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The amount of solar energy radiation in Afghanistan and the methods of using modern technologies in electricity production for large-scale exploitation

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Abstract

Solar energy is one of the most important, cheapest and most harmless sources of energy in the world and it is the main source of all the energies on earth. Afghanistan is a country that has more than eight months or 250 sunny days in per year and is one of the best countries in the world in terms of solar energy potential. Most parts of Afghanistan are deserts and sandy that are not arable and usually have low rainfall and high solar heat up to about 45 ℃. Considering the geographical location of Afghanistan and the scattered of the villages in the country, the use of solar energy is one of the most important factors that should be considered. In Afghanistan, the issue of using solar energy has been the focus of the government and people of Afghanistan for some time, and of course, since a few years ago, the use of sunlight to generate electricity in the solar way or solar panels in the country by the citizens of Afghanistan at their own expense it has begun. In recently, the government of the Republic has provided electricity to some villages that has a lot of sun by distributing solar panels and batteries. However, the use of this clean and free resource has not been used in a large and industrial scale as a solar power plant. In this study, the capacity of solar energy production in Afghanistan, the use of modern technologies and various methods of electricity production from solar energy, for large-scale exploitation, have been presented. This study used from library method. Using the concepts of thermodynamics and heat transfer, the analysis of steam production system, absorbers in solar receivers and thermal storage in solar systems have been discussed.

Key words: solar energy, large and industrial scale, solar power plant, modern technologies, steam production

1. Introduction

The sun is the closest star to the earth. The distance between the earth and the sun is 150 gigameters[1]. Also, the sun is a star that is formed from extremely hot gaseous matter with a diameter of approximately 1400 megameters[2]. According to this calculation, the diameter of the sun is about 110 times the diameter of the earth[3]. When we compare the mass of the earth[4] with the mass of the sun[5], we realize that the mass of the sun is 300 thousand times more; Assuming that the Sun is a hollow sphere, it can accommodate 300,000 Earth-like planets in its heart. The power of producing energy in the sun is 4×10^{23} KW; Equivalent to converting about four hundred million tons of wood into energy per second. The sun's energy is emitted in all directions, and only a small part of it, which is about 1.7×10^{11} KW, reaches the earth. Although this amount of energy is a small part of the total energy of the sun; But for half an hour or 1800 seconds, the energy sent by the sun to the earth can supply the energy of the people of the earth for a year [1]. The energy of the sun reaches the earth after eight minutes and twenty seconds. The effective temperature of the sun's surface is 5785 K, while the temperature of the sun's core is estimated to be 8×10^6 to 4×10^7K [1]. Sunlight reaches the earth's surface directly or indirectly through reflections and deviations that occur in the atmosphere. On a clear and sunny day, about 80 to 90 percent of the sun's rays reach the earth's surface. On a cloudy or dusty day, the direct radiation received from the sun will be zero. In today's world, systems that work with direct sunlight are used to generate electricity. Because in direct radiation, it is possible to concentrate the sun's rays on a small surface by means of mirrors and lenses and use the sun's energy.

2. Energy sources

In general, energy sources can be divided into two groups: renewable energy sources and non-renewable energy sources, which are also called reversible energy and irreversible energy. The use of non-renewable energy sources is only disposable, if such energy sources run out, it is simply not possible to compensate for its absence. Coal, oil, gas, etc. are examples of this type of energy. Fuel consumption of such materials will cause irreparable damage to humanity; Therefore, we can mention the increase of greenhouse gases, climate change, the increase of carbon dioxide and toxic gases, and as a result, the temperature of the earth increases. In order to prevent the increase of these harms, the use of renewable energy sources or environmentally friendly energies, such as solar energy, wind energy, water energy, etc, should be considered. The benefits that these resources have are that it reduces environmental pollution, including reducing air pollution and premature deaths and saving health costs. Another advantage of renewable energy sources is that they do not run out; Therefore, the sun is expected to provide energy for humanity for more than five Milliard years.

