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EFFECT OF SOLAR ENERGY ON SUPPLY SECURITY IN AN INTERCONNECTED SYSTEM

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Abstract- In this study, Turkiye's energy resources were evaluated and the place of solar energy in these resources was examined. The most efficient regions of solar energy were determined. The 400 kV electrical connection diagram was examined. Turkiye's electricity installed capacity was analyzed. The value that renewable energy sources add to the production-consumption balance and their advantages over fossil fuel power plants have been examined. The voltage stability of the region before and after the solar power plant installed in the Karapinar region was analyzed. The importance of supply security provided by solar energy to the interconnected system has been examined and suggestions have been made for the system.

Keywords: Renewable Energy, Interconnected System, Energy Supply Security, Solar Power Plant, PV Solar.

1. INTRODUCTION

The acceleration of scientific and technological developments in the world has increased the demand for energy and electricity. In addition, the industry has increased electricity consumption on a personal basis with services that meet people's living needs and offer more relaxing solutions in their daily lives. In order to balance the increase in electricity consumption with electricity production, it is necessary to increase the number of power plants on a global scale or increase the power produced. In current production plants, more than half of the energy resources are provided by fossil fuels such as natural gas, coal and oil, which will be exhausted in the near future. The world's energy needs increases by approximately 4-5% every year. The reserves of fossil fuel that meet the demand corresponding to this increase are decreasing much faster. As the growth in the world continues like this, the lowest estimate shows that the oil reserves will decrease significantly within 30 years and will not be able to meet the needs. A similar situation is foreseen for natural gas and coal. In addition, the fossil fuel used has visibly increased the average world temperature, as well as air pollution, and caused an increase in disasters such as storms, floods, extreme droughts and melting glaciers, which cause billions of dollars of damage every year [1]. People must clean up and turn to replaceable energy sources without waiting for fossil fuel reserves to run out.

Before renewable energy sources came to the fore, fossil fuels such as natural gas, coal and oil were mostly used in energy production. The use of fossil fuels not only increased carbon emissions into the atmosphere, but as a result of the use of these resources, the natural balance of the world began to deteriorate and environmental pollution increased. As a result of these events, changes in atmospheric events have made the concepts of climate change and global warming an important situation in our lives. Among the precautions to be taken to prevent such negativities and make the world a livable place; The use of fossil fuel and more widely used energy sources should be terminated. Instead of these energy sources, the use of clean, environmentally friendly and renewable energy sources should be increased [2]. The reserves of fossil-based energy resources will be depleted in a short time. For this reason, it is also necessary for countries like Turkey, which imports most of the energy it needs, to protect the environment and evaluate what is more economically beneficial [3].

- There are many studies on PV in the literature;

A PV panel has a negative electric field on the front side and a positive one on the back side, which is typical of silicon semiconducting resources [4]. Energy consumption is increasing rapidly every year. The most economical and reliable source to power communication base stations located in areas far from settlements and the electricity grid is solar energy [5]. However, SPEIC DC-DC converters work better with no ripples or oscillations at PV module output voltage. Fuzzy logic controllers are used to maximize power under fluctuating temperatures and irradiation. According to this module, at a 1000 PV system, output power increases while cell temperature decreases [6]. Solar energy is one of the renewable energy sources that has an important place despite the energy problems experienced today and has the qualities to meet the needs in regions with efficient production conditions [7]. Photovoltaic (PV) technology is the simplest form of electricity generation technology from an installation and design perspective, as well as being cheaper and easier to

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use as a separable technology. The PV exchange working source is resistant to semiconductor properties that convert solar energy directly into electricity. The efficiency demonstrated by a PV cell can be calculated according to the market based on the total solar irradiance of the electricity produced [8].

The radiation released by the transformation of hydrogen gas in the core of the sun into helium is called solar energy. The fact that the costs incurred in electricity production are proportionally lower than other energy sources and that its economic lifespan is longer than other sources, and that it is a green energy that is harmless to the environment, is at the forefront of preferences. Turkiye's sunshine duration is 2 thousand 460 hours. Since the average annual solar radiation is 1311 kWh/m^2, it is a very rich country in terms of the use of solar resources and its target in electricity production exceeds 500 GW [9]. According to the Ministry of Energy and Natural Resources, Turkiye's solar radiation map is shown in Figure 1.

