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Remodeling of Nuclear Power Plant using Accessible Resources and New Generation Safety Mechanism

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Abstract: *Energy grows increasingly important with globalization. An analysis of existing nuclear power plant models and possible renovations to increase their efficiency has been reviewed. Spent fuel is considered to be most hazardous. Reuse of spent fuels and rods can lead to supplementary production of power. Partnering of two power generation system can also be constructed to solve major domestic needs of people. Even after countless technological advancement in our day to day life, the safety over nuclear energy is still debatable. Hence a hazardous useful energy production can be made safe through a smart support system which can easily predict accidents in a nuclear power plant. Thus this is going to be an overview of efficient nuclear power production in a safe environment and what makes a hybrid nuclear power plant the most efficient and user friendly.*
Keywords - *Nuclear power plant, nuclear energy, supplementary production, spent fuel and rods.*

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I. INTRODUCTION

Nuclear energy has one of the lowest environmental impacts since; it does not emit carbon-di-oxide during its production. According to a recent evaluation, a nuclear power plant can supply electricity each year to serve 60 million homes. At present, about 11% of world's electricity is provided by nuclear energy and is increasing rapidly. Though the cost of construction and maintaining of a nuclear power reactor is very high, the efficiency of it is only 35%. The main shortcomings of the nuclear power plant are its low efficiency and its safety. The International Atomic Energy Agency (IAEA) defines nuclear safety as ‘‘the achievement of proper operating conditions, prevention of accident consequences, resulting in protection of workers, the public and the environment from undue radiation hazards”. The increase in population and globalization has magnified the demands of people in the past decade. The only solution to all these afflictions is by building an efficient nuclear power plant which not only produces power but at the same time can meet the needs of people and work with a complete range of protection and stability. Thus in this article, we are about to review the possible ways of enhancing the efficiency of a nuclear power plant and the partnering of a nuclear plant with other plants and providing a safe environment.

II. Enhancing Efficiency Of A Npp By Using Solar Power

Solar power is the most widely available renewable energy source. Various power production plants have been built and used to convert solar energy into electricity. Even though the efficiency of these plants are comparatively low, they are still supported as they don't cause any harm to the environment and the solar heat is available at free of cost. Various ways to enhance its performance are still being studied. Few Promising structures are discussed below.

Nuclear Power Plant	Year of Commencing	Net Capacity	Type of Reactors Used	Number of Units in NPP
Kashiwazaki-Kariwa NPP, Japan	1997	7,965 MW	BWR	Five units
Bruce Nuclear Generating Station, Canada	1987	6,234 MW	PHWR	Eight units
Hanul Nuclear Power Plant, South Korea	2005	6,189 MW	PWR	Six units
Hanbit Nuclear Power Plant, South Korea	1986	6,164 MW	PWR	Six units
Zaporizhzhia Nuclear Power Plant, Ukraine	1985	6,000 MW	VVER	Six units

Table 1: Top 5 Nuclear power plants with high capacities

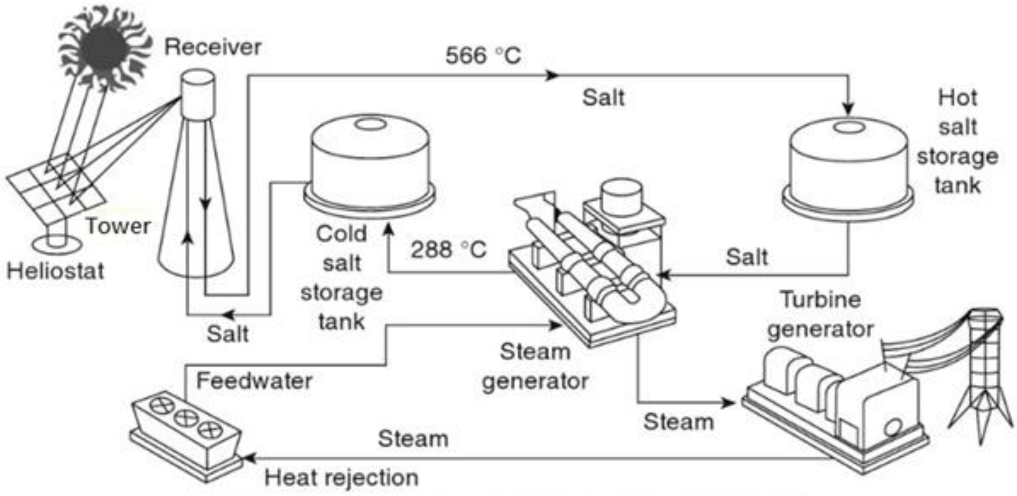
2.1 Solar Chimney Power Plant (Scpp):

