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Improvement of Geothermal Power Plants by Utilizing Hydrogen Steam Superheating: A Review

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Abstract

The rapid growth of geothermal power plants is due to their great potential and environmentally friendly energy source. In its development, hydrogen is used as energy storage for several intermittent renewable energy sources. Hydrogen Steam Superheating utilizing hydrogen products can pressure steam as additional fuel to operate steam turbines. The electrolysis method with high-temperature water fluid produces more hydrogen content and is more efficient than ambient temperature water; therefore, it is suitable for producing superheating hydrogen steam by electrolysis using geothermal power plants. A combined cycle (flash & binary) geothermal power plant with additional hydrogen steam superheating can increase the power 8 - 9 MW using the mixed working fluid R-31-10 and RC-318 in a binary cycle power plant and improve the thermal efficiency of flash cycles by up to 12.3%. Thus, the application of adding hydrogen steam superheating is a method that can be utilized to increase the power capacity of geothermal power plants, replacing the current conventional method of drilling to open steam production wells.

1. Introduction

Medium voltage switchgear is an electrical power system equipment that functions as a divider, connector, controller, and protection. In Indonesia's electric power system, managed by the State Electricity Company, medium voltage switchgear is generally used in Substations. Medium voltage switchgear is one of the essential components in the electric power distribution system with a 20 kV rated voltage. Several types of medium voltage switchgear have main constituent components in the form of circuit breakers (CB). As its functions for protection and metering, medium voltage switchgear is also equipped with instrument transformers in the form of Current Transformers (CT) and Voltage Transformers (VT). There are various kinds of problems in medium voltage switchgear that cause failure of the distribution system, one of the worst of these failures is an explosion which disrupts the distribution of electric power to customers. Most of these failures are caused by explosions generated by the Voltage Transformer (VT). Based on Research and Development Center of State Electricity Company shows that the ferroresonance phenomenon causes the highest VT failure. The explosions of VT due to ferroresonance occur in certain types of VT, and production years. Therefore, designing the right VT and medium voltage switchgear is essential to avoid this ferroresonance phenomenon.

Sustainable energy developed from renewable energy, a fuel source for electrical power, has grown quite rapidly. In 2000, only 18.7% of renewable energy sources were used as a source of world electrical energy, then increased in 2018 to 25.6%, and it is predicted that in 2024 it will reach 30% in the world [1]. However, the global electricity demand continues to decline by 1% in 2020 due to the Covid-19 pandemic, leading to non-renewable energy sources dropping by 3% and an increase in the use of renewable energy sources from solar photovoltaic of 23% and wind of 12% [1].

Geothermal energy is generated from the decay of radioactive particles in rocks in the earth's core [2]. Geothermal energy power plants can only be built on geothermal sources with high temperatures located near the surface. The development of a geothermal power plant system and the improvement in drilling and excavation technology allow the creation of a geothermal power generation system combined with other energy sources in one system to improve efficiency.

Hydrogen becomes clean energy when produced with renewable energy sources (green hydrogen) developed in many countries, especially developing countries. Many countries will use hydrogen estimated to become a future environmentally friendly and highly efficient fuel [3]. The supplied energy produced from hydrogen is clean since it only has water steam as an emission during the process. Hydrogen energy, especially in the form of hydrogen fuel cells, offers advantages such as unlimited and non-polluting fuel, thus attracting many industries such as the automotive and power generation industries to use it [4].

Hydrogen is considered a secondary source of energy and an energy carrier, and the process is by combining oxygen from the air with primary fuel to increase turbine power. The utilization of hydrogen as a power plant is still relatively low at 0.2% with the newest gas turbines. It is designed to accept 3 - 5% of the total hydrogen fuel, which is expected to increase to 30% in the next decade [5]. Hydrogen fuel has an essential role in reducing environmental impact, so it is projected to replace fossil fuels in the future entirely.

The development of hydrogen gas as a fuel that could be used singly or in a gas mixture known as Brown's gas was discovered by Yull Brown in 1974. Brown's gas, also called Oxyhydrogen, is a mixture of monatomic and diatomic H_2 with O_2. Brown's gas has better economic, high efficiency, and environmental affinity than acetylene gas and LPG (*Liquefied Petroleum Gas*) [6]. When burned, Brown's Gas deflates because its volume is greater than the H_2 and O_2 gases mixture before the combustion process. Brown's gas does not exhibit the monatomic properties of O or H, but it produces some H_2 and O_2 during production. These H_2 and O_2 gases as an alternative fuel source to increase steam supply by burning H_2 and O_2 gases in steam generators that produce superheating steam as an additional supply to improve steam turbine performance in geothermal power plants [7].