[1] 1.5×10^{11}m
[2] 1.4×10^{9}m
[3] 1.3×10^{7}m
[4] 6×10^{24}kg
[5] 2×10^{30}kg

3. The sun or a hydrogen fusion reactor

Early scientists explained the process of energy production in the sun in the form of chemical reactions similar to burning coal. Today the Sun is described as a hydrogen fusion reactor, where "hydrogen is converted into helium". But this phrase refers to a process that is more surprising and energizing than the act of burning coal, etc. Burning cannot produce energy with the magnitude mentioned above. The true source of solar energy is nuclear reactions. These nuclear reactions are similar to the reactions that occur in hydrogen bombs. According to the temperature of the sun's core mentioned in the introduction and with a pressure of one billion atmospheres, in such an environment, atoms also boil and during this process a lot of energy is released. If we pay attention to the fuel of this reaction, which is hydrogen atom; the hydrogen atom, the simplest atom in the universe, is composed of a proton (a particle with a positive charge) in the nucleus and an electron (a particle with a negative charge) at a distance from the nucleus. In this process, we deal with nuclear changes and ignore electrons. Under normal conditions, two protons repel each other because they have positive charges. But the conditions that prevail in the core of the sun with high temperature and high pressure, the nuclear binding force is more effective than the electrostatic separation force. As a result, these two protons attract each other with positive charges. When two or more nuclear particles fuse together and a new element is formed as a result. The first stage of this reaction takes place when two hydrogen nuclei fuse together and a special form of hydrogen called deuterium $({}^{2}_{1}\mathrm{H})$ is formed:

$${}^{1}_{1}\mathrm{H} + {}^{1}_{1}H \rightarrow {}^{2}_{1}\mathrm{H} + {}^{\circ}_{1}e + neutrino$$

${}^{\circ}_{1}e$ (positron) is a subatomic particle whose mass is the same as that of an electron, but has a positive charge. Neutrino is a subatomic particle with very small mass and no electric charge, but these particles carry large amounts of solar energy. The second step of the reaction takes place when the deuterium atom fuses with another hydrogen atom, and as a result, helium-3 $({}^{3}_{2}\mathrm{H})$ and gamma rays (γ) are produced:

$${}^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{H} + \gamma$$

Gamma rays are actually a type of electromagnetic radiation that carries a large amount of solar energy. The third step of the reaction occurs when two helium-3 atoms fuse together, and as a result, one helium-4 atom $({}^{4}_{1}\mathrm{H})$ and two hydrogen atoms are formed:

$${}^{3}_{2}\mathrm{H} + {}^{3}_{2}\mathrm{H} \rightarrow {}^{4}_{2}H + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}H$$

Because two hydrogen atoms remain in the final reaction, only four hydrogen atoms are used to form helium-4 atoms; but the mass of the helium-4 atom is slightly less than the mass of the hydrogen atom. The difference is the mass that turns into energy.

4. The situation of solar energy in Afghanistan

Afghanistan, like other countries in the world, has problems from the point of view of lack of energy. Fortunately, Afghanistan has a huge and free solar energy potential and is among the countries that has more than eight months or 250 sunny days in per year. During a year, the sun shines more than 3000 hours [14]. According to this, solar energy is one of the most important types of renewable energy, safe and harmless in this country. The exact date of the start of work in the field of using solar energy in Afghanistan is unknown; however, studies show that paying attention to the importance of using solar energy in providing thermal energy in low temperatures, the works in this direction have been planned informally and individually [14]. Solar energy is effective in preserving the environment and can restore a significant contribution to the structure of the energy balance in the regions of the country. Most of the southern, southwestern and western parts and some parts of northern Afghanistan are deserts and uncultivable sandy plains and usually have low rainfall and high temperature up to about 45 degrees Celsius. If only one percent of the southern regions of the country, which includes the desert, are used, then Afghanitan will get 1036.5 million kilowatt hours of electricity every year.

Solar radiation absorption table in some provinces [14].

