Journal of Nuclear Energy Science & Power Generation Technology

Research Article A SCITECHNOL JOURNAL

The Energy Potential of Deuterium in Nuclear Energy

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Received date: 09 February, 2022, Manuscript No. JNPGT-22-47026;

Editor assigned date: 11 February, 2022, PreQC No. JNPGT-22-47026 (PQ);

Reviewed date: 25 February, 2022, QC No. JNPGT-22-47026;

Revised date: 13 April 2022, Manuscript No. JNPGT-22-47026 (R);

Published date: 04 May 2022, DOI: 10.4172/2325-9809.1000292

Abstract

Environmental preservation via deployment of green energy is increasingly becoming an everyday occurrence. In recent years, a slew of new green energy sources have been developed. Despite the challenges that this approach originally encountered, it ultimately led in the advancement and implementation of revolutionary green energy technologies. The most significant global challenge, particularly for wind and solar power stations, is the lack of consistent and reliable green energy output. This research paper offers ways to address the unappealing element of green energy generation that occurs on an irregular basis. The fundamental concept is to build specifically constructed nuclear power stations that acts as energy storage. Nuclear power plants could, in fact, act as proper energy buffers, able to operate at a minimum capacity when green energy is consistently produced, but also to operate at gradually increased potentials when wind as well as solar energy production decreases. Two significant contributions are made to the research work: proposes the use of nuclear power plants to create an energy buffer; demonstrates the theoretic features necessary to complete the fusion reaction. The proposed methodology can be further used by researchers to enhance the capabilities of nuclear power plants to generate more energy with available resource.

Keywords: Energy sources; Green energy; Nuclear energy; Nuclear fission; Power station

Introduction

Initially, nuclear energy has been extensively subsidized and controlled, however the unforeseen consequence of these measures was a pricing distortion in nuclear power, concealing real investment costs and resulting in enormous inefficiency. Subsidies and restrictions imposed by the Nuclear Regulatory Commission (NRC) should be repealed under the Price-Anderson Act. In fact, researchers argue for the elimination of all government-induced market inefficiencies in the energy sector. Every day, human as well as environmental Carbon Dioxide (CO_2) is emitted into the earth's atmosphere, having a sufficient supply to endure the next one hundred years. There is Carbon Dioxide in the atmosphere as part of the Earth's environment, which is a major greenhouse gas generated by human activities. However, human activities have hampered natural CO_2 sinks' ability to remove such gas in the atmosphere. Annual Carbon (C) emissions from the burning of fossil fuels have been approaching 10,000 gigatons in recent years, and they have been continuously rising at a rate of 1% per year.

This increasing carbon dioxide concentration contributes to our planet's global warming. Replacing and retrofitting current equipment with carbon dioxide-free equivalents that work as well as or superior is one approach to fight global warming. The years 1970-1980 were marked by a severe energy resource crisis. Hydrocarbon-based energy polluted the environment and were becoming more depleted. The number of fossil fuel-fueled cars and major businesses (huge energy users) has been steadily increasing. The development of new energy resources was critical at the time. Fission nuclear energy was presented as a necessary evil in these extreme situations. Nuclear fission reactors plants have provided our blue planet with a new source of huge amounts of energy [3]. These nuclear power facilities provide a lot of benefits, but they also have a lot of drawbacks. Nuclear fission energy is used to fill the current energy gap and give big oil corporations more time to find natural gas, new oil, and shale gas resources. Furthermore, energy generated from nuclear fission is usually inexpensive and harmless under regulated circumstances. Nuclear energy produced via fission still requires a fuel (uranium) which is abundant on the globe, it eventually runs out, as is the case with hydrocarbons. Furthermore, the most difficult problem there at nuclear fission reactor is that both the fuel and the by-products seem to be radioactive and hazardous.