One of the most flourishing solar power plants is the solar chimney power plant. The solar chimney power plant (SCPP) is a concept for a renewable-energy power plant for generating electricity from low-temperature solar heat. Sunshine warms the air underneath a very wide roofed collector arrangement surrounding the central core of a very tall chimney tower. In 1903, Isidoro Cabanyes, a colonel in the Spanish army, suggested a solar chimney power plant in the magazine La energía eléctrica. In 1982, a small-scale experimental model of a solar Chimney power plant was built in Manzanares, about 150 km south of Madrid, Spain. The power plant operated for almost eight years. The tower's wires were not preserved against corrosion and failed due to rust and storm winds. The tower blew over and was decommissioned in 1989. The central principle on which it works is that the sun heats up the ground and the air below the collector roof. The heated air follows the raised inclination of the roof. It then continues at high speed through the chimney and drives wind generators at its bottom. The higher the chimney, lower the pressure at its top and thus, increasing the flow rate and thus power output. The efficiency of the solar chimney power plant is less than 2%, and this depends on various factors, it also depends on the height of the tower. However, the area under the collector roof can also be utilized as a greenhouse for agricultural purposes. The efficiency of this plant can be increased either by building it in a very hot environment or adding it to a co power production system. The use of fossil fuels as an energy source has resulted in side effects in our environment and on human health and they are exhausting at a faster rate with the emission of GFG in the atmosphere and also causing global warming.[1]. The SCPP always runs for a longer period with just a little maintenance. The main shortcoming of an SCPP is that the efficiency of it is remarkably low, ranging from 0.5 to 10% of the solar energy input. The first efficiency evolution of an SCPP was on 1926 by Prof. Bernard Dubos, he proposed the installation of a solar chimney with adequate slope alterations. Since then, various productivity enhancement of solar power plant has been suggested.[2] Usage of reflectors to focus the extra solar heat on the collectors may increase the efficiency of the SCPP by 22.6%.[3] The main parameters on which the productivity mainly relies on is a height of the chimney, turbine pressure drop, the broadness of the collector, heat storage beneath the collector and slope of the collector. A CFD (computational fluid dynamics) proof has also been submitted. The efficiency of SCPP became the lowest at night due to lack of thermal heat and eventually, a thriving idea for hybrid SCPP was proposed by Mohammad A. Aurybi et.al.**,**[4] to improve the efficiency during the night by using exhaust gases from an additional thermal power plant, this will increase the thermal energy of the air flow in the collector. And this idea has been enormously discussed by Nima Fathi et.al,[5] where the cooling tower of a Nuclear power plant was replaced by an SCPP. By this idea, a 1000 MW nuclear plant having an efficiency of 35.3% was increased to 42%. A cooling tower in nuclear power plant effectively uses a large amount of water to cool down the excess heat from the plant. By substituting this with an SCPP can not only prove to be more efficient but also can be a solution to water insufficiency. This idea of SCPP replacing a cooling tower can be applied to PWR, MSR or VHTR. Thus, from a complete analysis of all works the low-efficiency SCPP can be added to nuclear plants to improve efficiency and its low productivity can also be reduced and can be effectively used even at nights by using certain efficient techniques and certain criteria as mentioned above by various authors. According to Nima Fathi et.al,[5] the thermal efficiency of the combined plant is the ratio of electrical energy produced to heat produced.

$$\eta = \frac{\text{Electrical energy generated}}{\text{Heat produced by the reactor}}$$

2.2. Concentrated Solar Power Plant (Csp):

Concentrated solar power(CSP) systems generate solar power by using mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area[6] suggested the concept of combining a concentrated solar power plant (CSP) to a nuclear power plant. CSP uses a huge number of heliostats to concentrate solar heat on the chimney. This may result in superheating of the steam. The maximum temperature that can be reached is about 600° Celsius. Supplementing concentrated power plant to NPP may help in superheating of the waste heat which is moved to the cooling tower thus increasing the efficiency. Addition of CSP rather than using a cooling tower may result in additional electricity production in a nuclear power plant with no drawbacks.



