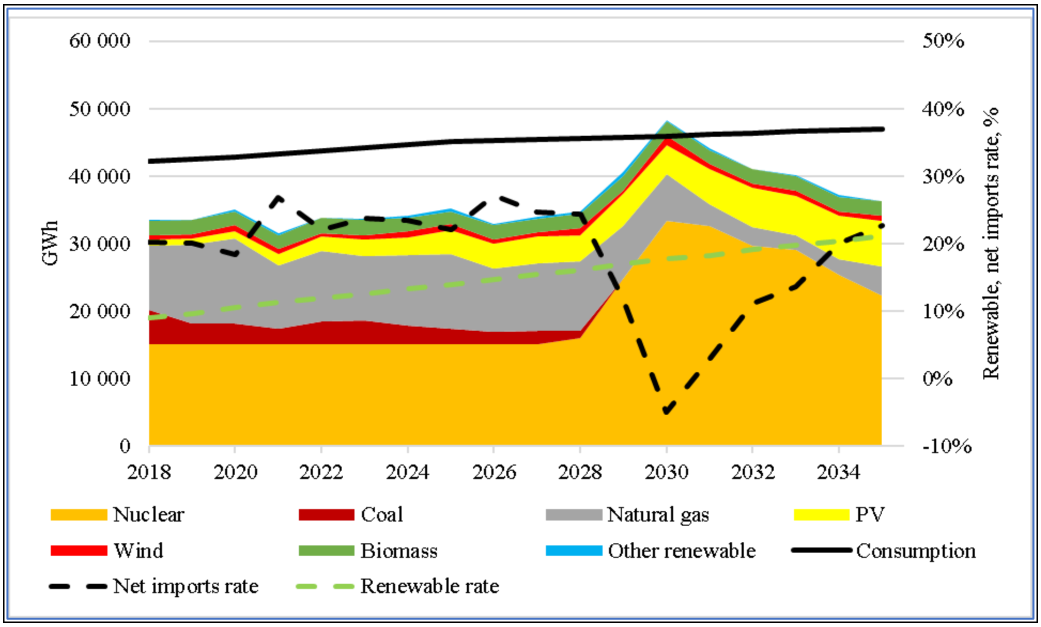

Figure 14. Current provisions scenario measures electricity mix, renewables and net imports, 2018-2035 [12]

5. CONCLUSIONS

In this article we have reviewed the potentials of solar panels and their operational aspects. We have summarized the development trends between countries using renewable energies. Evolutionary trends show that the use of solar panels is growing the best compared to other renewable energy sources. Integrating a solar system into national grids can reduce transmission and distribution pipeline losses, increase grid stability, lower production costs and reduce the need to invest in new utility generation capacity. The purpose of this article was to review current and future plans for the production and integration of large-scale solar systems in a network dominated by conventional fossil fuels. Much of the research has shown positive results in terms of integration. The effects of integration on system stability and security should be carefully considered before installing a facility. Prior to deployment, advanced integration technologies should be considered. Optimized forecasting is essential for proper system stability.

Due to the economic viability and robustness of the system, solar technology can be treated as a major guideline for sustainable development.

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