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An evaluation of nuclear fusion, nuclear fission and ITER Reactor

DR. TIM HOPKINS
Massachusetts Institute of Technology, USA

DR. ANIKET VERMA
Indian Institute of Technology, Madras

Desperate measures are indeed needed to deal with desperate times. In today's 21st century, energy is fueling almost everything. However, our overreliance on conventional sources of energy may turn out to be disastrous for us. Therefore, there is a need to understand the concepts of nuclear energy, nuclear fusion, nuclear fission and to understand our progress in this line so far.

Keywords: Nuclear energy, Nuclear fusion, Nuclear fission, ITER

INTRODUCTION

With the advent of the third decade of the 21st century, the demand for energy is growing at a rapid pace (Atkinson, 2011). With industrial revolution 4.0 at its peak stage, there has been a massive increase in human demand for energy so as to meet its ever-growing needs (Rifkin, 2002). While the conventional sources of energy such as coal, petrol, oil and gas are depleting swiftly, they won't be able to last for more than the present century at the present rate of consumption (Yergin, 2011). Therefore, there is indeed a need of continuous search for more and more renewable energy. However, amongst the different sources of renewable energy such as solar energy, wind energy, tidal energy, hydel energy, thermal energy etc. only nuclear energy appears to be so sustainable that it can drive our demand for centuries without causing any major adverse effect (Gupta et al., 1996). Nuclear energy has potential of offering infinite amount of energy with very restricted limitations. Howsoever it may sound ambitious, it is actually extremely challenging to create a nuclear energy at such a massive scale (Stacey, 1982). While nuclear fusion and nuclear fission are two methods generally accepted for creation of nuclear energy, the fission technology has not been commercially exploited much and the fusion technology is still in its research phase (Schmitt, 2006). These technologies offer the potential of igniting the Industrial Revolution 5.0 and are of interests to this study. The present study is expected to be presented in a scientific manner so as to gauge the attention of the reader to every technicality presented here.

RESEARCH OBJECTIVES

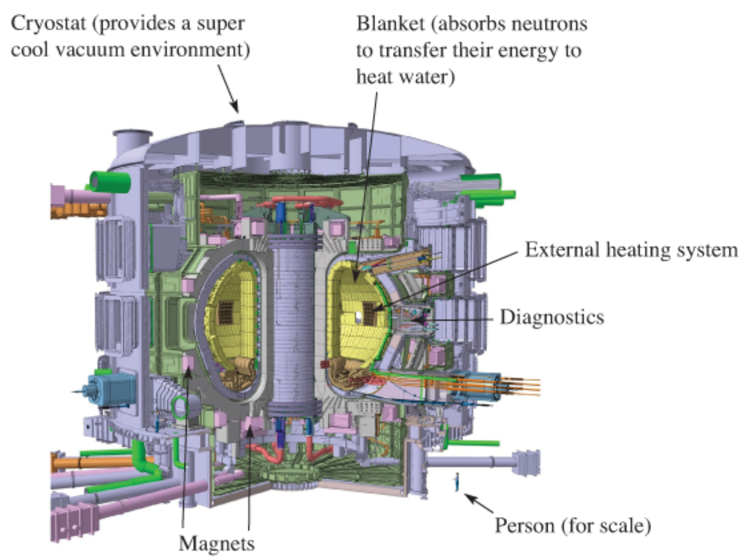
This research has the objective of understanding the concept of nuclear energy, the difference between nuclear fusion and nuclear fission, and the role of International Thermonuclear Experimental Reactor. This study further aims to expand the available literature in the field of nuclear science and tries to answer difficult questions such as why are we not able to gain enough traction in the field of nuclear fusion, what is the role of International Thermonuclear Experimental Reactor and how successful it has been so far, what is Tokamak and, how has been India's participation in ITER? Thereafter, the objective is to present this knowledge in such a manner that the general public at large is able to understand the basics of nuclear physics and are able to contribute their inputs to the overall scientific advancements. This research will therefore serve literary as well as societal purposes.