N0	provinces	Geographical location (latitude and longitude)	Average sunlight $(\mathrm{Kwh/m^2 day})$
1	Herat	34.5N&62.3E	5.40
2	Ghor	34.6N&65.3E	5.40
3	Daikondy	34.6N&66.1E	5.35
4	Paktika	33.0N&69.1E	5.34
5	Ghazni	33.6N&67.9E	5.30
6	Logar	34.2N&69.1E	5.30
7	Paktia	33.9N&69.6E	5.27
8	Kapisia	35.0N&69.7E	5.27
9	Wardak	34.5N&68.1E	5.25
10	Laghman	34.9N&70.2E	5.20
11	Bamiyan	34.9N&67.1E	5.20
12	Parwan	35.2N&69.2E	5.15
13	Khost	33.4N&69.9E	5.14
14	A Part of Faryab	35.6N&64.4E	5.12
15	A part of Sarpol	35.6N&66.1E	5.12
16	Nangarhar	34.4N&70.5E	5.10
17	Some parts of Konar	35.0N&71.1E	5.10
18	A large part of Badghis	35.2N&64.0E	5.10
19	A part of Baghlan	35.4N&68.1E	5.10
20	Some parts of Nuristan	35.4N&70.6E	5.10

Solar energy can be used in various ways. There is a type of it in Spain called PS20. The power of PS20 is obtained from 1255 mirrors. The surface of each mirror is 120 square meters and its height is 162 meters. The mirrors focus the light to one point and the water turns into steam as a result of the heat rising, and the water vapor flows into the electricity generation turbine and produces 20 megawatts of electricity. Another type is the battery that is common in Afghanistan. Solar battery with bilateral sensitivity (up to 80% of the effective activity coefficient of the one-sided one) are designed and widely used.

In recently, the use of solar energy to turn on lamps and heat water in bathrooms, cooking lights on both sides of the roads, and generating electricity has become common for many people. In the city of Kabul, up to 30% of houses use solar energy. The previous government (Republic) has provided electricity to some villages that have a lot of sunshine by distributing mirrors and battery. So far, solar electricity has been promoted in some parts of Ghor province, Bamyan, Kabul, Kapisa, Badakhshan, Helmand, Kandahar, Mazar-e-Sharif, Khost, Nuristan, Paktia, Uruzgan, Wardak and a number of villages in Afghanistan and has not threatened the people and the environment.

5. Technologies used in solar energy to produce electricity

There are two main options for converting solar energy into electrical energy. One is the use of PV systems and the other is the use of solar heat absorption systems. In the PV method, solar rays are directly converted into electricity by semiconductors. Also, in the thermal absorption method, electric power is converted into mechanical energy through thermodynamic processes and with the help of heat converting devices. Thermal absorption methods are usually divided into two categories: concentrating and deconcentrating the sun's heat. However, among all the methods of generating electricity from renewable sources, the solar PV method is considered the simplest and most elegant method. First, the two technologies of PV and solar heat concentrator are introduced, and then some examples of technologies for converting solar energy into electrical energy are mentioned.

5-1. Photovoltaic (PV)

In PV technology, solar rays are converted into electricity by small semiconductor cell plates, called "solar cells". PV cells are made in two forms: flat plate and concentrator. The flat plate type is the same as the common solar cells that direct the light to the semiconductor and then convert it into electricity. But concentrating cells first direct the sunlight with the help of a concentrating reflector and then direct it towards the solar cell. A solar module is formed by connecting solar cells to each other.

The production power of the solar cell and module alone may only be enough to charge a small battery. To build a system with a significant output (power plant), it is necessary that several modules work together at the same time. Just as solar cells are connected to make modules, modules must be connected in series and parallel to create the right amount of voltage and current. The system built in this way is called a solar array.