Scheme 1. Concentrated solar tower power plant with thermal storage

III. Smart Support System For Accident Prevention:

Nuclear power plants operate in a similar way to simple cycle coal or oil plants but, rather than burning fuel, they break atoms (Nuclear Fission) apart to release heat energy. This is used to boil water, this then produces steam, and powers a turbine from which electricity is generated. This excess heat may cause accidents at certain circumstances. Apart from this, nuclear accidents have occurred throughout the world since their first day of functioning. And their impacts are still the same.[1] One of the worst accidents in the history of nuclear power plants is Mile Island, the USA which failed on March 1979, and The Chernobyl Nuclear Power Plant in Ukraine which failed on April of 1986 and the Fukushima Daiichi Nuclear Power Plant in Japan on March 2011. After every disaster, the safety of a power plant has become debatable among the public. During the construction of every nuclear power plant the safety measures are given the most importance, but still accidents of an NPP continues, and every time a mishap occurs it always occurs startlingly and by a completely distinct cause, this leaves the researchers with a desire to construct a mechanism which can predict accidents and work as a combined electronic system.[7] Nuclear accidents in a power plant may be caused due to various factors and the most important among them are LOCA (loss of coolant accident), SGTR (Steam generator tube rupture), MSLB (Main Steam Line Break), FWLB (Feed water line break), CSS (Containment spray system) and instrument failure. Acceptable Risk Frequency with Consequence called the "Farmer Curve" was introduced as a standard tool for nuclear risk analysis. This was proposed to determine the possibilities of accidents in a Nuclear power plant. With this determination, it was easier for researchers to propose safety measures.[8] “Probabilistic consequences” of a constructed nuclear plant can be estimated using Farmer Curve. And depending on this assessment, more safety measures were made in a working power plant. Typical Farmer curve plots a graph between the annual frequency of accidents and property damage from human-made dangers. Pressurized water reactors (PWRs) compose the majority of the world's nuclear power plant and are one of three types of light water reactor (LWR), the other types being boiling water reactors (BWRs) and supercritical water reactors (SCWRs). In a PWR, the primary coolant (water) is drawn under high pressure to the reactor core. It is then heated by the energy released by the fission of atoms. The heated water then flows to a steam generator where it transfers its thermal energy to a secondary system where steam is generated and flows to turbines which, in turn, spins an electric generator. B. Gjorgieva et.al,[9] suggests a method for PWR safety which can be achieved by using a modified method for water injection. This design was influenced by the Fukushima accident caused due to loss of coolant. The proposed design consists of a water source, pipes, valves, a moving fossil-fuel driven pump connected to a secondary water storage device. And this model is clearly useful in determining the LOCA (Loss of Coolant Accident) in the reactors during the energy generation or unexpected accidents. Combining supplementary water storage tank to refill as the coolant was a good design but this doesn’t seem to be quite promising because LOCA is not the only potential accident that can be caused in a nuclear power plant. Thus, finally, a computerization tool to indicate the working of a nuclear plant and all its instruments with an indication of undergoing process was developed. This was found to be an astounding development towards the safety progress of a nuclear power plant. Due to the fourth industrial revolution throughout the world, various researchers have been working on Artificial Intelligence and a programmed tool to maintain various complicated operations. K. H. Yoo et.al., suggests a smart support system for the power plant. This program comes up with a code called the Modular Accident Analysis Program (MAAP). This is a blend of MATLAB and Python program. This program is capable of the prediction of the accident scenario and accident location with accuracy. It is also capable to predict the present working status of the plant. This consists of seven subsystems and certain configuration data's were also updated to the system. The main intention was to predict the accidents caused in the Reactor vessel (RV), Containment vessel (CV), Instrument failure, Assessment module it is also capable of keeping track of golden time which is nothing but the prediction of time take to complete a particular process in NPP. The introduction of a programmed computerized tool may predict 80% of all accidents and will be a great success towards the safety of the new generation Nuclear power plant. V.V. Korobkin et.al,[10] explains about a new generation refueling mechanism and control system. This concept explains the working of the refueling and control system as a single computer-aided component. The main advantage of this component is that there is no necessity for the plant to shut down while refueling and both the control of various processes and refueling mechanism works under as a single automated segment which predicts the present work with complete accuracy. However, it suggests the aid of a single human operator for certain decision-making responsibilities. Novo Voronezh, at Russia is currently developing its first single component refueling and ICS mechanism. Thus participation of human operator supported by an intelligent interface is more safety assuring. Energy generation from nuclear power plants can be a more promising energy source when their safety is improved. Machine and computer analysis have always proved to be more accurate throughout the decade and hence, achieving the safety of a nuclear power plant using computerized tools will definitely prove nuclear energy production to be very safe. And this will help in the encouragement of more nuclear power plants throughout the world.

