Aquadest Production with Compression System: Influence Cyclone Separator Pressure and Percentage of Water Discharged on Specific Energy Consumption

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ARTICLE INFO	ABSTRACT
	The ease of people in obtaining clean water is still a problem in Indonesia. The reason is that there are still more than 25% of the people who have not been able to use clean water to meet their daily needs. Indonesia was in the spotlight because it was considered as one of the countries that became the most significant contributor to water pollution, especially through plastic waste. The need for clean and safe water is growing as the population growth as well. Seawater desalination has become one of the essential commercial processes for providing clean water to many communities and industrial sectors that play an important role in socio-economic development in several developing countries, especially in Africa and several countries in the Middle East. The region, which suffers from the scarcity of fresh water. This paper aims to simulate the processing of seawater into clean water ready for use. The source of heat that is use comes from the cooling water condenser of steam turbine power plants. The method to be used is a thermodynamic simulation by using temperature in the cyclone separator and the percentage of water discharged into the sea variation to find out the amount of aquadest production and the Specific Energy Consumption (SEC) in the system. The lower temperature in a cyclone separator, the more aquadest production. The more mass water discharged to the sea, the less SEC will obtain. The minimum SEC is -1137.62 kJ/kg $_{aquadest}$ for 0.86 kg/s aquadest at 99% of mass water discharge and 2.645 kPa pressure in the cyclone separator and then the higher SEC is 440.53 kJ/kg $_{aquadest}$ for 0.338 kg/s at 89% of mass water discharge and 0.706 kPa pressure in the cyclone separator. The effect of lowering the condenser pressure is to increase the power of steam turbine 1181.85 kW, and then the cooling water temperature of the condenser decrease from 37.5°C to 32.5°C. The cooling water of condenser will be discharged partially into the sea at 32.5°C, which is safe for the environment.

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1. Introduction

The ease of Indonesian society in obtaining clean water is still a problem in Indonesia. The reason is that there are still more than 25% of the people who have not been able to use clean water to meet their daily needs. Indonesia was in the spotlight because it needs as one of the countries that became the most significant contributor to water pollution, primarily through plastic waste. The needs for clean and safe water are growing as the population growth as well [1]. This problem makes it difficult for many people to use clean water. Water is very vital for human survival in the world because humans will not be able to live without water. Water and energy interrelationship significantly intensify due to its economical, regional as well as ecological implications [2].

As we know, about 70% of the earth is covered by the sea, and the sea surrounds 71% of Indonesia. Areas on the coast of Indonesia, especially in big cities and in many other places around the world, are a clean water crisis. The clean water crisis includes drinking water and water for other needs, with a total clean water requirement per person per day is 60 L [3]. Water can be obtained from rivers, groundwater, lakes, and seawater. Approximately 97% of the water on earth is seawater that is not ready to use. This causes the processing technology needed to convert it into freshwater for use to meet the daily needs of humans. It needs to develop an environmentally friendly, clean water treatment technology to overcome the problem of clean water crisis [4]. The supply of freshwater needs to be increased because it is thought that in 2025, two-thirds of the human race will experience a shortage of clean water [5]. Seawater desalination has become one of the essential commercial processes for providing clean water to many communities and industrial sectors that play an important role in socio-economic development in several developing countries, especially in Africa and several countries in the Middle East region, which suffers from the scarcity of freshwater. [6].

In producing water, a long process is needed. Whereas to obtain clean water, it is necessary to separate the harmful particles contained in raw water that are not for consumption — the main problem in processing seawater into is needed water. Namely having excessive mineral content, high salt content, bacteria, impurities such as these small solids, so it cannot be consumed by the humans process of processing seawater into clean water that commonly uses is the desalination process. The desalination process is simply a separation process that is used to reduce the content of dissolved salts from seawater so that the water can be used. The desalination process involves three liquid streams, i.e., bait in the form of water which has high salt content, a low salinity product, and a high salinity concentrate. Desalination process products are generally water with a dissolved salt content of less than 500 mg / l, which is accommodated and will use for domestic, industrial, and agricultural purposes. The by-product of the desalination process is brine. Brine is a high concentration salt solution (more than 35000 mg / l dissolved salt). The quality of this water is determined by the total dissolved solids (TDS), which have units of parts per million (ppm) expressed by the smaller the ppm, the better the quality of water to be produced [7].