Figure 1: Schematic of cell, module and solar array

5-2. Concentrators of optical rays of linear parabola

Figure 2 shows one of the linear parabolic power plants of the United States of America, which consists of a large number of long reflectors of light rays. These long parabolic reflectors focus the sunlight after reflection along a long line called the focus. To use the generated heat, a tube containing a fluid that absorbs heat is placed along the focal line. This pipe is designed in such a way that it has the ability to absorb the most thermal energy and withstand the highest temperature. These pipes are usually made of steel with a black coating and a protective layer of glass, and there is still a gap between this protective layer and the steel pipe, which reduces the temperature. To increase efficiency, it is possible to add anti-reflective single-layer glass to the outer surface. In all parabola power generation systems, industrial oils are used as fluid (heat transfer) from the collector pipes for the heat exchanger. The water is heated in the heat exchanger and then becomes steam. The heat-receiving fluid pumped in the pipes is usually a mixed oil such as motor oil, which can operate at very high temperatures. During operation, the temperature of this liquid may reach 300 to 400 degrees Celsius. After passing through the absorbent tubes, the oil enters a closed system and its heat is used to produce steam to rotate the generator turbine and generate electricity. Next, the fluid returns to the collectors to absorb more heat and this cycle repeats continuously.

Figure 2: Linear shaped parabola power plant

Figure 3 shows the arrangement of a linear parabolic collector. Each set of linear parabolic collectors may be 5 to 6 meters wide, one to two meters high and more than 150 meters long. A large number of these sets are needed to provide energy to the power plant. For example, in one of the power plants in California, 490 collectors have been used with the capacity of producing 30 megawatts of electricity [11].

Linear parabolic reflectors are usually oriented north and south and mounted on a solar tracking system that tracks the sun's movement from east to west. This moving system is made of steel or aluminum. The first linear parabola reflectors were made of 4 mm glass with very high weight and price. In recent years, new developments have been made with the aim of reducing cost and weight, and new methods and materials such as polished aluminum are used instead of glass mirrors [12]. The result of energy conversion is one of the key success factors of a solar thermal power plant. Reflecting mirrors should be installed well and in the exact place to have the most efficiency in receiving sunlight. Also, the sun tracking system should adjust the position of each reflector to the best location during the day. Finally, heat absorbing tubes should also work at the highest possible efficiency [13].

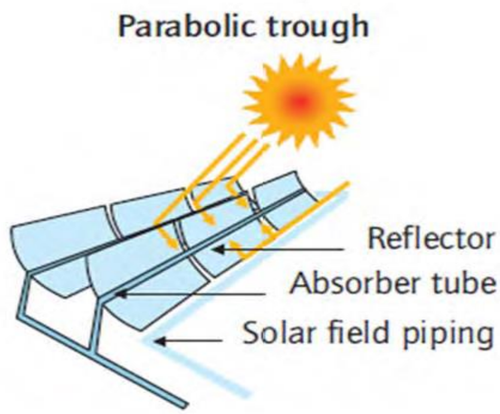

Figure 3: Schematic of linear parabola light rays concentrator system

5-3. Solar towers

Solar tower, the example of which can be seen in Figure 4-1, is often referred to as solar power plants with a central receiver. In other words, solar towers are known as central receiver systems. Solar towers are made up of hundreds or thousands of small reflectors that focus the sun's rays on the main receivers located in the center of the mirrors. In these systems, molten salts are used as a heat transfer fluid. These power plants are another method of using the sun's thermal energy, in which a solar tower in the center of the light-receiving farm consists of heliostat arrays (a mirror wheel that keeps the sun's rays in a fixed direction) Placed. On the top of the tower, receivers are designed to absorb the sun's heat. To achieve higher efficiency, each mirror has a solar tracking system that adjusts its direction according to the movement of the sun in such a way that it has the most reflection towards the receiver at the top of the tower.

The receiver is also designed in such a way that it has the ability to absorb the resulting energy with the highest efficiency and transfer it to the heat absorbent fluid. According to the design of the system, this fluid can be water, molten salt or air. Solar towers are usually designed with the ability to store energy and therefore can work around the clock (24 hours).

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The first solar towers are called Solar 1 and Solar 2, which were built in California, USA. However, these two projects remained as experimental programs and never reached the commercial stage. Solar 1 heat transfer system between 1982 and 1988 was based on water. This system was changed to molten salt in 1996 and continued its activity under the name of Solar Unit 2 between 1996 and 1999. The capacity of both units was 10 MW. The image of the tower and heliostats of these power plants can be seen in Figure 4-2.