In Indonesia, there are 312 geothermal fields spread across several islands with a total potential estimated of 28910 GW [8]. In applying superheating steam to geothermal power plants, many aspects should be considered, such as the technical and economic aspects adjusted to the needs and demands of electrical energy in the surrounding location. In Indonesia, the development of Hydrogen steam superheating can be carried out in geothermal fields in remote areas such as the Mataloko Geothermal Power Plant, East Nusa Tenggara, which in 2015 still has an electrification ratio of 58.67% [9]. The total steam supply from three wells produced is only about 25 tons/hour. Mataloko Geothermal Power Plant requires about 40 tons/hour of steam to generate 2.5 MW of electricity [10]. The comparison cost between addition wells and producing hydrogen is one of the parameters for developing hydrogen steam superheating.

Currently, there were around 80-85% of hydrogen production in the world derived through reforming methane vapor from natural gas for a large scale, including industry, coal gasification about 10-15%, and electrolysis of water about 5%, which is commonly used in small-scale production [11]. This industrial method of producing hydrogen is considered to be energy-intensive and not always environmentally friendly. Developing sustainable and renewable energy-based hydrogen production techniques (wind, solar, biomass, geothermal) will gradually replace fossil-based low-carbon hydrogen. In this transition condition, global warming issues related to greenhouse gas emissions to the atmosphere are of critical importance, which will lead to scenarios of hydrogen production, whether carbon capture or sequestration or decarburization can be applied as a mitigation or adaptation measure to avoid the release of CO_2 [12].

2. Materials and Methods

A. Hydrogen Production Methods

Hydrogen is one of the elements widely available in nature, but not entirely in the form of gases. Some are in the form of compounds, for example, water, coal, and natural gas. The production of hydrogen gas from these compounds requires energy to break chemical bonds. Hydrogen as an energy carrier is secondary energy that must be processed to become another energy source, including natural gas in coal gasification, methanol electrolysis, water electrolysis which is relatively expensive. Another method uses biogas; however, it still requires sufficiently high heat energy during its process. In the industrial world, many industries still use oil, coal, and natural gas as raw materials to produce hydrogen, which has dangerous and damaging by-products to the environment. This practice is due to the various advantages and disadvantages obtained, and further studies need to be carried out to examine each method [13].

Hydrogen is also used as a hydrogenation agent by adding saturation to unsaturated fats, such as methanol and vegetable oils, to upgrade biodiesel quality [14]. Nowadays, hydrogen is used as a fuel-cell material for vehicles projected to overcome the disadvantages of BEV (Battery Electrical Vehicle) [15].

A technology used to produce hydrogen can also work according to the benefits of geothermal energy, which has several advantages, including increasing the efficiency of the electrolytic process to reduce pollution compared to conventional hydrogen production. Some hydrogen production processes are developed by utilizing geothermal energy, such as steam reforming, water electrolysis, and the thermochemistry of the sulfur-iodine cycle. Each process is always entered by feed and energy, then the output is in the desired chemical, and energy losses are included.

a. Water Electrolysis

This process using electricity to separated water molecules (H & O) in a common way to produce hydrogen. Electricity also flows through a cell intermediary with two electrodes containing an electrolyte solution (potassium hydroxide). The reactions that occur from the electrolysis are described [16]:

$2H_3O+ + 2e- H_2 + 2H_2O$ cathode (1)

$3H_2O$ $½O_2 + 2H_3O+ + 2e-$ anode (2)

H_2O $H_2 + ½O_2$ (3)

Water electrolysis is carried out by passing an electric current to the water through two electrodes (cathode and anode). In order to speed up the electrolysis process, therefore the water is mixed with a catalyst. One of the catalysts that can be used for the electrolysis process is KOH (Potassium Hydroxide). This KOH solution will break hydrogen gas and oxygen gas in water easily and form HHO. Production of HHO gas estimated will be increased by raising the concentration of KOH catalyst. With the effect of current, which comes from the voltage, it is possible to accelerate the production of HHO gas from electrolysis results [17].

The efficiency of an existing electrolysis process is generally 80%, being the only method of hydrogen production without carbon dioxide emissions into the atmosphere (zero-emission) if electricity is used from renewable sources [18].