Desalination technology has been developed in recent decades to produce drinking water. At present, the thermal desalination process reaches more than 65% of the production capacity of the desalination industry [8]. The technology in processing saltwater into fresh water that is ready to use has been developed by researchers, especially researchers from the Middle East who have a hot climate and find it difficult to obtain fresh water. Desalination technology is divided into three, among others; (1) a membrane process in which a semipermeable membrane separates product water from dissolved salts, and (2) a thermal process in which feed water is heated under the appropriate operating temperature and pressure, and its vapor is condensed as pure water [9]. Nowadays, membrane processes are adapted in the application of waste water treatment and seawater desalination [2]. Effective membrane technologies utilization as sustainable answer for various

applications entails novel membrane materials as well as customized separation characteristics. In the process of desalination with a membrane of saltwater will pass through the membrane and salt trapped in the membrane [10]. Desalination with membranes is divided into several more types, including forward osmosis (FO), reverse osmosis (RO), electro-dyalysis (ED), and nanofiltration (NF). The desalination system by utilizing thermal is done by utilizing a heating and condensation system so that water vapor will be condensed into freshwater, and water with high salt content (brine) will be removed. Desalination that utilizes thermal energy is divided into multi-stage flash distillation (MSF), Humidification-dehumidification (HDH), multi-effect distillation (MED), thermal vapor compression (TVC), Adsorption desalination (AD) and Freeze desalination (FD) [11].

Much research has been done to process seawater into ready to use water. For example, seawater desalination technology using microbes is a process of seawater desalination that is driven by microbial respiration [12]. Current desalination technology can be classified as a single-phase process, for example, Reverse osmosis, electro-dialysis. Otherwise, it can be classified as a phase change process, for example, distillation and solar [13]. The reverse osmosis, electrodialysis, and refining processes require energy from non-renewable fossil fuel sources [14].

Desalination is also able to achieve using the hydrating process. This desalination method is carried out using diagramming to assist the cyclopentane process at atmospheric pressure. Although this method is cheap and easy, because limited mass transfer under constant conditions dramatically inhibits the growth of hydrates, causing only a small portion of the conversion [15]. Sevda *et al.,* [12] using microbial respiration to purify water, and they have made the volume of a single seawater desalination chamber increase from 3 ml to 15 L. On many occasions, researchers have also competed in developing SWRO (seawater reverse osmosis) technology to produce desalination water [16]. Wang *et al.,* [17] studied the thermodynamic analysis of reverse desalination osmosis units with and without energy recovery systems, in addition to specific energy consumption for reverse osmosis can change depending on the SWRO configuration.

In thermal desalination systems such as MSF and MED it has an advantage compared to RO systems that can treat water with higher TDS up to 175000 mg / L so that it can operate in a long enough time to produce water quality with low and consistent TDS. To improve the desalination efficiency by using this method, it can utilize industrial waste heat systems or other heat sources as a preheater and can be combined with mechanical or thermal vapor compression systems [18].

At the end of the 20th century, there was a study conducted by simulating the thermal multi-effect distillation (MED) desalination system, which consisted of 8 units of the evaporator, 10 units of external feed preheater and 6 units of flash drums. Each evaporator has a heat transfer area of $800m^2$, and a heat transfer area heater of $100m^2$. This seawater is heated at the first stage to its boiling point at a pressure of 120kPa. At the end of the process, this system succeeded in producing steam that was ready to be condensed as much as 2kg/s [19]. With this MED desalination system has been developed to obtain better performance from the system. One way is to combine the MED system with the solar thermal cycle. This research was conducted in a simulation that aims to see the advantages between Multi-effect distillation parallel feed configuration (MED-PF) or (Multi-effect distillation thermal vapor compression (MED-PF-TVC), both of which are combined with solar thermal cycle. In both systems using a steam ejector, the steam ejector decreases the pressure, which can cause the steam produced to increase and causes the gain ratio (GR) to increase as well. In this simulation, it is targeted to produce freshwater of $5000m^3$ / day with the temperature of the inlet water to be treated at the temperature of 22°C and the number of effects used are equal to 4. In MED-PF-TVS the compression ratio of the thermal vapor compressor is used 2. The results obtained indicate that MED-PF-TVC has lower energy consumption when compared to MED-PF method

between MED-PF-TVC and MED-PF produces a gain ratio (GR) of 21.23 and 16. The results obtained indicate a substantial difference [20].

There are also studies that utilize vacuum in producing freshwater. This research uses the desalination (VHDH) vacuum humidification-dehumidification (VHDH) system. This desalination system also utilizes a solar water heater to increase its temperature before entering the humidifier. The humidifier is connected with a vacuum pump to cause vacuum to the humidifier, which can increase the production of freshwater. The vacuum pressure obtained to achieve the best efficiency is at 70kPa [21].

Water treatment is also very important, especially in the oil and gas industry. In the oil and gas industry, which is mostly located on the coast, has the closest water source, namely seawater. So that this seawater is processed to reduce its salt content so that it is safe to use in condensers. Research conducted by Chen *et al.,* [22] conducted a simulation of seawater lecture using the aspen plus software. This simulation is carried out to obtain which desalination system can produce fresh water at the lowest cost by utilizing thermal from flare gas. The results show that the proposed TVC process is technically feasible and cost-effective in most locations; it can also be one-third of the disposal costs compared to the remote injection method.