RESEARCH ANALSYSIS

Nuclear energy generates from two concepts of nuclear fusion and a nuclear fission. Sun, which is the star of our solar system has an inherent nuclear fusion happening at very high temperatures which is providing it infinite amount of energy. Nuclear fusion refers to a process wherein two different nuclei join together to create a new element while releasing a massive amount of energy (Gilleland et al. 1989). What is happening inside the sun is that the molecules of Tritium and Deuterium are combining together to create Helium and a neutral neutron (Smith, 1985). This combination is resulting in a massive amount of release of energy which is the nuclear energy (Gupta, 1996). While, what is happening in the nuclear fission process is just opposite to what is happening in the fusion process. During a nuclear fission process, a heavy unstable nucleus splits up into two daughter nuclei and this division is accompanied with the release of energy. There are fundamental differences between fusion and fission processes. Apart from their mechanical difference, the nuclear fusion involves combination of Tritium and Deuterium while nuclear fission involves split up of unstable molecules such as Uranium and Plutonium (Wang & Niu, 2012). The fusion process entails generation of huge amount of energy much more than what is generated by the fission process (Rifkin, 2002). Fusion processes are also better in terms of the residual generation vis a vis fission procedure. The fission process produces long life radioactive material which may pollute the environment if not safely disposed (White, 1998). While the fusion reactors are believed to produce short life radioactive waste because the procedure is about creating helium which is an inert gas in itself. Fission processes are able to create self-sustaining reactions because the split up of nucleus can lead to an initiation of a chain reaction however fusion requires creating a tremendous amount of temperature, heat and pressure which may not be possible for a self-sustaining reaction. This is also the reason for the question that why are we at a nascent stage on developing fusion reactors while we have been rapidly advancing in developing fission reactors. Accordingly, the availability of required amount of temperature, heat, pressure and infrastructure allows fission technology to be explored at a faster pace than the fusion procedures. The International Thermonuclear Experimental Reactor is a 1985 initiated experiment which aims to create a fusion reactor facility in the south of France (Monneret, 2015). It is an intercountry coordination wherein the world's best scientist and nuclear physicists are putting in their time, money, energy and resources to make nuclear fusion possible. The signatories to this ITER include India, China, USA Russian Federation, European Union and Japan and others totalling 35 nations. While the countries are sharing the cost of project construction, maintenance, operations, decommissioning, they will also share the results, the benefits and intellectual property generated by the project. The European Union, which is acting as the host, is contributing 45% of the project cost while the rest of the parties are required to contribute 9% each and moreover the 90% of such contribution is to be in the form of kind and not in monetary form (Schmitt, 2006). Furthermore, every country is required to create a domestic agency which will act as facilitation agency to live up to the commitments made to the ITER. The following figure denotes the inner architectural model of ITER reactor.

Figure 1.

Inner architectural model of ITER reactor



Note. This figure denotes the inner model of ITER fusion reactor (Faizan, 2019).

ITER manufacturing has been segment amongst the member countries on the basis of different components that are required to be assembled such as Cryostat, Magnets, External heating systems, Blankets, Diagnostics runner, scales etc.

India, being an active supporter of ITER project, joined it in 2005. India has been providing its services in developing cooling systems, heating systems, power supplies, in wall shielding, diagnostic services etc. India has decided to contribute $2.2 billion as its commitment. ITER India which is joint venture of Institute of Plasma Research and Department of Atomic Energy has been nominated as India’s domestic agency to ITER as per the requirements mentioned above.

It is to be understood that despite of the fact that nuclear fusion is difficult to generate and sustain on Earth, it is still being focused upon is because it offers a source of abundant energy nearly 4,000,000 times more than what obtained from burning coal, oil, gas and even four times more what is obtained from the nuclear fission reaction. It is considered as a clean fuel when compared to the conventional sources of energy. Furthermore, it is offering zero carbon emission free from greenhouse gases and therefore support the Paris agreement and the climate change negotiations. Nuclear fusion energy is massively needed for the parties to meet up to their nationally determined contributions boldly declared at various forums and to achieve their commitment to become net climate neutral in a very short period of time (Monneret et al., 2015).

Furthermore, nuclear fusion has limited risk of proliferation because nuclear fusion does not require fissile materials like uranium or plutonium (Yergin, 2011). Its input material cannot be used for making nuclear weapons or weapons of mass destruction (Yergin, 2006).

The ITER has been able to develop Tokamak which is enabling it to create nuclear fusion in the near future (Goswami et al., 1998). It is a magnetic fusion device which can harness the fusion energy and can make a nuclear fusion possible (Gilleland et al., 1989). Tokamak can be considered as an equipment wherein the energy produced is absorbed inside the walls as heat, which is then used to produce steam and then electricity by way of turbines and generators (Gupta, 1996). Tokamak uses magnetic field to control the hot plasma which further enables the fusion between tritium and deuterium releasing massive amounts of energy (Gilleland et al., 1989). Tokamak is considered safe as there is no risk of the device melting down because if in a case any disturbance happens, the plasma can cool down within a second and the reaction will stop automatically (Gilleland et al., 1989), thereby eliminating the risks of public disasters which have become usual now at coal mines, oil fields, gas fields, offshore petrol pumping plants etc (Cedigaz, 2010).

CONCLUSION

The demand for energy is going to increase at a rapid pace in the coming future. The developed countries urgently need to join hands with the emerging economies so that a sustainable solution can be taken up to meet up the energy requirements. The requirement of exploring non-conventional sources of energy is being continuously raised at multiple platforms for a number of years now. Nuclear energy offers a source of clean energy and a possible fuel of the future. It offers infinite applications and may be used for space science, nuclear science, electricity generation, health sector, telecommunication sector, education, gaming etc. The International Thermonuclear Experimental Reactor in France has been indeed a marvellous achievement in making nuclear fusion possible.

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