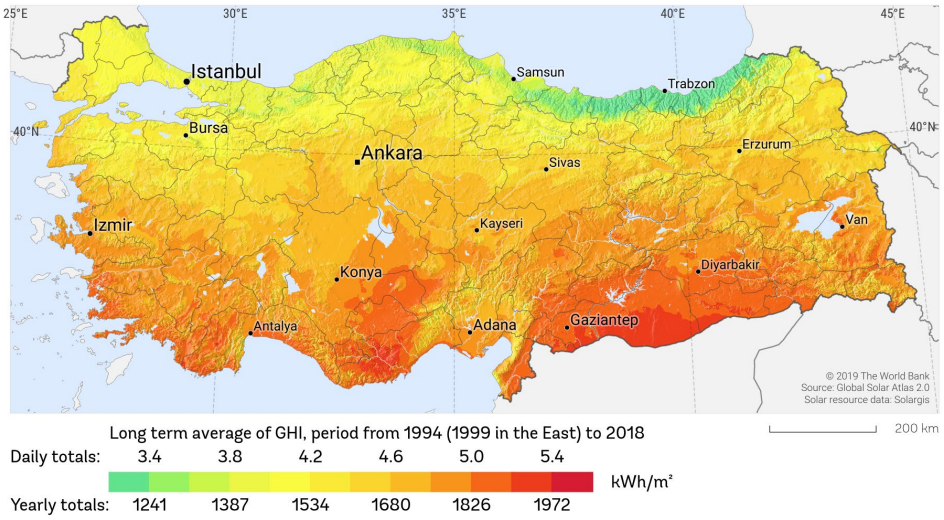

Figure 1. Turkiye's solar radiation [10]

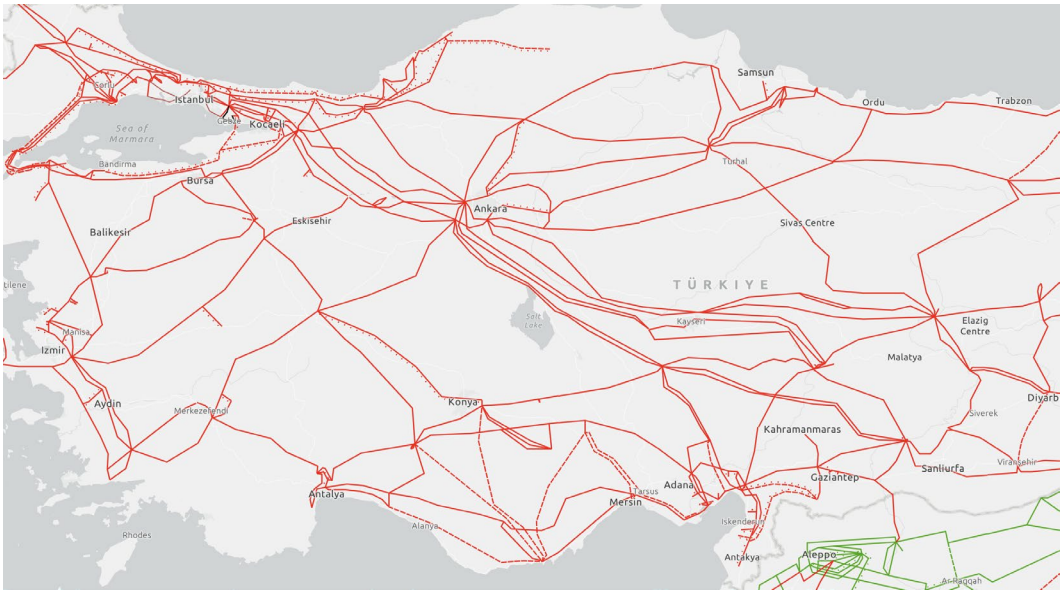

Figure 2. Turkiye's electricity transmission scheme [13]

2. THE IMPORTANCE OF RENEWABLE ENERGY IN INTERCONNECTED SYSTEM

2.1. Turkiye's Electricity Transmission System

The International Energy Agency (IEA) defines the interconnected system as "the system established between all power plants, substations and subscribers of a region or a country to meet the electrical energy needs of that place" [11]. The connection between the power plants that convert any energy source into electrical energy and the transmission network that connects the centers that consume electricity is provided by using the interconnected system. Conductors, poles, transformers, and other equipment that ensure safe use of the network are the elements that make up the transmission network [12]. Turkiye's 400 kV electricity transmission map according to ENTSO-E (European Network of Transmission System Operators) is shown in Figure 2.