Desalination systems can be combined with power plant cycles in which the heat from the steam turbine will be will absorb to cooling water in the condenser. The cooling water will be used to produces aquadest by desalination process. Hot water that is used to cool the condenser will be throttled until a pressure drop occurs in the cyclone separator. Due to a decrease in pressure on the cyclone separator, hot water that has passed through the throttle valve will change in phase between the vapor and liquid. In the research conducted by Kosasih *et al.,* [14], the condensation of the vapor is using a refrigeration system. Ahmed Hegazy collects water through a vacuum evaporator for collect steam condensation and energy consumption around 1-8 kWh/kg [24]. Ebrahimi Khosrow studied the use of low-temperature heat sources for the desalination of seawater. To follow up on the efforts of the above researchers in producing desalination water [25].

 Energy consumption from the thermal desalination process can be reduced at the steam power plant by utilizing the heat released by the turbine condensation vapor to provide the primary thermal energy needed for the MSF or MED desalination process. High efficiency of electric energy production requires low steam condensation temperatures close to ambient temperature. By reducing the pressure of the steam power condenser plant, it can increase the turbine power generated by the steam power plant [26]. Not only the pressure on the condenser can be varied, but variations in the pinch point temperature difference (PPTD) can also be used to optimize the performance of the condenser [27]. In addition to the two variations above, two variations can be done, variations in the amount of water discharged directly into the sea, as well as variations in water pressure in cold water container tubes to increase the efficiency of aquadest production and thermodynamic efficiency [28].

Cyclone separator is an innovation that can be applied in a desalination system. There is a device that can separate the water vapor from the flue gas, the cyclone separator. The study that reviews the efficiency of the cyclone separator's performance against the variation of the flue gas temperature used. Increasing exhaust gas temperature reduces transfer efficiency. According to theory and calculations, higher gas temperatures help the nucleation and growth of fine particles. However, high gas temperatures also significantly reduce the system saturation ratio, which has a significant negative impact on the separation process. As a result, the growth of fine particle condensation and removal efficiency will be suppressed [29].

There is also recent research on the influence of the wall-mounted cyclone on the purification and separation performance of supersonic separators. This is a new type of cyclone for separating particles. The results obtained in this study are the number, thickness, rotation angle of the cyclone,

and the size of the drainage holes all affect the separation performance. As the number of blades increases, thickness, angle of rotation, and drainage opening, the efficiency of the separation of liquid droplets is increased, but at this time, the effect on the flow field in the separator increases, resulting in inadequate gas expansion, increasing shock waves, and other problems. Considering the above factors, it was finally determined that the length of the cyclone was 0.02 m, the number of blades was 3, the thickness of the blades was 0.25 mm, and the angle of rotation of the blades was 60°. The width of the drainage opening gap must be 2.5 mm [30]. Not only to separate particles that can create air pollution, but this cyclone separator can also separate the water content in the flue gas. The efficiency of this cyclone separator can be calculated, which is influenced by geometry [31].

This paper aims to describe a system for producing Aquadest. This research method and process is an innovation that utilizes warm wastewater condenser output from a steam power plant. In steam power plants usually throwing away warm water in vain, therefore in this system, warm water will be choked in a slowdown to cause a drastic reduction in pressure and temperature. Generally, warm water is immediately discharged into the sea after the process without being used. Seawater with high temperatures is dangerous for the environment because it can damage the marine ecosystem. The evolution of stable marine habitats depends on various factors, including water temperature. If an ecosystem gets warm, it can create opportunities where outside species or bacteria can suddenly develop where they have Secrets. It can cause forced migration and even species extinction. In this simulation, some hot water waste is flowed back into the system by throttling, so that the warm water phase can be turned into water vapor and then can be yielding aquadest. Next, the water vapor is compress by vapor compressor to produce aquadest. Vapor-compression system is the most commonly used system for refrigeration and air-conditioning applications [32]. But in this research, using vapor compressor to increase the vapore temperature. The hot vapor will condense by using water cooling condenser. Aquadest production is different from desalination water production because aquadest production uses changes in the water phase, so the results from condensed water vapor must be pure. Another advantage of this system can produce aquadest at a low cost. Adding desalination system to a steam power plant does not provide a system weakness, actually changing the condenser pressure will increase the power generated from the power plant [16,33]. Using this tool can also reduce the temperature of wastewater into the sea, so it must be more environmentally friendly.

In this paper, we will explain the effect of pressure in the cyclone separator and the percentage of mass water discharge to aquades production and specific energy consumption using the throttling process method. This study aims to continue research before method simulations in steam power plants to produce aquadest by using the throttling and compression process.