The molten salt system of Solar Power Plant 2 was a combination of sodium and potassium nitrates with the ability to melt at a temperature of about 220 degrees Celsius. In this method, after leaving the cold tank, the molten salt, passing through the receiver, absorbs the heat from the mirrors of the solar farm and enters the hot salt tank with a temperature of more than 550 degrees Celsius to be. Next, after leaving the storage tank and passing through the heat exchanger, the molten salt transfers its heat to the water and evaporates it, causing the turbine to move and generate electricity. Then, the cooled molten salt with a temperature of about 290 degrees Celsius returns to the cold storage tank to be prepared to pass through the solar energy receiver. The order of this process can be seen in Figure 4-3

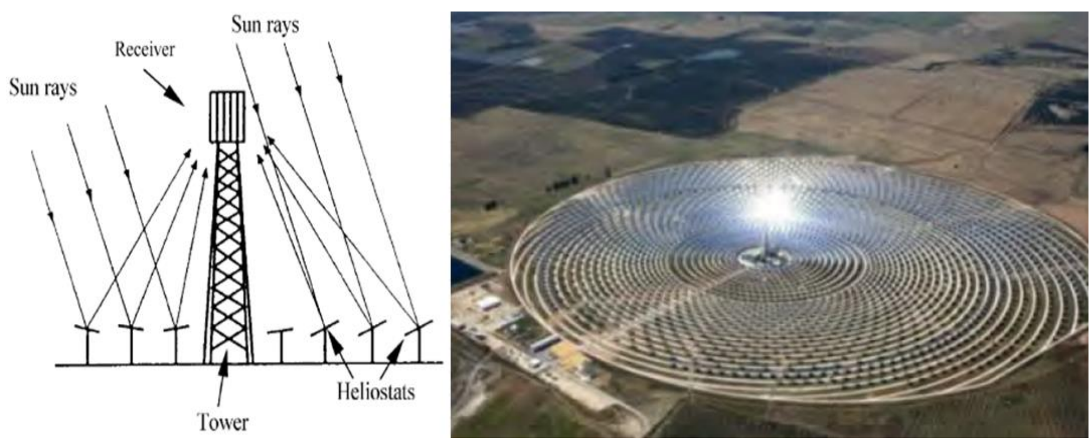

Figure 4-1: Arrangement of mirrors and central receiver in solar towers

Solar towers generally reach a high temperature, so they are more efficient and the cost of power generation has lower.

Figure 4-2: Tower and heliostats used in solar power plants 1 and 2

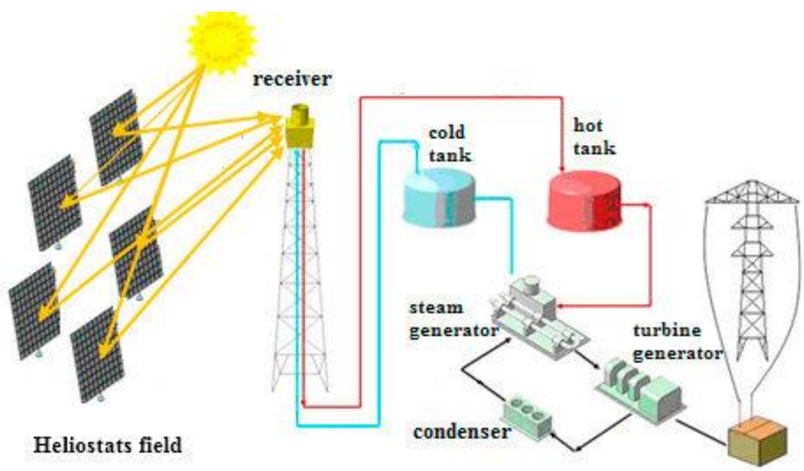

Figure 4-3: Schematic of solar tower power plant and its components

5-4. Solar plates or dishes

Another type of solar heat concentrating power plants is solar plates. This type of power plant receives the sun's radiation by using a rotating parabolic plate and directs it to its focal point. A heat engine placed in the center of the plate turns the resulting heat into mechanical motion and starts the generator. Examples of these solar plates can be seen in Figure 5-1. In common solar panels, a special heat engine called Stirling engine is used, which has a very high efficiency. Recently, efforts have been made in the field of using small gas turbines based on the thermodynamic cycle of Brighton.