2.2. Electricity Supply Security

IEA defines energy supply security as "uninterrupted availability of energy resources at an affordable price" [14]. Electricity supply security is the ability to respond to changes in the supply-demand balance in electricity consumption. A definition such as "Providing sufficient amounts of quality and clean energy at affordable prices and without interruption" indicates that the energy must be clean as well as sufficient.

There must be four criteria in the system used for the safe consumption of electricity. These criteria state that electricity must be usable, accessible, affordable and at an acceptable level [15]. At the same time, it should be noted in that energy prices must be at a level acceptable for the consumer. Following the determined criteria, concerns about the environmental effects of the energy used also come into play. In order to prevent these concerns, not only the discovery of the energy source to be consumed, its supply to the consumer, its economic suitability, but also its acceptance by the user is required. If energy resources are sensitive to the living area and harmless to human health, it will be important for the society to use a green energy source in order to leave a healthy living space for future generations without any problems. The components of the electricity supply life are shown in Figure 3.

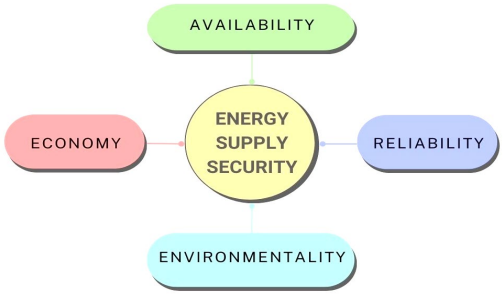

Figure 3. Energy supply security components

2.3. The Importance of Renewable Energy

Electricity transmission in the world is provided by alternating current (AC) as it is a more economical and more accepted practice. Unlike DC (direct current), alternating current cannot be stored due to its nature, so it must be consumed as soon as it is produced. In Turkiye, electricity consumption is high in the western regions due to reasons such as industry, population, economy and geography. TEIAS (Turkish Electricity Transmission Corporation) ensures electricity supply security by continuously monitoring this production and consumption balance through the transmission network. In order not to increase the load on the transmission network and not to endanger the security of supply, the best approach would be to produce electricity where it is consumed. For this reason, SPP (solar power plant) also come to the fore because large power plants such as TPP (thermal power plant), HEPP (hydroelectric power plant) and NPP (nuclear power plant) cannot be installed in every consumption area. In addition, production must increase at the same rate to ensure energy supply security during periods when consumption is high. Due to the energy crisis in the world, there may be inadequacies in fossil-based electricity production. It is possible to prevent these deficiencies by using solar energy, which is a renewable energy source that is harmless to the environment, is simple to use, and can be installed and transported in convenient locations without requiring high costs in installation.

As a result of the advantages provided by Turkiye's geographical location, the use of solar energy and wind energy is extremely convenient. Since Turkiye, imports most of the resources used to produce electricity for its energy needs, will reduce its foreign dependency on energy by increasing its investments and studies in renewable energy sources. Compared to competing systems, it does not require advanced technology and can be easily installed in the region where it is located, and since it has an advantageous position in terms of lifetime, it is a very financially convenient solution for long periods of time.

3. EXAMINING TURKIYE'S ENERGY PRODUCTION

3.1. Electricity Generation Sources of Power Plants

Although the tendency towards renewable and green resources has increased depending on the source of electricity produced in the international conjuncture, there is still a great deal of energy resources based on fossil fuels.