2. Methodology

This research was conducted at the Universitas Indonesia's Applied Heat Transfer Research Group (AHTRG) mechanical engineering laboratory. This research is a continuation that has been done by Kosasih *et al.,* [1]. This research starts with identifying the problem to produces aquadest and also to overcome the environmental problem. The steam power plant can be combined to utilize the condenser heat. So, we collect the temperature and the pressure of the 50 MW steam power plant component. Next, design the system of the desalination plant. The desalination plant is using a thermal vapor compression system and throttle valve to decrease the pressure in the cyclone separator. It is the difference between the research before by Kosasih *et al.,* [1]. The mass of water discharge (m_{WD}) and pressure in cyclone separators are the independent variables. The research flow chart diagram shows in Figure 1 below.
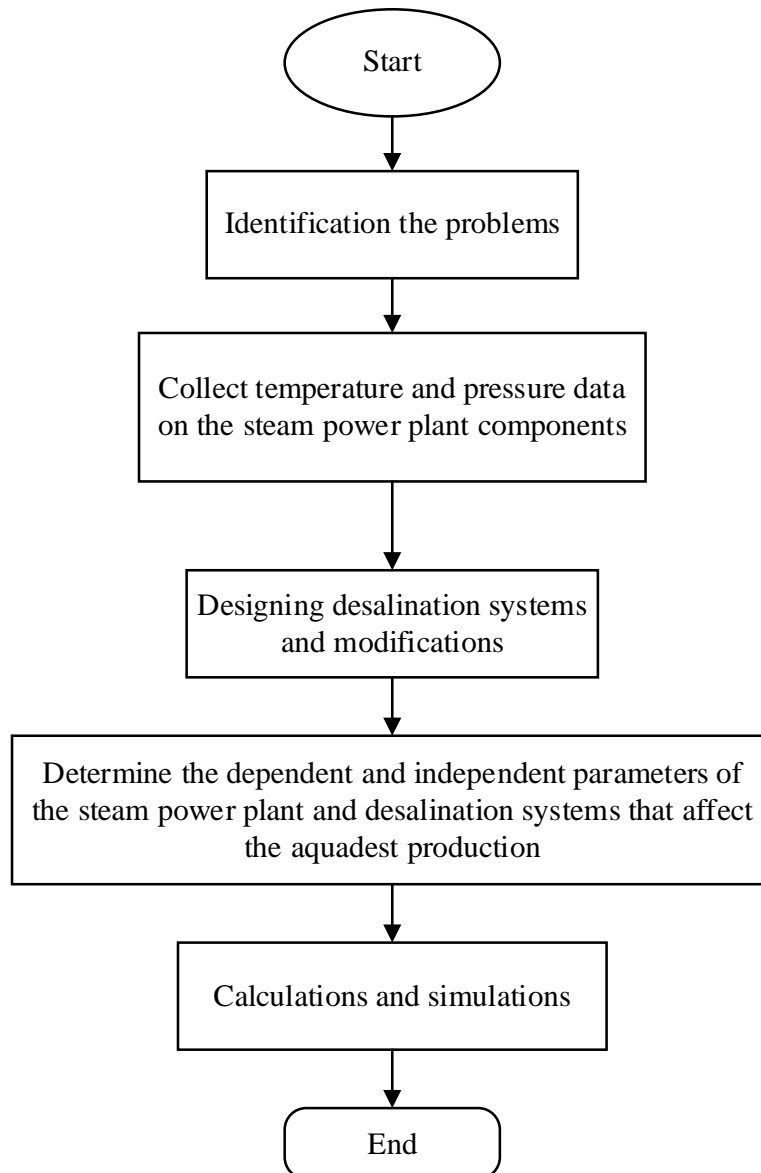
Fig. 1. Research flow chart diagram

The thermodynamic simulation is using Microsoft excel to calculate the several equations. We are also using IAPWS IF97 Excel Steam Tables add-ins for Microsoft excel by Magnus Holmgren to find the steam and water properties. The thermodynamic simulation method uses theoretical calculations as a system that has been integrated into power plants to get specific energy consumption. In this case, we use the data in 50 MW Steam power plant with temperature inlet turbine 510°C, pressure inlet turbine 8.9 Mpa, condenser temperature 47.5°C, condenser pressure 10.89 kPa, efficiency isentropic of the steam turbine 87% and ΔT pinch in condenser 10°C. However, in this simulation, the temperature in the condenser using 42.5°C at 8.42 kPa pressure. The purpose of lowering the condenser temperature to obtain how much the increase of the turbine power.