Nuclear fission energy had been a necessary immoral at the time, but it was not well accepted. Despite the associated dangers, this kind of energy is being used to manage humanity's growing urgent energy problem until more sophisticated technologies allows us to switch to cleaner, greener sources of energy. If furthered, nuclear fusion has the ability to be the largest and most powerful energy source. Despite considerable advances, nuclear fusion power plants are still a long way off. The moment for nuclear power generation is now, even if it hasn't been invented yet. Nuclear fusion energy has many benefits such as fuel utilized in this technique is not hazardous in the first place and this isn't the first hydrogen or regular water isotope, since fusion among two protons is very difficult [5]. It usually employs the second isotope of hydrogen or heavy water. Because water is abundant, the fuel required for fusion reactions is limitless, inexpensive, and simple to get, environmentally benign, as well as radioactive or non-toxic. Fusion processes produce a significant quantity of energy and helium, thus there are no radioactive by-products (such as to the nuclear fission). The response itself is considerably more manageable [1].

Because it is impossible to anticipate when fusion reactors will be operational in significant numbers, it is imperative that we prepare ahead of time with green energy fields. Green energy adoption is gradually becoming an everyday occurrence for environmental preservation. Various forms of green energy have been introduced throughout the globe, particularly in recent years. The process, which began slowly but eventually resulted in the development and introduction of innovative renewable technologies, is now being hampered by significant new roadblocks. The most challenging

challenge faced by the global community was the unpredictability and fluctuation of green energy output. All new energies must be free of the negative effects that have plagued fossil fuels and nuclear power. Renewable and "free" energy sources are required for valid global alternative energy sources. When compared to traditional energy sources, these alternatives must emit less carbon. Biomass, wind, geothermal, hydroelectric, photovoltaic solar, tidal, wave, and nuclear power are all possibilities.

Wind and solar photovoltaic farms are the most common at the moment, owing to their ease of construction and operation. However, their major dependability and technical issue is that they go through periods when they generate less or none at all. The central concept of this article is to build nuclear power facilities that are specifically intended to serve as a realistic storage of energy. When sustainable wind or solar Photo Voltaic energy (PV) is consistently generated, these specifically built nuclear power plants might run at a lower capacity, but at progressively increasing capacity when wind and solar power generation slows or stops, they can act as an energy buffers [2].

Literature Review

Team of experts [3] argue for a hands-off approach in which the nuclear sector is allowed to its own resources, free of government restrictions and subsidies, to thrive or fail as it sees fit. As a result, they hold neither a right-wing conservative (removal of restrictions) nor a left-wing liberal stance (removing subsidies). They suggest a free-market approach to nuclear power, which is diametrically opposed to both views. Nuclear power is never free of the government's suffocating influence. Heavy regulation has hampered entrepreneurs' ability to develop and offer innovative nuclear-fuelled energy generating technologies. The government's stringent guidelines are based on obsolete technology and an incorrect regulatory mind set, and they prevent nuclear power production from evolving. Environmentalists who are anti-market misinterpret the consequences of a free economy in nuclear power as well as argue against it focused on issues that are really created by government intervention.

Team of experts present a new technique for evaluating nuclear energy's detrimental effect on agricultural land. The need for a financial assessment of nuclear energy's detrimental effect on agricultural land as well as the environment has been established. On the basis their study of the condition of the land and the living world, methods for evaluating the financial harm of nuclear energy's negative effect are suggested. On the basis of assessments of the condition of the ecosystem on agricultural land, examples of monetary damage estimates for such Russian Federation from negative impacts are given.

Team of experts [4] studies the history of Greenhouse Gas Emissions (GHGe) as well as their connections to nuclear energy policy, especially in Turkey. Nuclear power now emits much less greenhouse gases and has high energy efficiency, while also meeting 10.6% of global primary electricity demand. As a result, nations started to seriously consider nuclear energy as an alternative to fossil fuels. In accordance with this, Turkey has begun construction of its third nuclear power station, with the goal of meeting at minimum 15% of its main electricity demand. As a signatory to the Kyoto Protocol, Turkey is nonetheless decreasing its reliance on fossil fuels, but also aiming to meet its GHGe targets. The globalizing globe, fast expanding technology, and rising population have created a slew of issues that have thrown the global ecological balance off. Existing energy sources have now reached a point where they can no longer satisfy the world's present demands. Because fossil fuels eventually run out in the not-too-distant future, humanity will be forced to explore other energy sources.