One of the advanced electrolysis methods is High-Temperature Steam Electrolysis (HTSE) which being developed with high operating temperatures of 700 - 900ºC. Considering, replacing some of the electrical input with thermal energy, which is much cheaper than electrical energy, impacts the production cost of hydrogen compared with conventional electrolysis [19].

However, in reality, in the early stages of development, this technology also requires a sizable capital of 1300 $ / kW for Alkaline Water Electrolysis (AWE) and 2500 $/kW for Polymer Electrone Membrane (PEM) [20]. The electrolysis installation with PEM has a high working density and efficiency of up to 85% or more however, the development of the PEM method requires cathodes and anodes of new non-precious metals to reduce investment costs [21].

b. Steam Reforming

The steam reforming method is a thermal decomposition process that currently generates 48% of the world's hydrogen production [22]. This process reacts by reacting a natural gas in the form of methane and steam, which is present at high temperatures, and high thermal efficiency due to natural gas in the form of fossil fuels contains CH_4 (methane), including short chain and light hydrocarbon molecules [23]. Natural Gas also contains much heavier hydrocarbon molecules such as ethane, propane, and butane [24].

There are two reactions, first reaction is a reforming, which is an endothermic reaction, and using a catalyst at high temperature. The reforming reaction is carried out in a reformer containing a nickel catalyst which is at a pressure of around 1-30 atm [25].

The second reaction is exothermic (shift reaction). The next stage is a separation process of carbon dioxide as well as hydrogen purification. The steps for the steam reforming reaction are as follows [26]:

$CH_4 + H_2O = CO + 3H_2$ (4)

$CO + H_2O = CO_2 + H_2$ (5)

The heat needed for steam reforming reaction can be obtained by utilizing heat coming from nuclear power plants with High-Temperature Test Reactor (HTTR) type that has wall cooling with helium gas. Steam reforming process using fossil fuels, the heat needed to burn methane is also excessive, resulting in a reactant occurrence [26].

In its application, the utilization of nuclear heat can also reduce the loss of reactants. In a heat reforming supplied by a nuclear power plant, the heat originates from the secondary loop of the nuclear rector. It is transferred to the intermediate steam or methane mixture as an intermediate heat exchanger. The purity of a gas resulting from steam reforming is now using an upgradeable solution. Then the removal of CO_2 gas with an alkaline scrubber besides that it can also use an amine solution, in the end hydrogen gas produced is then cooled by low temperature and purified [27].

c. Thermochemical Process of the Sulfur-Iodine Cycle

The sulfur-iodine (S-I) cycle produces hydrogen thermochemically by splitting water into hydrogen and oxygen through a chemical reaction at high temperatures [28]. This S-I process benefits from being environmentally friendly, high thermal efficiency, and easy to combine with renewable and sustainable energy sources such as solar, wind, and biomass [29]. This process has the advantage of producing hydrogen efficiently without emitting CO_2 gas. This process consists of three chemical reactions, namely [28]:

$H_2SO_4 = H_2O + SO_2 + ½O_2$ (6)

$I_2 + SO_2 + 2\,H_2O = 2\,H\text{-}I + H_2SO_4$ (7)

$2\,HI = H_2 + I_2$ (8)

The first reaction is the decomposition of sulfuric acid, which then produces H_2O, SO_2, as well as oxygen gas. SO_2 Gas is recycled and then used in the second reaction. The second reaction is the reaction between I_2, SO_2, and H_2O, including an exothermic reaction by the excess of iodine solution. This reaction is then produced with two product phases, namely the heavier phase, the HI phase. The lighter phases, such as the H_2SO_4 phases, will be separated using the centrifugal method. The third reaction is then decomposition with Hydrogen Iodine (H-I) using distillation. All reactants other than water are also regenerated or recycled to be fed to the second reaction. Its development in a nuclear power plant is being developed to produce hydrogen with a 50 MW thermal Sulfur Iodine cycle. The thermal efficiency of this process is predicted to be 50% [30].

B. Geothermal Power Plants

A geothermal power plant is a thermal power plant that does not require fuel, therefore they do not affect fuel price fluctuations. However, the capital issued tends to be high. Deep drilling accounts for more than half of the overall normal, and exploring existing geothermal sources will add even more risks. In a study in the U.S.A (United States of America), flash cycle geothermal power plants with an investment value of $ 1100 to $ 1200 per kW in early 1994 their price decreased to $ 600 to $ 800 per kW in just three years. In the binary cycle, it is believed that there has been no significant change in costs due to the lack of competition in the geothermal market [31].