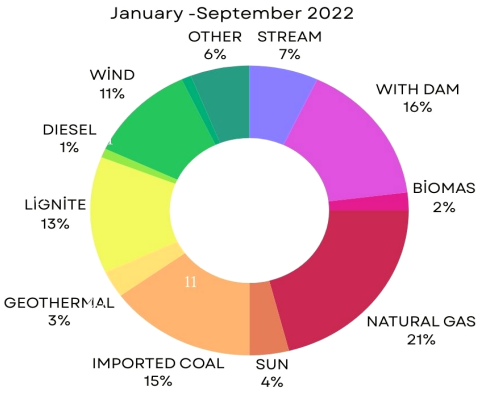

Figure 4. Electricity production rates of power plants in Turkiye

As shown in Figure 4, it is observed that almost half of the resources used in energy production in Turkiye consist of fossil resources. According to the information obtained from TEIAS Load Distribution Information System [16], the electricity produced until August 2022; It includes 21% natural gas, 29% coal, 4% liquid fuel (such as fuel oil, diesel) and others. 41% of the energy produced belongs to renewable resources. Among these resources, solar energy constitutes only 4%.

3.2. Turkiye's Installed Electric Power

Turkiye's electricity installed power announced by the Ministry of Energy and Natural Resources, Turkiye's installed power reached 100,473 MW at the end of July 2022.Ratio of installed power to resources used in

electricity generation; hydroelectricity 31%, natural gas 25%, coal 21%, wind 1%, solar 8.2%, geothermal 1.7% and other resources 2.4%. In addition, according to Ministry data, the number of power plants used in the production of Turkiye's electrical energy has increased to 10,953 as of July 2022. According to the source of these power plants, hydroelectricity is 750, coal is 67, wind is 356, geothermal is 63, natural gas is 347, solar is 8,882 (including unlicensed power plants), and other sources are 488 [16].

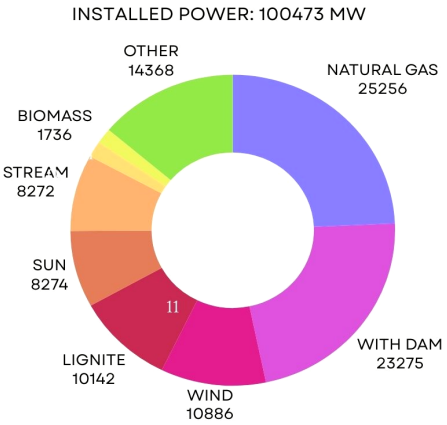

Figure 5. Turkiye's installed electrical power

4. IMPORTANCE OF SOLAR ENERGY TO INTERCONNECTED SYSTEM IN TERMS OF REGIONAL SUPPLY SECURITY

As a result of the developments in the world, a large-scale energy crisis has occurred on a global basis. Solar power plants stand out as the most effective and fastest solution to this energy crisis. Investments in these power plants have also accelerated in Turkiye. In this section the impact of Karapinar Solar Power Plant that is located in Konya, Turkiye has been examined. The Karapinar SPP has the largest installed capacity among the solar power plants in TEIAS's 400 kV electricity network, on regional supply.

- The Karapinar SPP consists of 2 transformer centers: Meke and Acigol. Acigol substation is connected to the 154 kV network and Meke substation is connected to the 400 kV network. The installed power of the power plant, whose acceptance processes continue periodically, is planned to be 1 GW when the panel assembly processes are completely completed. As of August 2022, the installed power of the power plant is 226 MW in Acigol and 641 MW in Meke.

The Karapinar Meke SPP, with its connected busbars Karatay TC (Transformer Center) and Yesilhisar TC, is located very close to regions such as Konya, Kayseri and Ankara, where energy consumption due to industry and population is high. Likewise, Karapinar Acigol SPP is located very close to regions where agricultural energy consumption is high, such as Karaman, Nigde and Aksaray. According to TEIAS, the interconnected system connection of Karapinar Solar Power Plant is shown in Figure 6 [17].