Team of experts studied the combustion, gaseous, and particle outputs of a diesel engine running on Biodiesel Pentanol (BP) mixes at various engine speeds. The findings show that increasing the pentanol percentage delays the onset of combustion. From CA10 through CA90, all of the BP mixes burn quicker than biodiesel as well as diesel fuel. In most instances, the quicker burning of BP mixes results in a greater Brake Thermal Efficiency (BTE) than biodiesel and diesel fuel. In most test circumstances, adding pentanol to biodiesel lowers particle mass as well as number concentrations owing to greater oxygen concentration for fuel/air stoichiometry, ignition delay for fuel/air interaction, and lower viscosity for better atomization. The alcohol group throughout biodiesel is much less effective than the Functional group in pentanol in suppressing the production of soot precursors. The increasing amount of pentanol reduces the diameter of main particles. The oxidation reactivity of BP10 particle emissions is greater than that of BP20 as well as BP30. Because of its enhanced combustion performance and lower particulate emissions, pentanol-biodiesel may be regarded a viable replacement fuel for diesel engines, according to this research.

Team of experts [5] looked at the long-term viability of national energy policies in nations that are pursuing or intending to pursue nuclear energy generation. The solutions were evaluated based on the presence of 56 sustainability aspects organized into seven categories. The concepts of sustainability employed in the plans, as well as information on engagement and public involvement in their development, were also examined. The majority of the plans referenced sustainability yet did not define it. Environmental, governance, and economic elements of sustainability were cited less often than risk, waste management, as well as social aspects of sustainability. The data on consultation as well as public involvement revealed just a small portion of these procedures. The supply and use of energy are critical in the transition to a more sustainable society. Despite the fact that nuclear energy is being used or planned in 40 nations across the world, the significance of nuclear technology to sustainable development continues to be a topic of dispute.

Methodology

Design

The heat produced by nuclear fission is used in today's nuclear power plants. A heavy atomic nucleus (typically uranium or plutonium) breaks into two smaller atoms, releasing a significant amount of energy in the process. Nuclear fusion, on the other hand, happens when many light atomic nuclei meet with plenty of energy to bond and create a heavier nucleus. The release or uptake of enormous quantities of energy occurs as a result of this process; in the case of extremely light nuclei, the energy released is 3 to 4 times greater than that released during fission. In general, fusing two nuclei having masses less than iron releases energy, while fusing two nuclei having weights greater than iron absorbs energy.

Nuclear fusion happens naturally in the centers of stars as well as being a source of enormous heat. While fission doesn't really occur in nature, it is a generator of tremendous heat. Hydrogen isotopes combine together to create helium atoms in the Sun. A little quantity

of mass is transformed into energy throughout this process. This pairing of two nuclei with same charge necessitates increased kinetic energies that seem to be greater than the nuclei's electrostatic repulsion. The atoms' electrons are taken away by the very high temperature, leaving just the nuclei. Figure 1 shows deuterium-tritium fusion reaction. Here, Deuterium is fused with Tritium and output produced are neutron, helium and energy Figure 1.

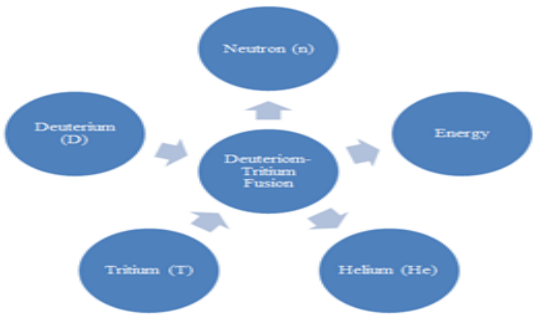

Figure 1: Illustrates deuterium-tritium fusion reaction. In this reaction deuterium is fused with tritium and output produced are neutron, helium and energy.

The sun seems to be a reasonably young star composed mainly of hydrogen in comparison to the rest of cosmos. High temperatures inside the cores of new-born stars initiate a nuclear fusion reaction, converting hydrogen to helium. Stars, on the other hand, begin to combine helium into carbon as well as oxygen until their core temperature is reached 130 ×106 K. Carbon and oxygen continue to be fused into neon in larger stars, which is subsequently melted into silicon, which is finally fused into iron.