Electricity generated by geothermal with scalable, including a small generator, can provide electricity for a rural area, even though it requires high funds. This issue causes the electricity price from geothermal energy to be challenging to compete with power plants from other renewable energy sources.

A geothermal power plant has the same principle as any other power plant which uses a steam turbine. The heat that comes from this fuel is used to heat water or other suitable fluids. In several case studies, the fluid used in the power plant experienced phase changes; afterward, it is used to rotate the turbine linked to the generator to generate electricity. Then the fluid will be cooled in the condenser and then returned to the previous heat source in a liquid phase.

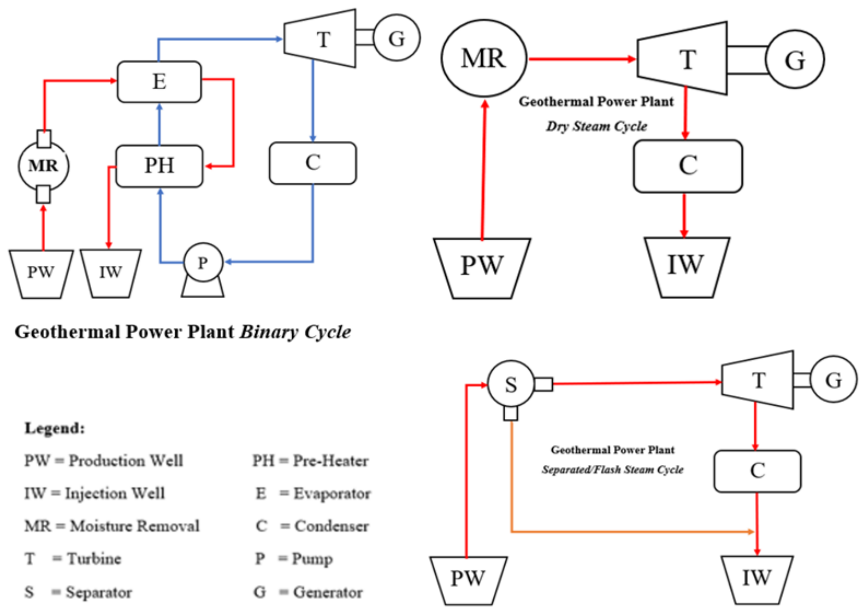

Figure 1. Geothermal Power Plants System

1. Dry Steam Cycle

Dry steam cycle using superheated steam as working fluid. This system is the simplest, where geothermal steam from many production wells is directly flowed to moisture removal to filter particles before entering the turbine which is coupled to a generator to be converted into electrical energy [32].

2. Separation Cycle

The working principle of the steam cycle from the separation is a mixture of steam and liquid (brine) with high pressure from the depths of the earth into the tank to separate the steam from the fluid (brine) then the steam is produced to turn a turbine, while the fluid is re-injected back into the earth. This type is commonly called a single flash cycle and then upgraded to a double flash cycle which can produce 15-25% more power than a single flash cycle with the same data of geothermal fluid [33].

3. Binary Cycle

Binary cycles are applied when the geothermal fluid has a low enthalpy and liquid dominated, but with new chemical technology that allows the development of new mixtures of working fluids. The benefit of such power plants is that the geothermal fluid is circulating in a loop. The geothermal fluid is not too hot because it has flowed through the secondary fluid, which has a boiling point below the boiling point of water. After all, the secondary fluid is evaporating and then turning the turbine. Secondary fluids are organic fluids such as Refrigerant R134a, Isobutane, Isopentane, n-pentane, n-butane, and ammonia. Examples of advanced this method include Kalina Cycle using a mixed fluid of water with ammonia and Organic Rankine Cycle (ORC) using organic fluids [34].

a. Efforts to Produce Hydrogen Steam Superheating from Geothermal

Many methods are used to produce hydrogen in geothermal power plants, such as directly utilizing geothermal steam, water electrolysis, and thermochemically. By utilizing NCG (Non-Condensable Gas) gas produced by geothermal steam, hydrogen production in the Bjamarflag geothermal field, Northern Ireland reaches 50 tons of H_2 each year [35]. The feasibility study of geothermal energy for hydrogen production estimates that using geothermal energy is about 16% of energy consumption used for electrolysis and 2% for the liquefaction process [36].

The electrolysis process is a simple method to produce hydrogen steam superheating because it separates the elements of hydrogen and oxygen, which are then combined again in the Hydrogen Oxygen Steam Generator (HOSG) to be burned to produce high pressure steam [37]. Water electrolysis uses electricity in a geothermal power plant system to produce pure H_2 and O_2 gases [38].