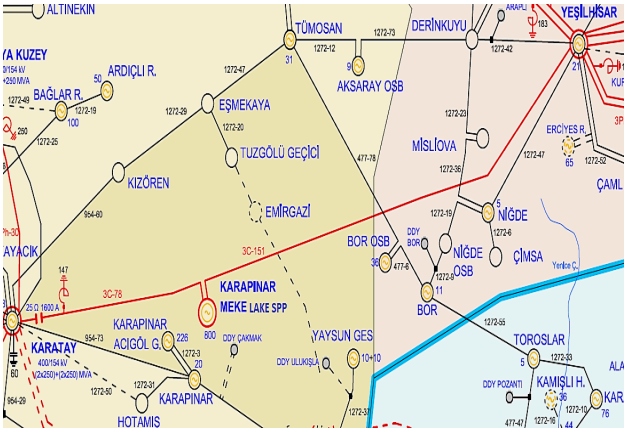

Figure 6. Connection of Karapinar solar power plant to the interconnected system

As of May 2021, when the power plant was put into operation, it continues its production uninterruptedly depending on the sun, without any harm to the climate and living things, with the advantages of being a renewable and green energy source. Since the region is poor in terms of other energy production sources, serious problems were encountered in voltage regulation due to consumption in energy supply before the power plant in question was put into operation. With the commissioning of the power plant, voltage regulation has been stabilized with the principle of produce where you consume.

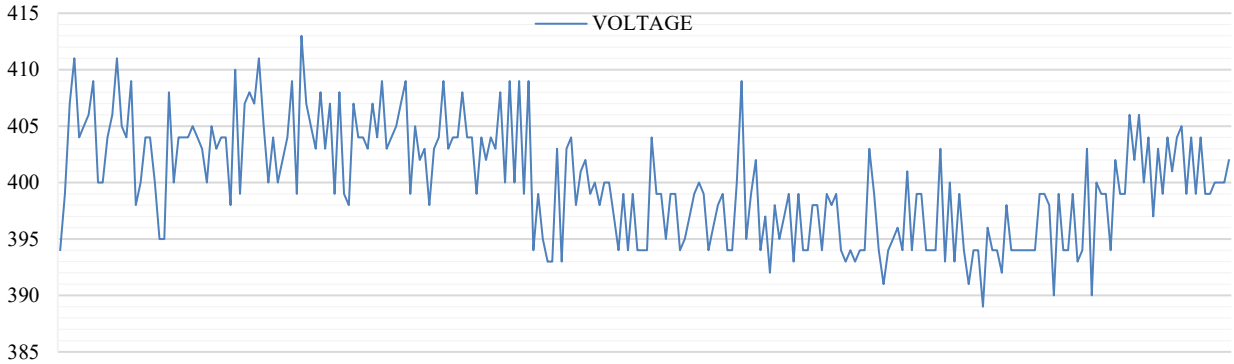

Figure 7. Karatay transformer center busbar-1 voltage (before)

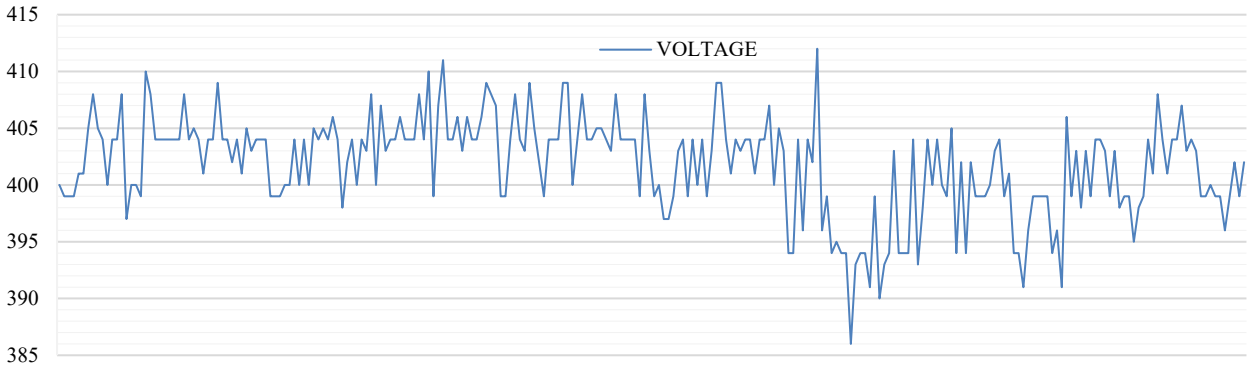

Figure 8. Karatay transformer center busbar-1 voltage (after)