Reaction involved

Fusion energy offers potential to provide safe, clean, and virtually unlimited electricity. Although fusion processes may exist for light nuclei weighing less than iron, other elements would not fuse until they are in the core of a star. To generate burning plasmas inside experimental fusion power plants such as tokamaks, scientists need a fuel that is reasonably simple to manufacture, store, and drive to fusion. The currently the best chance for fusion reactors involves deuterium-tritium fuel. This fuel achieves fusion states at lower temperatures relative to other elements as it releases more energy than some other fusion processes [6].

Hydrogen is one of the most prevalent elements in the universe, etc and deuterium as well as tritium is two of the element's isotopes. Nevertheless, all hydrogen isotopes get a proton, deuterium additionally includes a neutron, and tritium contains two neutrons, therefore their ion masses are higher than protium, the hydrogen isotope lacking neutrons. When deuterium as well as tritium fuses, they form a helium nucleus that contains two neutrons and two protons. The reaction generates an energetic neutron. Fusion power plants could transform energy produced from fusion processes into electricity to run our homes, companies, and other requirements.

Data collection

To get to catastrophic energy, which relies on light nuclei fusion, we need to cross over from fissionable materials. One of the most noteworthy features is that the fuel is often used in fusion reactions. It's extremely easy to make from regular tap water. In 1931, Harold Urey became the first person to extract Deuterium from water. Even back then, certain tiny electrostatic linear accelerators showed that the D-D process was an exothermic reaction. At this time, we understand that nuclear fusion might generate energy from both Deuterium, the second hydrogen isotope, and from Tritium, the third hydrogen isotope. The composition of hydrogen isotopes involved in fusion reaction is shown in Table 1 [7].

S.No	Isotopes	Composition
1	Deuterium	It contains two nucleons, one proton and one neutron.
2	Tritium	It contains three nucleons, one protons and two neutrons.

Table 1: Illustrates the composition of hydrogen isotopes involved in fusion reaction. When deuterium and tritium fuse, they form a helium nucleus, that contains two neutrons and two protons.

Data analysis

The fusion process would've been even and easy if we used even heavier hydrogen isotopes, but these isotopes are difficult to get by now. Tritium, the 3rd isotope of hydrogen, could only be produced via nuclear reactions involving two Deuterium nuclei and cannot be directly accessed (as Deuterium). The only initial reaction conceivable is between two Deuterium nuclei, a Tritium nucleus containing a proton and energy is obtained from this; an isotope of helium is obtained from this. As well as energy may be produced as shown in equations 1 and 2:

$$_1^2D+_1^2D \rightarrow _1^3T+1MeV+_1^1H+3MeV=_1^3T+_1^1H+4MeV \quad (1)$$

$$_1^2D+_1^2D \rightarrow _1^3T+1MeV+_1^1H+3MeV=_1^3T+_1^1H+4MeV \quad (2)$$

After obtaining Tritium, fusion between a Deuterium nucleus and a Tritium nucleus may occur yielding a Helium atom having high energy and neutron as shown in Equation 3. This kind of fusion reaction is preferred, but it requires a combination among two nuclei of Deuterium first:

$$_1^2D+_1^2T \rightarrow _2^3He+3.5MeV+_1^1n+14MeV=_2^4He+_1^1n+17.5MeV \quad (3)$$

Nuclear reaction among a Helium isotope and Deuterium nucleus may occur as shown in Equation 4:

$$_1^2D+_2^3He \rightarrow _2^4He+3.7MeV+_1^1H+14.7MeV=_2^4He+_1^1H+18.4MeV \quad (4)$$

The Deuterium nuclei have to have enough kinetic energy to drive the electrostatic rejection forces generated by the positive ions on the nucleus's protons in order for these processes to take place. Deuterium fuel is provided by heavy water, or D2O. To begin with, Tritium is created via a reaction between two Deuterium nuclei. Tritium may be made in the lab using the process described below in Equation 5 [8]:

$$_3^6Li+_1^1n \rightarrow _1^3T+_2^4He+4.6MeV \quad (5)$$

Lithium may be seen in significant amounts in environment. Neutrons are produced in the second and first+third reactions, which are required for reaction 5 (with Lithium). This necessitates the addition of Deuterium (heavy water) to Lithium. As a result, Deuterium and Lithium are the starting ingredients for fusion. All of

the fusion processes depicted produce He as well as energy. As a result, the fusion process is both cleaner and more efficient than nuclear fission. At very high temperatures, hot fusion happens spontaneously. Because obtaining the required high temperature in hot fusion has still been stimulating. In order to generate cold fusion, the Deuterium nuclei must be accelerated in linear as well as circular accelerator. For a favorable ultimate yield of fusion reactions, the appropriate energy of accelerating Deuterium nuclei must be properly calibrated [9].