Figure 2 shows a flow diagram of a desalination thermodynamic simulation combined with a steam power plant. This flow diagram shows that seawater entering the system is mixing with cold water (9) pumped from a cyclone separator. This mixing process makes the enthalpy of the cooling water mixture rise. The enthalpy value of this mixture can be found using the following equation below.
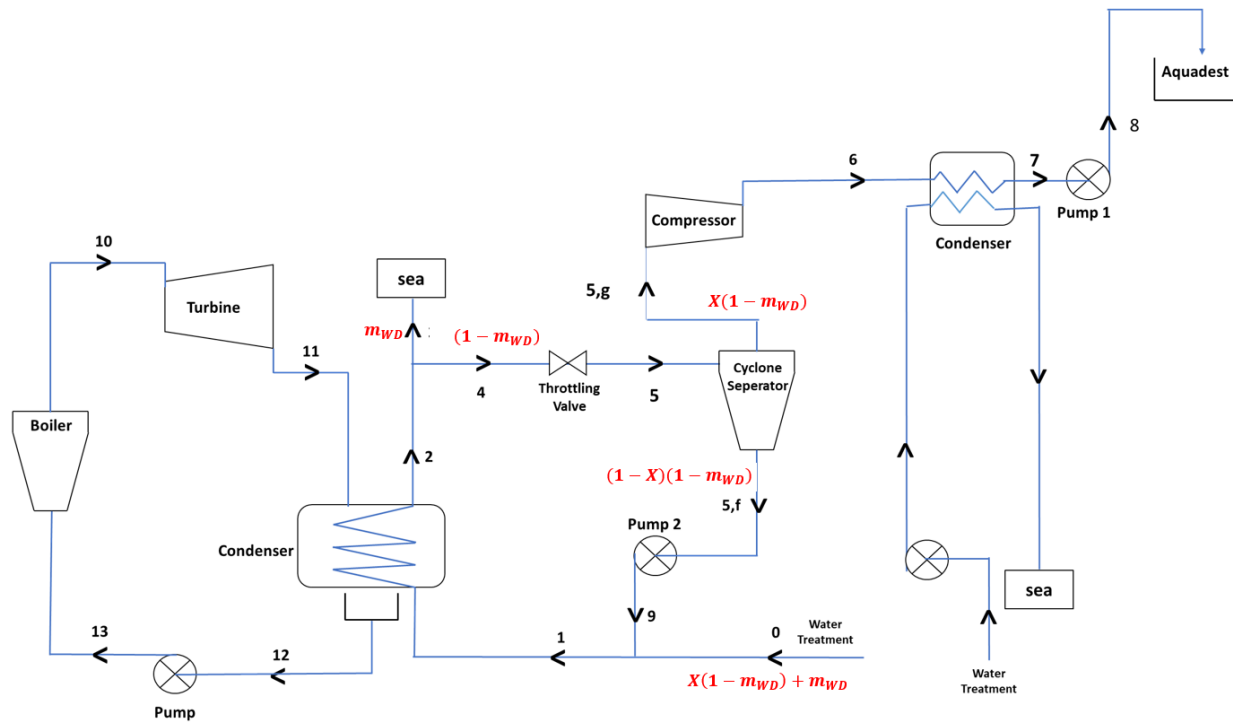
Fig. 2. Schematic Diagram of Throttling Process

$$h_1 = (1 - m_{WD})(1 - X)h_9 + (X(1 - m_{WD}) + m_{WD})h_0 \tag{1}$$

where h is enthalpy, X is the essential vapor fraction, and m_{WD} is the mass water discharge fraction. To calculate the h_9, it can be calculated using the equation listed below.

$$h_9 = h_{5,f} + v(p_1 + p_5) \tag{2}$$

where $h_{5,f}$ is enthalpy of saturated liquid from cyclone separator and $h_{5,f}$ is enthalpy of saturated liquid from cyclone separator(5,f), p_1 is the pressure of mixing water, and p_5 is pressure in the cyclone separator. h_9 is the enthalpy of cold water outlet from pump 2 (9). Mass fraction of vapor X can be calculated equation below.

$$h_5 = h_{5,f} + X(h_{5,g} - h_{5,f}) \tag{3}$$

where $h_{5,f}$ is enthalpy of saturated liquid from cyclone separator and $h_{5,g}$ is enthalpy of saturated vapor from cyclone separator. The h_5 is the enthalpy in a cyclone separator. Then the mixed water flows towards the condenser (1). Water entering the condenser will absorb the latent heat from the working fluid in the steam power plant. The following equation, Q condenser can express this heat release in the condenser (Q_c) of the steam power plant can be calculated by the equation below.

$$Q_c = m_T(h_{11} - h_{12}) \tag{4}$$

$$Q_c = m_{cw}(h_2 - h_1) \tag{5}$$

From Eq. (4) and Eq. (5), it can be a substitution to find the mass flow of cooling water (m_{cw}). In this calculation, we assume the mass flow of the turbine (m_T) is 1 kg/s unit. After mass flow cooling water is known, it can calculate the mass aquadest (m_{Aq}) by using the equation below.

$$m_{Aq} = m_{cw}\left(X(1 - m_{WD})\right) \tag{6}$$

To find the value of enthalpy outlet condenses cooling water (h_2), enthalpy is the function of pressure 2 and temperature 2. To calculated temperature 2 can be solved by the equation below.

$$T_2 = T_{11} - \Delta T_{pinch} \tag{7}$$

Before calculating the energy consumption, it must calculate the increase of turbine power. The increase of turbine power is the effect of decreasing the temperature at the condenser power plant from 42.5°C to 37°C.

$$\Delta P_T = (h_{10} - h_{11new}) \dot{-} (h_{10} - h_{11old}) \tag{8}$$

Then the power of pump 1, pump 2, pump 3, and the vapor compressor can calculate by the equation below.

