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Qualitative Effect of Solar Eclipse on Non Conventional Sources of Power Generation

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ABSTRACT

Human beings have advanced in all aspects of life and have designed equipment that bear the potential to reduce manual work by using mechanisms wherein energy can be converted to work. However, these equipment largely depend on electrical energy for their operation. With technological advancement, numerous methods of generation of electrical energy have been in practice of which, extensive contemporary research is been conducted in the field of non conventional energy sources. These energy sources are generally renewable and can be considered perennial depending on the method of harnessing the energy. However, the key source of life on earth is the solar radiation. It is solar radiation that facilitates various forms of life on earth and ensures meeting of the energy demand. Various other conventional and non conventional energy sources depend directly or indirectly on solar radiation for their existence. Thus we can say that solar energy is the driving force of life on earth without which, everything will come to a standstill. However, there are rare events like eclipses that hinder the intensity of incoming solar radiation thereby disturbing the stability of the energy received by the earth. This paper shall consider six power generation methods using non conventional energy sources and the qualitative effect of a solar eclipse on the output of the same. For each case the basic working shall be explained after which, key factors affecting the working shall be put forward. Thereafter the qualitative effect of solar eclipse on the factors shall be discussed to draw a conclusion regarding the most affected and the least affected methods of power generation from non conventional energy sources in event of a solar eclipse.

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A. Solar Energy

Solar Energy can be termed as the primary source of energy for life. All three modes of heat transfer work in unison to deliver this energy to the earth. The Sun radiates energy, atmosphere transfers it by convection and the earth conducts it. Thus solar energy being the primary source of life, has a greater role to play in the stability of the energy exchange on earth.

Depending on factors like the time of the sidereal year and the time of the day, the earth receives solar energy accordingly. A solar power plant basically functions by collecting this energy in the form of radiation and then converting the same into electricity.

While the design of solar power plant is done considering the maxima, there are instances when the functioning is hindered by events like eclipses, cloud cover and so on.

The qualitative effect a solar eclipse has on the functioning of a solar power plant is a temporary destabilization of energy conversion, followed by a surge in the incoming radiation once the totality of the eclipse is passed.

Thus a solar eclipse can cause exponential deficit in the power generation until the totality is reached and then cause a similar exponential rise in the power generation. This can lead to fluctuation in the stability of the power grid and may lead to browning of the equipment if adequate design parameters have not been considered taking into account the rare occurrence of a solar eclipse.

This is the single most affected method of power generation that is most affected by eclipses. While partial solar eclipses may not even depict a pronounced effect on the power generation, total solar eclipses can be unequivocally predominant in causing instability in the power generation.

B. Wind Energy

Wind is another non conventional energy source which is naturally available but is not harnessed completely due to various reasons. There are reasons like the economics of setting up of a power plant, political factors and geographical factors that govern the feasibility of the power plant. Thus although wind may be available, power plant may not always be feasible to set up.

Wind is a result of flow of a convection current. Two main types of winds shall be considered for this study which shall be land winds and sea winds respectively. Both these winds

are caused by a pressure difference due to differing heat capacities of the land and adjacent water bodies.

It may be noted that the mechanism of both these winds lies in the fact that lands gets heated up or cooled faster compared to water bodies. The difference in the heating or cooling rates causes a convection current.

Land winds are caused during the night time and blow from the land to the water. These winds can be characterized by a local convection current at the coastal region and can facilitate setting up of wind power plants in the oceans. The overall process is such that as sun sets, the layer of air near to land gets cooled faster compared to that near the surface of the water body. This leads to a current of warm air from the water body to the land and a current of cold air from the land to the water. The factors affecting power generation using land winds include location and velocity of the wind incident on the blades of the wind mill. Sun is the reason because of which heating of the land or water takes place but since land winds occurs at night, and since there is no chance of occurrence of solar eclipse at night, there is no effect of solar eclipse on power generation using the energy of land winds.