The magnetic fields required to sustain the plasma should be maintained (particularly during cold fusion) to confine the nuclei more tightly. The fuel must be blasted with accelerating Deuterium nuclei. Heavy water as well as lithium will be used to make the fuel. To achieve maximum fuel ionization, it's critical to keep the fuel in a plasma state. Instead of Deuterium atoms, magnetic waves may produce Deuterium nuclei instead of Deuterium atoms.

Results and Discussion

The study shown here demonstrates several key theoretical elements that are obliged to take out the fusion process. It is essential to research and work to get a deeper grasp of these new features. According to equation 6 the radius of the Deuterium nucleus is the lowest between Deuterium as well as Tritium [10]:

Deuterium $A=2\ A^{1/3}= 1.259921$

$R_D=1.8268855223476E^{-15}$[m] (6a)

Tritium $A=3\ A^{1/3}= 1.44224957$

$R_T=2.0912618769457E^{-15}$[m] (6b)

After that the shortest distance between two particles which must collide is determined. This distance is equal to the diameter of the Deuterium nucleus, d12D as shown in Equation 7:

d12D=2RD=2x1.826885522347 6E-15 [m]
=3.6537710446952E-15 [m]=3.653771E-15 [m] (7)

The following equations 8 may be used to calculate the energy potential which prevents two particles from colliding:

$U=Ep=q1q2/(4\pi\varepsilon 0d12)$

$=(1.602E^{-19})^2/(4\pi 8.8541853E^{-12} x x\ 3.653771E^{-15})$

$=6.3128464855E^{-14}$[J]$=6.3128464855E^{-14} x\ 6.242E^{18}$[eV]

$=3.94E^{5}$[eV]$=3.94E^{2}$[keV]$=394$[keV] (8)

Here we have a depiction of the potential energy between two nearby particles, which may potentially be the energy needed to accelerate a particle before a collision occurs, as illustrated in Equations 8 and 9. A particle's kinetic energy and electrostatic potential energy must match up perfectly [11], Ep= $1/2mv^2$:

$$U=Ep=\frac{1}{4\pi .\varepsilon_0}+\frac{q_1q_2}{q_{12}}+\frac{q_1q_2}{8\pi .\varepsilon_0 .R}$$

$$Ep=\frac{1}{2}\ m.V^2 \quad (9)$$

The radius for Deuterium during rest (i.e., when it is not moving) was calculated using the equations (6a) and equations 10:

$$RD=r0\ .\ A^{1/3}$$

$R0=1,45E-15$[m] the average radius of a nucleon fixed (10)

A=the atomic mass

As stated in Equation 11, the required particle speed (v) for fusion has been calculated:

V=691664.8602 (m/s) (11)

If the rest mass (m0) as well as velocity (v) is known, one may use equation 12 to determine the radius of a Deuteron and any other basic mobile particle.

$$R=\sqrt{\frac{10}{8}}\ .\frac{h\ .\sqrt{c^2-v^2}\ .\sqrt{c^2-\frac{V}{2}-c\ .\sqrt{c^2-v^2}}}{\pi\ .\ m_0\ .c^2\ .v} \quad (12)$$

The value of a Deuteron's potential energy in motion is shown below Equation 13:

Radius of a Deuteron is RD=1.91788E-19 (m),

Mass of deuteron (m0)=3.34524E-27 (kg)

v=691664.8602 (m/s)

Planck constant (h)=6.626*10-34 (Js)

Light velocity (c)=2.997925*108 (m/s)