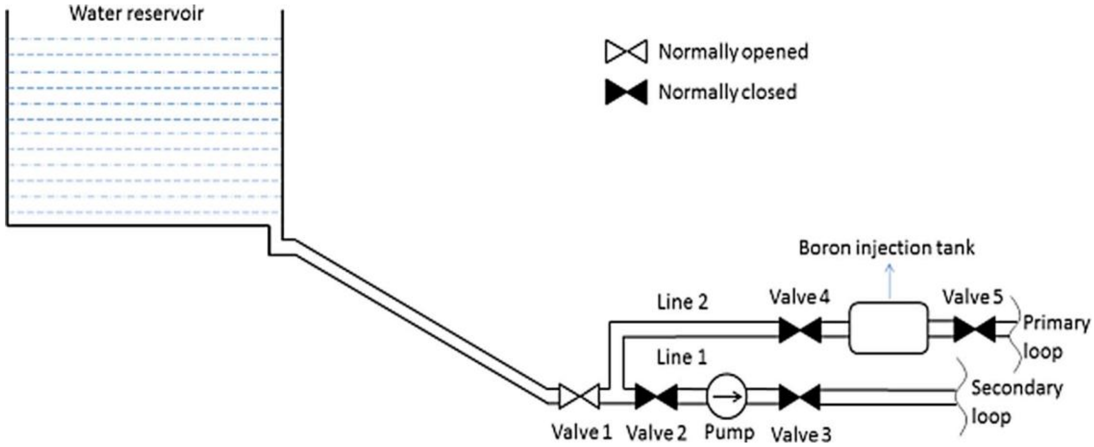


Fig. 2PSW supplementary water tank suggested system (**Blaze Gjorgiev et.al, 2017**)

IV. Multipurpose Power Plant:

Population increase throughout the world has led to increased necessities of people. By 2025, an estimated 1.8 billion people will live in areas with insufficient water and with two-thirds of the world's population living in water-stressed regions. 780 million people live without clean drinking water. And the need for water for agricultural needs has been growing day by day. The increase in population has led to a need of both clean water and energy and this necessity may increase greatly by the next decade. Hence, researchers have been thinking of all possible concepts to bring a solution to all human necessities.