Sea winds are caused during the day time and blow from the water to the land. These winds can blow over a large region of land and by collecting moisture can get converted to moisture bearing monsoon like winds. These require setting up of wind power plants on the surface of the earth, preferably at higher altitudes as wind energy can best be harnessed as it rises uphill. The overall process is such that as the sun rises, the layer of air near to land gets heated faster compared to that near the surface of the water body. This leads to a current of warm air from the land to the water body and a current of cold air from the water to the land. In this case too, the factors affecting power generation are location and wind velocity.

Depending on the incoming solar radiation, the land and the water surfaces get heated up to certain relative temperatures. These temperatures are a result of the magnitude of the incoming solar radiation. Greater the incoming solar radiation, greater the temperature and therefore greater is the resultant velocity of the winds caused. During an eclipse, from the beginning to the totality, the incoming solar radiation goes on decreasing. Thus theoretically, the temperature should relatively decrease causing a reduction in the velocity of the resultant wind depending on the value of the temperature. Further at the totality, the velocity of resultant wind should be minimum. As the eclipse moves from totality to its end, there is a surge in incoming solar radiation which can lead to a relatively greater increase in the overall temperatures. But since winds are formed based on the gradient and not individual temperatures, it can be theoretically said that until the temperature gradient is constant after the totality, the velocity of wind is unaffected but in event the temperature gradient increases, the wind velocity also increases proportionately.

Thus during an eclipse, from the beginning to the totality, there is a decrease in the wind velocity as little consideration will show that since the energy source itself is getting cut off, there will be lesser resultant exergy to warm the surfaces of the earth and water body. However after the totality, it is the temperature gradient that governs the resultant wind velocity.

C. Ocean Thermal Energy

This method of power generation is popularly known as Ocean Thermal Energy Conversion and abbreviated as OTEC. In this method, the solar energy incident on oceans is harnessed to generate electricity.

Oceans and water bodies cover around 72% of the earth's surface. This means there exists an extremely vast coverage of earth's surface that receives solar radiation which is mostly unused. The resulting effect is that the solar radiation causes low pressure zones thereby leading to winds carrying moisture. However, at certain locations, the thermal energy of the oceans can is being harnessed. The method is known as Ocean Thermal Energy Conversion. In this method, the working principle is that there exists a temperature gradient between the layers of ocean. The topmost layer receives the solar radiation and is at a temperature slightly higher than that of the consecutive layer and so on. This can lead to a convection current wherein energy is lost in the movement of water molecules. However, this energy can otherwise be constructively used to generate electrical power. In OTEC, a low boiling point substance like ammonia is used. When this substance comes in contact with warm water, it expands. This expansion is carried out over the blades of a turbine which can facilitate power generation. Thereafter, the expanded substance, is brought in indirect contact with the colder layers of water by which the cycle can be repeated.

The factors affecting the effectiveness of OTEC are mainly the location, time of the day and the temperature gradient. There are factors like substance used and the length of the circuit which shall be out of purview of this study.

OTEC essentially works only during day time and is not operational during the night due to a feeble temperature gradient that is quite inefficient to cause expansion of the low boiling point substance.

During the day time, as the altitude of the sun approaches maxima, there is a proportionate increase in the thermal gradient causing greater energy conversion. However, during an eclipse, from the beginning to the totality, there is decrease in the thermal gradient which reduces the power generation. At the totality, the thermal gradient is theoretically least and so is the power generation of the power plant. As the eclipse advances from the totality to its end, there is a surge in the incoming solar radiation which leads to variation in the thermal gradient. The thermal gradient is largely a function of the individual temperatures of various layers of ocean water. It may possibly happen that there might be an equivalent increase in the temperature of all the layers at the same point of time thereby rendering the thermal gradient to be constant. Thus depending on the magnitude of the thermal gradient, there is power generation that can be recorded.

D. Geothermal Energy

Geographically, the earth is made up of various layers. Every layer has numerous geological characteristics. These largely govern the geography of a location. There are locations wherein water is entrapped in certain pockets. There is a

layer of rocks which is in contact with this water pocket. Due to the movement of molten magma beneath layers of the earth, the layers of rocks adjacent to the same get heated up. This heat is conducted to the water pockets.