$$P_{pump\ 1} = \dot{m}_{Aq}\,(101.325 - p_7) \tag{9}$$

$$P_{pump\ 2} = \dot{m}_{cw}\,(1 - X)(1 - m_{WD})(h_9 - h_{5,f}) \tag{10}$$

Before calculating the power of pump 3, it must calculate the Q condenser aquadest (Q_{cAq}) by using the equation below.

$$Q_{cAq} = \dot{m}_{cwAq}\,C_{p\ water}\Delta T \tag{11}$$

where C_p is Specific heat of cooling water aquadest, and ΔT is temperature different at the condenser aquadest. Power pump 3 can calculate by the equation below.

$$P_{pump\ 3} = \dot{m}_{cwAq}\,v_7\Delta p \tag{12}$$

Pump 3 useful for pumping the cooling water for aquadest condenser, the pressure difference (Δp) can assume 100 kPa to against the friction in the pipe and the condenser. Next, the power of the vapor compressor can be calculated by the equation below.

$$P_{comp} = X(1 - m_{WD})\dot{m}_{cw}\left(h_6 - h_{5,g}\right) \tag{13}$$

From all the power requirements used in this method of throttling process, specific energy consumption (SEC) can be found by the equation:

$$SEC = \frac{P_{comp} + P_{pump\ 1} + P_{pump\ 2} + P_{pump\ 3} - \Delta P_T}{\dot{m}_{Aq}} \tag{14}$$

In this simulation method, there are several assumptions in the boundary conditions. Table 1 below shows the assumed constant parameters.

Table 1
Constant Parameters used in Simulation

Parameters	Values
Steam Power Plant capacity	50 MW
$\eta_{isentropic}$ turbine	87%
p_{11}	89 bar
T condenser old	47.5°C
T condenser new	42.5°C
ΔT condenser power plant	10°C
T_0	28°C
ΔT condenser aquadest	11°C
T condenser aquadest out	44°C
ΔT cwAq	11°C

3. Results

In this simulation, the pressure in the condenser decrease from 10.89 kPa at 47.5°C to 8.43 kPa at 42.5°C. Lowering the pressure in the condenser is directly proportional to the temperature decrease. The impact of lowering pressure or temperature in the condenser is to increase the power of the steam power plant. On the other hand, lowering the temperature in the condenser will affect the cooling water temperature. For the same ΔT pinch condenser 10°C, the cooling water of temperature the condenser decreases from 37.5°C to 32.5°C. The cooling water of condenser will be discharged partially into the sea at 32.5°C, which is very good for the environment because of the average temperature of seawater range from 28°C to 30°C.

For Figure 3, the temperature variation in the cyclone separator start from 0.706 kPa to 2.645 kPa on mass water discharge constant at 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, and 99%. The effect of vary the cyclone separator pressure cause the temperature in the cyclone separator decrease between 2°C to 22°C.

From Figure 3, the percentage of mass water discharge influence the SEC of the system. The minimum SEC is -1137.62kJ/kg aquadest at 99% of mass water discharge and 22°C temperature in the cyclone separator and then the higher SEC is 440.53kJ/kg aquadest at 89% of mass water discharge and 2°C temperature in the cyclone separator. Based on the data above, the more mass water discharge to the sea, the less SEC of the system. The graph above shows the effect of mass water discharge from 98% to 99% show the most significant SEC decrease. In this case, the more mass water discharge to the sea, it means the less of mass aquadest production. The value of aquadest production will influence the power of pump 1, pump 2, pump 3, and vapor compressor. The more mass aquadest production will increase the energy consumption of the pump and vapour compressor. However, the more mass aquadest production, it will decrease the specific energy of additional turbine power. For this reason, the graph above causes the SEC to reach a negative value.