There are two practical ways of producing hydrogen gas, namely the dry cell type and the wet cell type. The wet cell type has a relatively lower gas leakage rate than the dry cell type, therefore the gas production will be relatively higher. In previous research, they used variations in electric current, variations in pulse voltage [39].

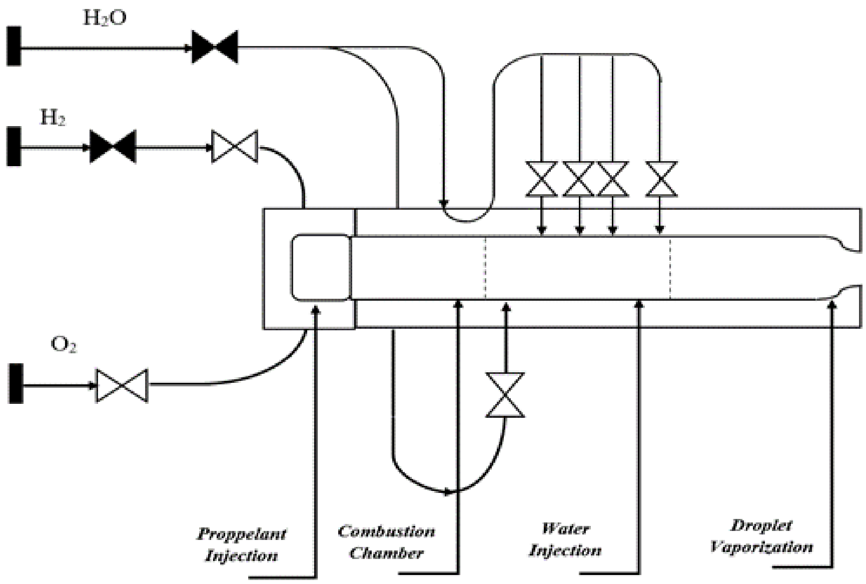

Figure 2 Concept of Hydrogen Oxygen Steam Generator

The production of hydrogen from the electrolysis process at a geothermal power plant has an estimated price of around 2.2-7 $/kg. This price is the lowest compared to other renewable energy sources such as solar 10-30 $/kg and wind 7-11 $/kg [40]. The Proton Exchange Membrane (PEM) electrolysis method is a simple, sustainable technology and has a high ability to produce hydrogen compared to the Alkaline Electrolysis method even though the cost required is lower. Modeling hydrogen production in geothermal power plants is categorized based on the source used for the electrolysis process [41].

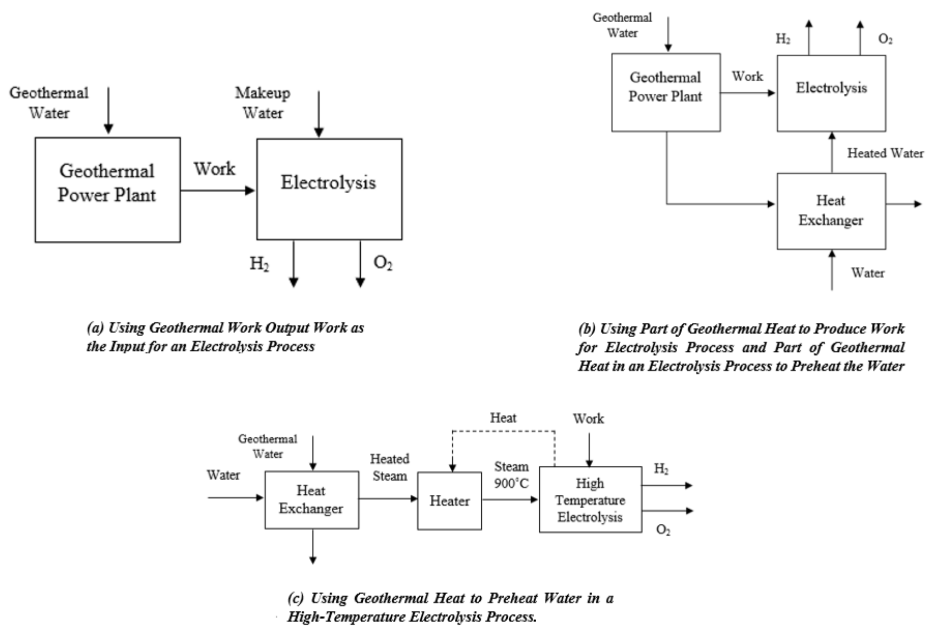

Figure 3. Methods of Hydrogen Production with Electrolysis in Geothermal Power Plants