The water pockets on absorbing the heat start generation of steam. Over a period of time, this steam can gather adequate potential and can erupt from the earth's surface in the form of a geyser. The energy of this steam can be harnessed in the form of geothermal energy.

The steam can be expanded over the blades of a turbine and power can be generated. However, it is evident that most of this process takes place with the energy already available in the earth and incoming solar radiation does not have any direct effect as such instantaneously on the process of steam formation. Since a solar eclipse lasts for a period of maximum four to five hours, pronounced effects may not be observed on the working of a geothermal power plant.

E. Biomass Energy

Biomass refers to the organic matter that makes the living organisms. This is mainly carbon, manifested in various allotropic forms.

Biomass energy conversion is a method of obtaining inflammable gases on account of decomposition of organic matter. There are various factor affecting the rate of decomposition and generation of gases. Few of them include the quality of organic matter used, dissolved impurities, weather conditions, psychrometric variables and so on.

Decomposition is best possible in locations with high humidity and suitable temperature such that the microorganisms can work out the process appropriately. Thus temperature is an important variable in the process of biomass energy conversion. If the temperature is too low or high, the microorganisms aiding decomposition may not survive. Thus it is essential that temperature is maintained at designed levels to facilitate process efficiency. Temperature is in turn a function of the magnitude of the incoming solar radiation. This is applicable in cases where temperature control units are not available. Such biomass energy conversion plants are large in number in the rural parts and constitute a major percentage of the biomass energy conversion units.

As the magnitude of incoming solar radiation increases, the effective temperature also increases. This can aid growth of microorganisms is the process parameters are adequately considered while designing the plant.

On the day of an eclipse, from the beginning to the totality, there is a steady decrease in the magnitude of incoming solar radiation. This leads to instability in the overall temperature of the biomass energy conversion plant. At the eclipse totality, the incoming solar radiation is theoretically least and as the eclipse advances from totality to the end, there is a surge in the magnitude of incoming solar radiation. This adds to the instability of temperature. As a result, on the day of eclipse, growth of microorganisms causing the required decomposition can be unstable, thereby leading to delay or imbalance in the schedule of obtaining the biogas of the desired quality.

F. Tidal Energy

Tidal Energy is one of the important non conventional renewable sources of energy.

Every 12 hours and 35 minutes, there is a change in the tidal conditions at a location near the ocean. There are two types of tides viz. high tide and low tide. Tides occur as a result of the gravitational force of the moon. However, owing to the rotation of the earth, the time is approximate as mentioned above for a certain tide.

Tidal energy conversion plants use a unique mechanism to harness the energy on account of this natural phenomenon of tide formation. Estuaries are formed alongside large water bodies. These estuaries are separated from the water body by a wall. The wall is fitted with a turbine and a valve. During high tide, when the water level in water body increases, the valve is opened and the water flows into the estuary through the valve which is connected to a low head hydraulic turbine. Once the level of water is equal, the valve is closed. When the high tide recedes, the water level in the water body decreases. At this instant, the valve is opened again and the water flows from the estuary to the water body through the low head hydraulic turbine and the valve.

By this, during every tidal epoch, energy can be harnessed and can be converted to power. This method does not depend on incoming solar radiation but is dependent on the altitude of the moon. Thus theoretically, it can be said that solar eclipse does not have a pronounced effect on the working of a tidal energy power plant.

Conclusion

Thus it can be concluded that the qualitative effect of solar eclipse on various major non conventional energy sources has been put forward. It has been found that except Tidal energy, all the other sources considered in this study are affected by the occurrence of a solar eclipse, the most affected being solar power plant while the least affected being Tidal energy conversion plant. The key parameter that governs this is the thermal gradient responsible for conversion of energy as according to heat transfer, it is not the individual temperature but the thermal gradient that acts as a driving force for heat transfer and in this case conversion of energy from its native form to electricity by means of a suitable mechanism.