From Figure 4, the graph shows the Specific Energy Consumption (SEC) to pressure in a cyclone separator. The pressure in the cyclone separator is the pressure as a function of temperature saturated in a cyclone separator. The trend of the graph above shows a decrease in SEC during the increase in pressure at the cyclone separator for each mass water discharge. If the pressure in the cyclone separator increase, that can make the decreased energy consumption and SEC for pump 2 and vapour compressor. The graph above shows the effect of mass water discharge from 98% to 99% show the most significant SEC decrease.
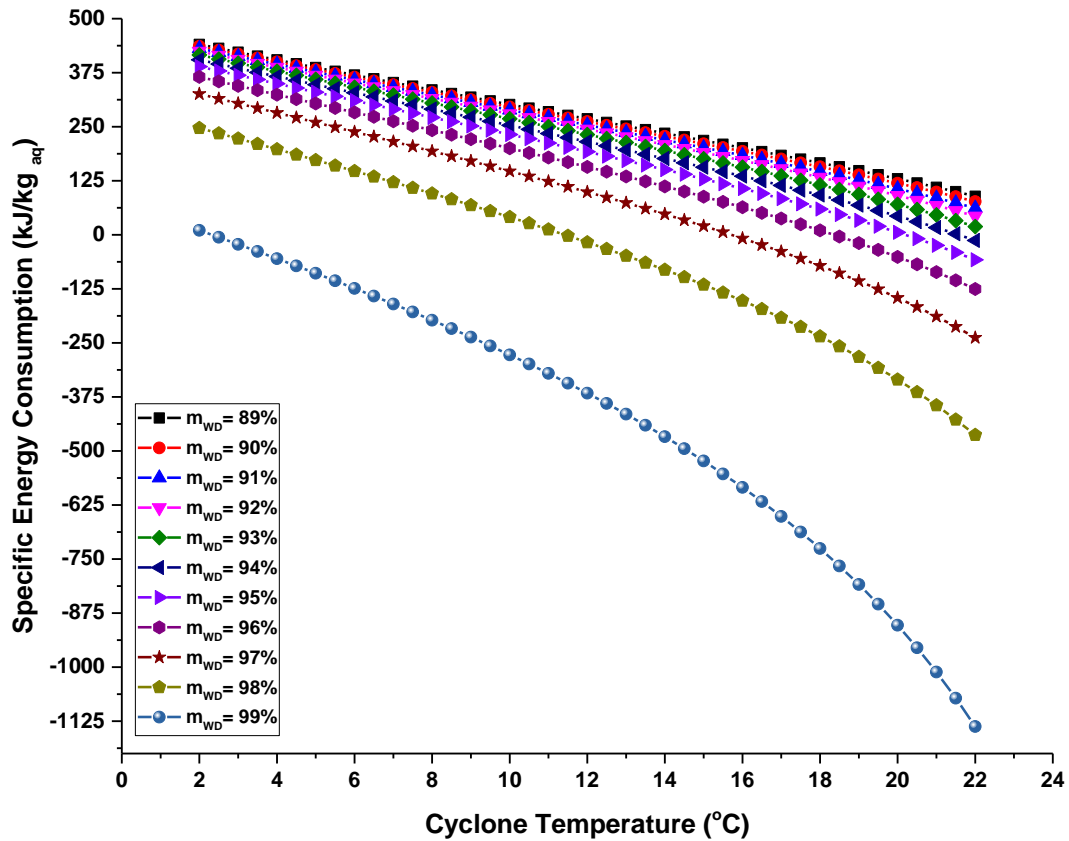
Fig. 3. Graph Specific Energy Consumption Vs Temperature in cyclone separator at the different percentages of mass water discharge
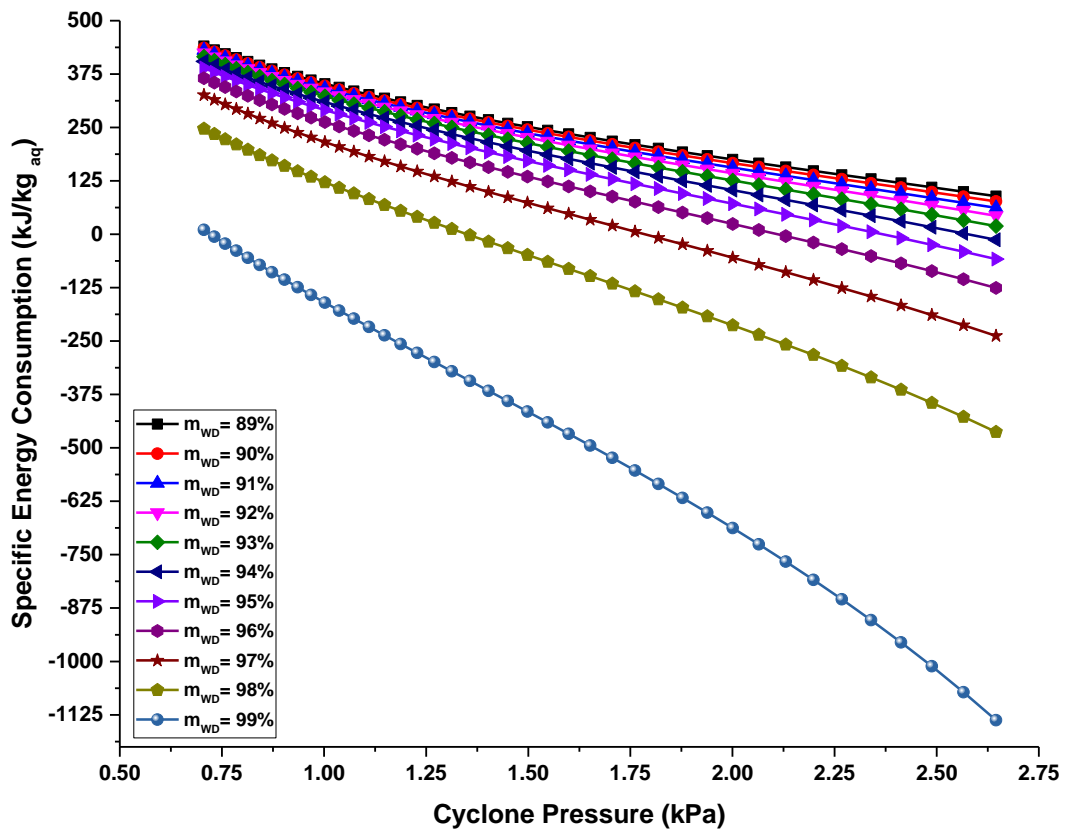