Three electrolysis process models that can consider in producing hydrogen, as well as oxygen in geothermal power plants in Figure 3 thermodynamic analysis of the electrolysis process modeling using electricity generated from geothermal power plants in case A (Figure 3) with a makeup water temperature of 25˚C, produces 0.001343 kg of hydrogen from every 1 kg of geothermal working fluid, in case B (figure 3) by using part of the geothermal heat to heat water from a temperature of 25 ˚C to 85 ˚C in a heat exchanger where the water is used for the electrolysis process produces 0.001418 kg of hydrogen for every 1 kg of geothermal working fluid. In case C (Figure 3) uses the High-Temperature Steam Electrolysis (HTSE) method with an additional heater so that the electrolysis process uses 900˚C steam heated using heat from the electrolysis process to produce 0.001911 kg of hydrogen per 1 kg of geothermal working fluid [42]. Another research was carried out on the flash binary combination cycle using power from a geothermal power plant as a working input for the electrolysis process of 156.865 kJ/kg with water electrolysis at a pressure of 1 atm in saturated liquid conditions to produce hydrogen at 0.0482 kg/s and modeling using water electrolysis heated to a temperature of 70˚C with a heat exchanger produces hydrogen of 0.04982 kg/s with electrolysis work of 151.979 kJ/kg [43]. Many research for geothermal-driven hydrogen production systems reviewed is show in table 1.

Table 1. Summary of geothermal-driven hydrogen production systems based on research

Reference	Objective	Hydrogen Production
Yilmaz *et.al* (2015) [44]	Thermodynamic & exergo-economic analyses	0.0498 kg/s
Yuksel & Ozturk (2017) [45]	Energy, exergy & thermo-economic analyses	0.075 kg/s
Yuksel *et.al* (2018) [46]	District cooling, domestic hot water & hydrogen production	0.055 kg/s
Kianfard *et.al* (2018) [47]	Desalination and hydrogen production	15.9 kg/h
Gholamian *et al*. (2018) [48]	Incorporating TEG and hydrogen production with geothermal-based ORC	304.2 kg/day
Cao *et al*. (2020) [49]	Working fluid selection	11.42 g/s
Han *et al*. (2020) [50]	Zeotropic mixtures	0.3683 kg/h
Ghaebi *et al*. (2017) [51]	Working fluid selection based on the total revenue required method	1.197 kg/s
Ebadollahi *et al*. (2019) [52]	Utilizing LNG as a heat sink	5.439 kg/h
Karakilcik *et al.* (2019) [53]	Investigation of Chlor-alkali cell	21.1 kg/h

The design of the hydrogen-oxygen steam generator must be adjusted by the parameters of the steam turbine used. Consumption of hydrogen and oxygen, respectively 132.3 kg/hour and 1058.2 kg/hour, required storage with pressure below 200 bar for hydrogen with a capacity of 177 m^3 and oxygen 89 m^3 to work 24 hours fully and automatically [54]. The investment cost of the hydrogen and oxygen storage system is estimated at USD 123000, of which 85% of the cost is electrolysis equipment [55].

b. Effect of Addition of Hydrogen Steam Superheating on the Flash Cycle

The fluid in the wellhead is a mixture of two phases of liquid and vapor in the separator. The pressure is lowered, the water content is separated while the steam is used to rotate the turbine, the schematic is described in Figure 4. There are some difficulties in using geothermal power plant with flashed steam system type, such as; it requires a lot of working fluid, it needs a deeper well, the mineral content is high therefore special designs of piping equipment, pumps, separators, and others are required [56].

The steam from the well is pumped to the separator to separate the steam and water content from obtaining dry steam. The water from the separation from the separator is then flowed into the settling basin or settling pond to be injected again into the bowels of the earth. The dry steam from the separator has then flowed to the scrubber. In scrubbers, the steam is filtered again to remove the condensate formed before entering the turbine so that the steam used is expected to be dry and clean. After that, the steam enters the turbine coupled with a generator to do work and generate electricity. The steam that comes out of the turbine is then condensed into the condenser to become liquid again and flows to the Cooling Tower. In the cooling tower, the water resulting from the condensation is cooled to a certain temperature then the water is flowed into a settling pool before being injected back into the bowels of the earth.