4.1. Desalination Plant With Nuclear Power Plant:

Addition of desalination plant to a nuclear power plant can overcome water scarcity. The functioning of a desalination plant works under many different processes and every process requires a large amount of power to run, and this reason has been considered as a major drawback for the working of a desalination plant.[11] Various Principles of desalination plants are osmosis, Electro dialysis, Distillation etc. Here, Distillation is the processof applying thermal heat energy and then condensing evaporated air to produce water. In recent years, Desalination has been done mostly by membrane osmosis method and at present, there are 73% membrane-based desalination plants and 27% thermal desalination plants. And the reason for using numerous osmosis based plants rather than the thermal plants is that thermal heat energy is difficult to be generated.[12] The combination of a nuclear power plant with desalination plant requires only less expense for construction when compared with a fossil fuel power production plant combined with desalination. One of the most water scarce regions includes gulf countries and by 2030 these countries have planned the highest nuclear desalination projects irrespective of their pros and cons.[13] A desalination plant can be added with other energy storage system (either a battery system or PHS) and wind power. The hybrid operating model of a desalination plant suggests an additional reservoir with traditional hydropower and wind power to solve the seasonally related issues. A Desalination plant takes in a large amount of salt water for purification, this water before being distilled is filtered and processed, this water before being desalinated can be used for power production similar to the hydroelectric power production.[14] The quantity of steam consumed for desalting seawater decreased from 4.8 to 3.9 kg/kWh with an increase in pressure from 500 to 1500 k Pa. The decrease in steam consumption rates leads to the improved thermal performance of the TVC desalination plant. Attaching a desalination plant with a nuclear power plant will be a good solution. Here, desalination takes place by a process of distillation. Distillation is a water purification process that uses a heat source to vaporize water and separate it from contaminants and other undesirable elements commonly found in ground and surface water. It then condenses the evaporated water to form a drinking liquid. The heat required to evaporate sea water is used from the heat generated from the nuclear power plant. But the main disadvantage has been suggested as the reduction of efficiency in a nuclear power plant by 10% and hence a concept of supercritical carbon dioxide Brayton cycle is employed. Where, Supercritical CO2 is a fluid state of carbon dioxide where it is held above its critical point (i.e., critical pressure and temperature). The density at that point is similar to that of a liquid and allows for the pumping power needed in a compressor to be significantly reduced, thus significantly increasing the thermal-to-electric energy conversion efficiency. This seems to be like an effective design, since the lost efficiency can be retrieved. Very successful nuclear desalination plants are working in countries like Hungary, Germany, Slovakia, and Switzerland.

4.2. Industrializing Nuclear Power Plant:

Propylene is an unsaturated organic compound. It is the second simplest member of the alkene class of hydrocarbons. The industrial applications of propylene are numerous and its need is increasing day by day. Propylene production involves the reaction between propane and bromine. This reaction needs to be initiated by gamma radiation.[15] Gamma radiations are produced due to the decay of nuclei and a nuclear power plant produces a large amount of gamma radiation during its cycle. Spent rods and fuel produce a very large amount of gamma radiation. The wasted gamma radiation can be used to initiate the propylene production reaction. This can be achieved by building a propylene production chemical plant with nuclear power plant. The waste radiation emission during fission can be reused. The nuclear power plant suggested here is an MSR as it is said to emit more radiation than any NPP. Various valuable medical isotopes can also be produced at an NPP. Nuclear radiation can be used to achieve various chemical modifications of materials. Hence, an additional industrial combination with NPP can be very successful in this era.

V. Recycling And Re-Use Of Spent Rods:

A fuel rod of an average nuclear power plant is capable of containing a maximum of 140 tonnes of uranium which lasts for 2-5 years. After a fuel rod has been completely used, the rods are replaced by a new rod by the process of refueling. The used rods are called as spent rods. Spent rods are hazardous as they always keep emitting gamma radiation even after their use for so many years. When the uranium fuel is fully utilized, usually after about 18 months, the spent rods are generally moved to deep pools of circulating water to cool down for about 10 years, though they remain dangerously radioactive for about 10,000 years. Instead of cooling the hazardous materials the radiation emission can be reused or the time taken to cool a spent rod. Since the early 1990s, various concepts have been proposed to reuse the spent rods.[16] Improving the cooling and the recycling of waste heat, a dry storage cask concept (UCAN) was proposed. This concept consists of a hybrid heat pipe and heat removal device, Stirling engine, and DC generator for cooling and recycling the spent fuel in a dry cask container rather than using water. Various tests involving many cooling methods which have an integrated system on the top of the dry cask using a heat pipe and a heat removal device with an air flow path on the canister wall is used. This method was introduced alternatively so that spent rods and fuels need not be cooled for so long in the presence of water. The experimental results showed the temperature distribution of the wall inside of the dry cask under normal conditions. Direct Energy Conversion From Gamma Ray to Electricity Using Silicon Semiconductor Cells. Spent fuels and rods emit high-level gamma rays for a very long period. Reuse of these spent rods could be a promising result. Conversion of gamma radiation into electrical energy is possible by using silicon semiconductor cells made of p-type Si single crystal with various distinct resistivity's ranging from 0.01 to 1000 Ohm-cm. The highest electric power acquired for each cell ranged from 0.002 to 200 micro-W/m2 and clearly increased with increasing the specific resistivity of Si wafers. A comparison study was also made by subjecting a single crystal Si solar cell to the gamma ray, and its maximum electric power was 2 micro-W/m^2. The output power of the present cell with high resistivity was two orders of magnitude higher than that of the Si solar cell. This clearly intimates that though a spent rod cannot help in producing a large amount of power it definitely can be reused.