Figure 5-1: Solar panels in a power plant

The structure of the solar plate is a mesh device (grid, hole) on which a large number of curved mirrors are installed. These mirrors may be made of glass or shiny metal and have a circular or rectangular shape. In the center of this plate there are bases on which the thermal engine is placed.

Normal plates have a diameter between 5 and 10 meters and a reflective surface equal to 20 to 80 square meters and can produce 4 to 25 kilowatts of energy. Although plates with size of 200 to 400 square meters and a production power of more than 50 kilowatts have also been made, factors such as raw materials and a suitable engine limit their industrial development.

The production power of existing Stirling engines does not exceed 25 kW. These motors perform better with smaller plates. Small gas turbine engines, known as micro- turbines, can provide more output; but their efficiency is much lower than Stirling engines [13].

Plates with Stirling motors are made in sizes between 5 and 25 kW. The theoretical efficiency of these engines is around 40% and their practical efficiency is close to 30%. There are also micro turbines with a capacity of more than 100 kW; but its highest capacity tested in a plate system was 30 kW. As mentioned earlier, these engines have a relatively low efficiency of around 25 to 35 percent. Like linear parabolic methods and solar towers, solar panels can also use the sun tracking system to achieve maximum efficiency.

European countries along with Australia and America have done the most research in the field of solar systems. The first solar plate system was tested in the 1980s in America. The cost of the plate and access to Stirling engines are among the factors affecting the commercialization of this system. The limited production of Stirling engines is one of the main reasons for paying more attention to micro turbines. However, it seems that with the increase of new development activities, the production of Stirling engines will increase in the near future.

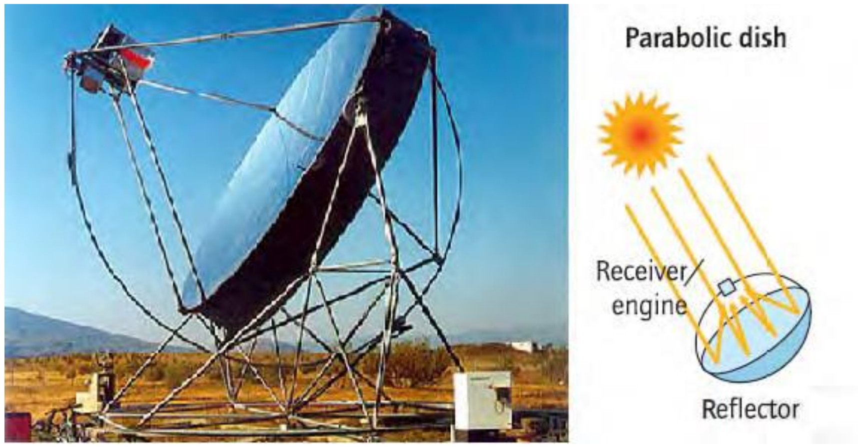

Figure 5-2: Solar parabolic dishes.

In systems with parabolic dishes, the power generation is in the range of tens of megawatts, while in systems with solar towers, the power generation is in the range of 100 to 250 megawatts.

According to the thermal analysis of modern solar systems and the amount of solar radiation in Afghanistan, it is suggested to use linear parabola light rays concentrating systems and solar towers in electricity production for large-scale exploitation.

6. Conclusion

In the presented article, new technologies for using solar energy on a large scale were presented. The thermal analysis of solar systems was also discussed. According to the thermal analysis of modern solar systems and the amount of solar radiation in Afghanistan, it is suggested to use light rays concentrating systems and solar towers in electricity production for large-scale exploitation.

Utilization of clean and renewable energies to provide electrical energy is an inevitable solution in the development of countries in today's world. Surely, if the Afghan government and energy sector activists do not take advantage of the appropriate momentum in this direction, they will leave the future of energy production in Afghanistan to the businessmen of their foreign countries more than ever before. One of the rich sources of renewable energy is solar energy, which can be used as light and heat. Light energy is converted into electricity using photovoltaic technology and thermal energy through generators with turbines or heat engines along with various solar heat concentrating technologies.

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