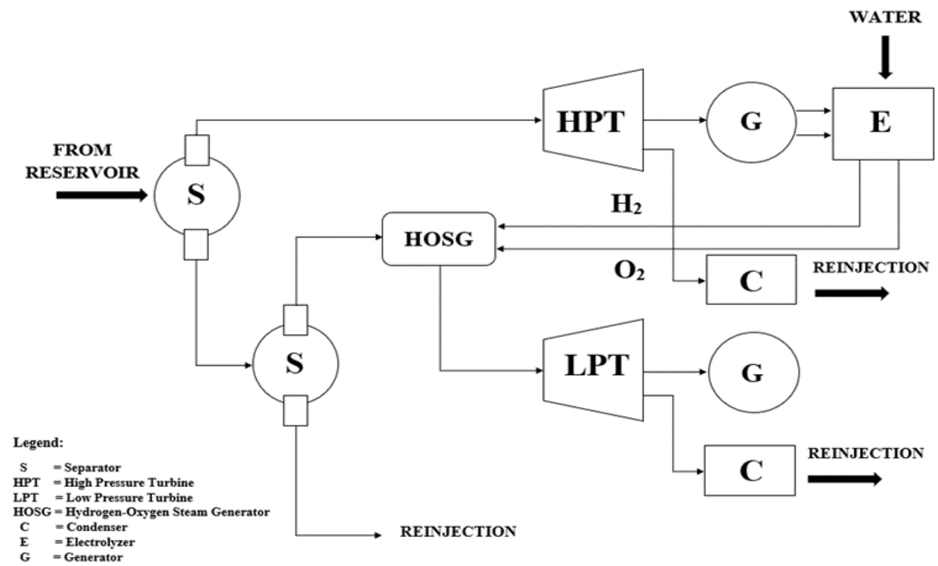

Figure 4. Double Flash Cycle with Hydrogen Steam Superheating at Geothermal Power Plant

In this double flash cycle, Hydrogen superheating hydrogen vapor helps increase the mass flow of steam from the second flasher to increase the power of the low-pressure steam turbine. The second flash process increases the steam flow temperature by 20-30 K in the turbine and improves steam quality by 2 - 4% at the turbine outlet [57]. The potential for steam production resulting from the second flash process increases thermal efficiency from 10% to 12.3% of the 11.1 MW geothermal power plant capacity [58].

c. Effect of Superheating Addition of Hydrogen Steam on the Binary Combination Cycle

System of Binary Cycle is generally used to increase thermal efficiency, so it is often used as a bottoming cycle. In increasing the efficiency of water from the ground it is used as a hot water source in a closed cycle to heat the organic fluid which is pumped back into the soil or reinjection. The heat exchange that occurs is the exchange of heat between geothermal fluid and organic fluid, so that dry steam is produced to drive the turbine with a closed Rankine cycle and is condensed on the surface of the condenser and the condensate that has been pumped back to the heat exchanger [59].

In its development, the binary cycle is combined with a flash cycle in which superheating of hydrogen steam is added to the flash cycle as the main cycle. The performance of the binary cycle is greatly influenced by the working fluid used. The organic fluid used is a Group I refrigerant, which is non-toxic, non-flammable, non-explosive, and certainly does not damage the ozone layer. This type of organic fluid uses refrigerants R-31-10 and RC-318 [60].