Figure 7 shows the Karatay TM Busbar 1 voltage during the summer peak period of the region between 15.05.2020 and 15.09.2020. Figure 8 shows the Karatay TM Busbar 1 voltage after Karapinar Meke SPP was put into operation between 15.05.2021 and 15.09.2021. The data used in Figures 7 and 8 were obtained from TEIAS load distribution information system [18]. According to the data [19] on Turkiye's electricity installed power announced by the Ministry of Energy and Natural Resources, Turkiye's installed power reached 100,473 MW at the end of July 2022. Considering the 1 GW installed power of Karapinar SPP when the panel assembly process is completed, it will meet 2% of Turkiye's energy consumption with solar energy alone.

5. SUGGESTIONS

The fact that Karapinar Acigol SPP was built at a single point with such a large installed power for the 154 kV network also caused some lines in the 154 kV network in the region to be loaded. The loading of the lines created the need to build a new line between Hotamis TM and Karatay TM due to operating conditions. For this reason, since production in solar power plants is continuous due to the sun, in order to reduce the load on transmission lines in power plant installations, SPPs should be installed at different points with different powers by distributing them to regional substations to relieve the load flow, not to a single point.

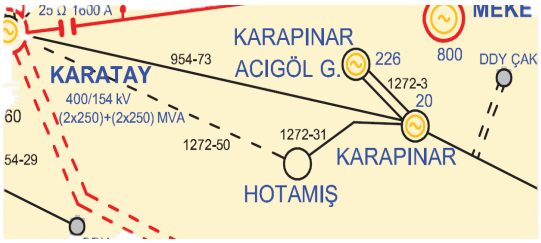

Figure 9. Connection of Hotamis TC to the interconnected system

Having such a large and powerful power plant in a single location causes sudden movements in the load flows of the transformers and lines in the region in the morning and evening hours, with the effect of solar energy, which will put the energy supply security in a dangerous situation. In order to prevent this mobility, the number of series and shunt equipment to prevent this mobility should be increased in substations close to the region.

As can be seen in Figures 7 and 8, it is seen that the busbar voltage at Karatay TM dropped to 383 kV at night on the specified dates. Due to excessive consumption during the region's summer peak period, voltage drops occurred at night when there was no production in the regional substations, which put energy supply security in a dangerous situation. In order to prevent such events, the electricity produced during the day should be used for consumption at night by using equipment that solar power plants will store energy during the day.

As a result of the latest developments on a global scale, Turkiye tries to balance its increasing need for electricity use with many different energy sources every year. With the accelerating increase in investments in renewable energy in the international conjuncture, Turkiye meets its increasing energy needs with the construction of more SPPs, RES and GPPs as a result of the energy crisis in the world. must meet. It should minimize its foreign dependency by using the power of its geography in the most appropriate way.

6. CONCLUSIONS

In regions where energy consumption is high, the installation of solar power plants and other renewable energy plants will be increased depending on the compatibility of climate and geographical conditions, and electricity will be produced where consumption is made. In this way, system line and transformer loads will be reduced and energy production that does not harm nature and society will be achieved. In addition, the faults that will occur will decrease as the load on the line and transformer system decreases. The financial burden to be paid in case of malfunctions will be reduced at the same rate. In this way, more economical and efficient energy will be obtained.

Although the tendency towards renewable and green resources has increased depending on the source of electricity produced in the international conjuncture, there is still a great deal of energy resources based on fossil fuels. The transition to completely clean and renewable energy in the world and in our country does not seem possible in a short time. Shedding light on future reform efforts through scientific research and studies will be important to ensure that this transition can take place in the most economical and problem-free manner.

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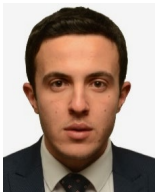
BIOGRAPHIES



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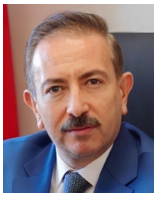

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