U = Ep=6.011333E-10 [J]
=3753521838 [eV]= 3759521.838 [KeV]
= 3753.521838 [MeV] = 3.753521838 [GeV] (13)

The obtained value of a Deuteron's potential energy in motion is 3.753521838 (GeV). Nuclear fission energy is being used to fill the current energy gap and give big oil corporations more time to find new oil, natural gas, and shale gas resources. Furthermore, nuclear fission power is usually inexpensive and safe under regulated circumstances. Regardless of the notion that energy from nuclear fission makes use of a readily available fuel, like hydrocarbons, it ultimately runs out. Another major issue just at nuclear fission facility would be that the fuel and byproducts appear to be radioactive as well as dangerous. Energy obtained from nuclear fission had been a necessary evil at the time, but it was not well accepted. Despite the associated dangers, this kind of energy is being used to manage humanity's growing urgent energy problem until more sophisticated technologies enable us to shift to substitute cleaner energies. Table 2 shows the output values of the calculated mathematical expression [12].

S. No	Term	Values
1	Radius of Deuterium (RD)	1.826885522347E-15 (m)
2	Radius of Tritium (RT)	2.0912618769457E-15 (m)
3	Shortest distance of collision (d12D)	3.65 * E-15 (m)
4	Energy potential to prevent collision	394 (KeV)
5	Potential energy of Deuterium	3.753521838 (GeV)

Table 2: Shows the output values of the calculated mathematical expression. The obtained value of a Deuteron's potential energy in motion is 3.753521838 (GeV).

Nuclear fusion energy, if further developed, has the potential to be the most powerful source of energy for humanity. Nuclear fusion energy has many benefits. The fuel utilized in this technique is not radioactive in the first place. Of fact, this isn't the first hydrogen or regular water isotope, since fusion among two protons is very difficult. It usually employs the 2nd isotope of hydrogen or heavy water. Because water is abundant, the fuel required for fusion reactions is limitless, inexpensive, and simple to get, environmentally benign [13].

Lithium are existing in significant proportion in nature and neutrons are produced in the second and first and third reactions, which are required for reaction 5 (with Lithium). This necessitates the addition of Deuterium (heavy water) to Lithium. As a result, Deuterium and Lithium are the starting ingredients for fusion. All of the fusion processes depicted produce helium (He) and energy and these are considered as an inert element. As a result, the fusion process is both cleaner and more efficient than nuclear fission. At very high temperatures, hot fusion happens spontaneously. Because obtaining the required high temperature in hot fusion has always been challenging, one should ponder on colder nuclear fusion. Cold fusion are produced when the Deuterium nuclei is accelerated in linear as well as circular accelerators. For a favorable ultimate yield of fusion reactions, the appropriate energy of accelerating Deuterium nuclei must be properly calibrated [14].

The magnetic fields required to sustain the plasma should be maintained (particularly during cold fusion) to confine the nuclei more tightly. The fuel must be blasted with accelerating Deuterium nuclei. Heavy water as well as lithium will be used to make the fuel. Maintaining the fuel in a plasma state in order to achieve high fuel ionization will help establish the optimum lithium percentage. As an alternative to the atom of Deuterium the nuclei of Deuterium are generated under these circumstances, which may be driven by electromagnetic fields [15].

Conclusion

The use of renewable energy sources to help preserve the environment is becoming more and more of a regular occurrence. Recent years have seen the introduction of many new green energy options. Despite the challenges at the beginning of the process, new green energy innovations were accelerated and implemented as a consequence. Despite this, new significant roadblocks continue to appear and the most challenging challenge for green energy producers across the globe is the lack of regular and predictable output from sources like wind and solar. According to the findings of this research the obtained value of a Deuteron's potential energy in motion is 3.753521838 (GeV). There are a number of potential solutions to the problem of intermittent green energy generation. The fundamental concept is to build energy buffer nuclear power reactors that are specifically built for this purpose. Wind farms are dependable, cost-effective, long-term, environmentally responsible, and reasonably priced. Nuclear fission power stations have provided the blue planet with a significant quantity of energy, but the era of nuclear fusion energy plants is rapidly coming. The methods used in this research work can be used in related studies to further enhance the potential energy of deuteron to higher extent.

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