VI. Conclusions

It's often said that we have enough coal to last hundreds of years. But if we step up production our oil and gas reserves will be depleting at faster rates, the coal deposits we know about will run out in 2088. Oil will run out in 53 years, natural gas in 54 and coal in 110. We have managed to exhaust these fossil fuels which have their origins somewhere between 541 and 66 million years ago in less than 200 years. This will result in the necessity of electrical power production by the next decade. The reason behind not encouraging nuclear power production is that it has certain drawbacks such as, inappreciable efficiency, radioactive waste which cannot be disposed of easily and accidental nuclear accidents. But nuclear power plant produces no polluting gas, the source is inexpensive, NPP does not contribute to global warming, nuclear energy is also cost-competitive, Generating electricity in nuclear reactors is cheaper than electricity generating from oil, gas, and coal, not to speak of the renewable energy sources. Thus, nuclear power production will be more encouraged when its drawbacks are diminished and more hybrid power plant design needs to be proposed. And such a unique hybrid power plant needs to contain supplementary co-production plant which is capable of meeting the demands of people in the vicinity, more accurate accident prediction, which can reuse spent fuel and use waste heat and waste radiation to produce additional power. Such a hybrid plant is proposed and additional concepts are also suggested. When such a power plant is assembled it will be the most efficient and successful Nuclear power plant in the history of humanity.

REFERENCES

[1]. H. H. Al-Kayiem, O. C. Aja, Renewable and Sustainable Energy Rev, 58, 2016, 1269-1292.
[2]. F. M. Hussain, F. A. Al-sulaiman,, Energy Conversion and Management, 177, 2018, 30-42.
[3]. A. Hassan, M. Ali, A. Waqas, Energy, 142, 2018, 411-425.
[4]. H. H. Al-Kayiem, M. A. Aurybi, Syed, Energy, 166, 2019, 490-505.
[5]. Nima Fathi, Patrick McDaniel, Seyed Sobhan Aleyasin, J. Cleaner Production, 180, 2018, 407-416.
[6]. D. Popov, A. Borissova, Energy, 125, 2017, 736-746.
[7]. K. H. Yoo, J. H. Back, Nuclear engineering and Technology, 50, 2018, 562-569.
[8]. S. Wheatley, B. K. Sovacool, D. Sornette, Energy Research and Social Science, 15, 2016, 96-100.
[9]. B. Gjorgiev, A. Volkanovski, G. Sansavini, Nuclear Engineering and Design, 323, 2017, 8-15.
[10]. V. V. Korobkin, V. P. Povarov, Nuclear Energy and Technology, 3, 2017, 302-306.
[11]. F. E. Ahmed, R. Hashaikeh, N. Hilal, Energy and future outlook, Desalination, 453, 2019, 54-76.
[12]. S. U-D Khan, S. U-D Khan, Renewable Energy Powered Desalination Handbook, 2018, 225-264.
[13]. Y-C. Tsai, C-P Chiu, F-K Ko, Energy, 113, 2016, 1018-1030.
[14]. P. Asiedu-Boatenga, E. H. K. Akaho, B. J. B. Nyarko, Nuclear Engineering and Design, 242, 2012, 143-147.
[15]. D. Schmeda-Lopez, T. B. McConnaughy, E. W. McFarland, Energy, 162, 2018, 491-504.
[16]. I. G. Kim, I. C. Bang, Energy conversion and management, 173, 2018, 233-243.

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