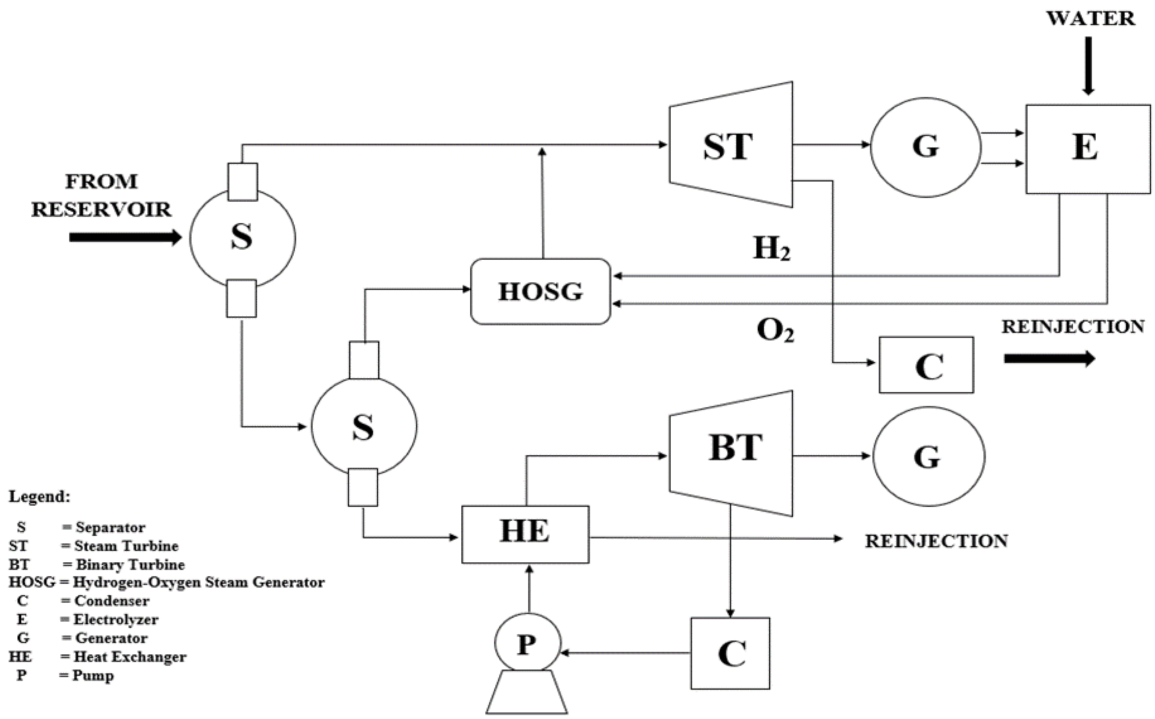

Figure 5. Combine Cycle with Hydrogen Steam Superheating at Geothermal Power Plant

Power generated by the binary cycle with the mixed working fluid R-31-10 with RC-318 increased by 8.5 - 9.0 MW, but in the flash cycle, the turbine power was reduced to 5.5 MW due to increased pressure in the separator from 0.15 to 0.45 MPa. The numerical modeling results on the combined binary cycle using a separator reduce the turbine power yield by 0.2 – 1.0%, but there is a possibility of reducing the steam's humidity level at the turbine outlet by 1.0 – 3.0%. Based on a numerical study, the organic fluid R-31-10 is the right choice to produce a large power output with a small brine flow in the binary cycle [61].

3. Results and Discussions

The method of hydrogen steam superheating to increase the power of steam turbines in geothermal power plants encounters various challenges. The production of hydrogen is an essential factor in the feasibility of this system, apart from the substantial cost of hydrogen and the process to obtain it. The hydrogen production method to produce hydrogen steam superheating should use a renewable energy source in a single grid, such as combining photovoltaic cells or small-scale wind turbines that are geographically adapted to the surrounding geothermal power plant area to create sustainable development in the energy sector.

Hydrogen production from water electrolysis is possible to implement in geothermal power plants, considering its flexibility and ease of obtaining raw materials. In the future, the development of electrolysis water will allow the use of the HTSE method with high temperature and pressure steam generated by utilizing a heater or residual steam from the turbine outlet to obtain a sufficiently large hydrogen content, although further studies are needed.

Additional hydrogen steam superheating is considered feasible in existing geothermal power plants that need additional power capacity. Several geothermal power plants in Eastern Indonesia have limited capacities and cover areas with low electrification rates. In the future, the population in this area will increase and impact the increment of energy demand.

4. Conclusion

Hydrogen can become the dominant energy to replace fossil fuels in the future. This encourages the development and research on modeling the use of hydrogen. Therefore it can be used as much as possible in various sectors, especially in power generation.

In electrical power generation sector with renewable energy sources has an intermittent nature that requires energy reserves at peak conditions to fulfill the load demand. Hydrogen has various advantages that are considered appropriate for use as a secondary resource processed in the form of energy storage. Hydrogen steam superheating is a development innovation for steam power plants with energy sources from geothermal.

Method of high-temperature water electrolysis for producing hydrogen in a binary flash combined cycle geothermal power plant system with organic fluids R31-10 and RC-318 makes the binary cycle is environmentally friendly for the recommended method to be used.

Implementation of hydrogen steam superheating in geothermal power plants encounters various challenges, such as the hydrogen production method to the steam generator. The current method to increase the capacity of geothermal power plants is by preparing new wells to produce more steam, but with various risks that have been taken into account. In the future, hydrogen steam superheating method is worth considering as a replacement of the previous method to create a geothermal power generation system that is efficient, reliable, and sustainable.

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