Fig. 4. Graph Specific Energy Consumption vs. Pressure in cyclone separator at different percentages of mass water discharge

Based on the Figure 5, it shows the effect of the decrease in the pressure in cyclone separator caused the decrease of the temperature and aquadest production. The minimum aquadest production is 0,86 kg/s at 99% of mass water discharge and 2.645 kPa of cyclone separator pressure, and then the maximum aquadest production is 17.12 kg/s at 89% of mass water discharge and 0.706 kPa of cyclone separator pressure. The lower pressure in the cyclone separator at constant percentage mass discharge water, it caused the $h_{5,f}$ decreased but the h_5 is constant. So, the different of h_5 and $h_{5,f}$ is increase. The value of enthalpy as function temperature saturated in the cyclone separator $h_{5,g}$ and $h_{5,f}$. Hence, the lower of pressure in the cyclone separator, the aquadest production will increase.
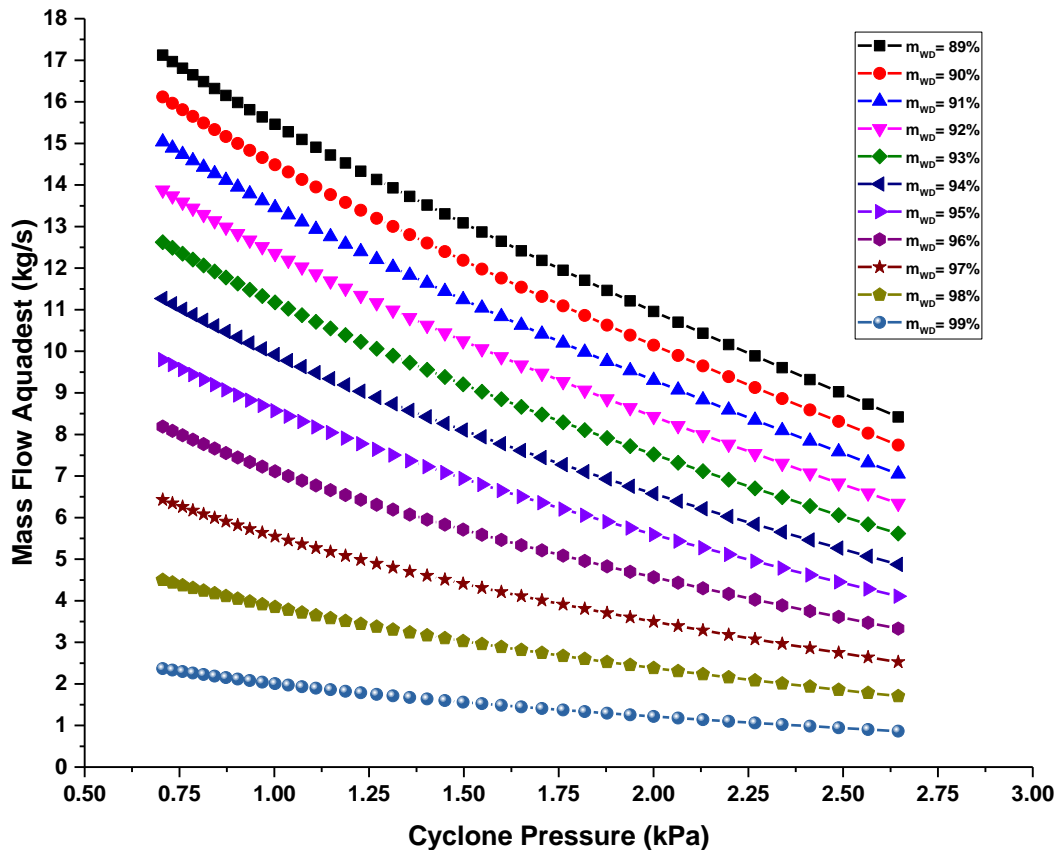

Fig. 5. Graph mass aquadest vs pressure in cyclone separator at a different percentages of mass water discharge

Next, the percentage of mass water discharge (m_{WD}) variation from 89% to 99% on constant pressure. Based on Figure 6, the graph shows the effect of percentage of mass water discharge to Specific Energy Consumption (SEC). The more percentage of mass water discharged to sea at a constant pressure in the cyclone separator, the less water throttled to cyclone separator. So, the aquadest production will be less.
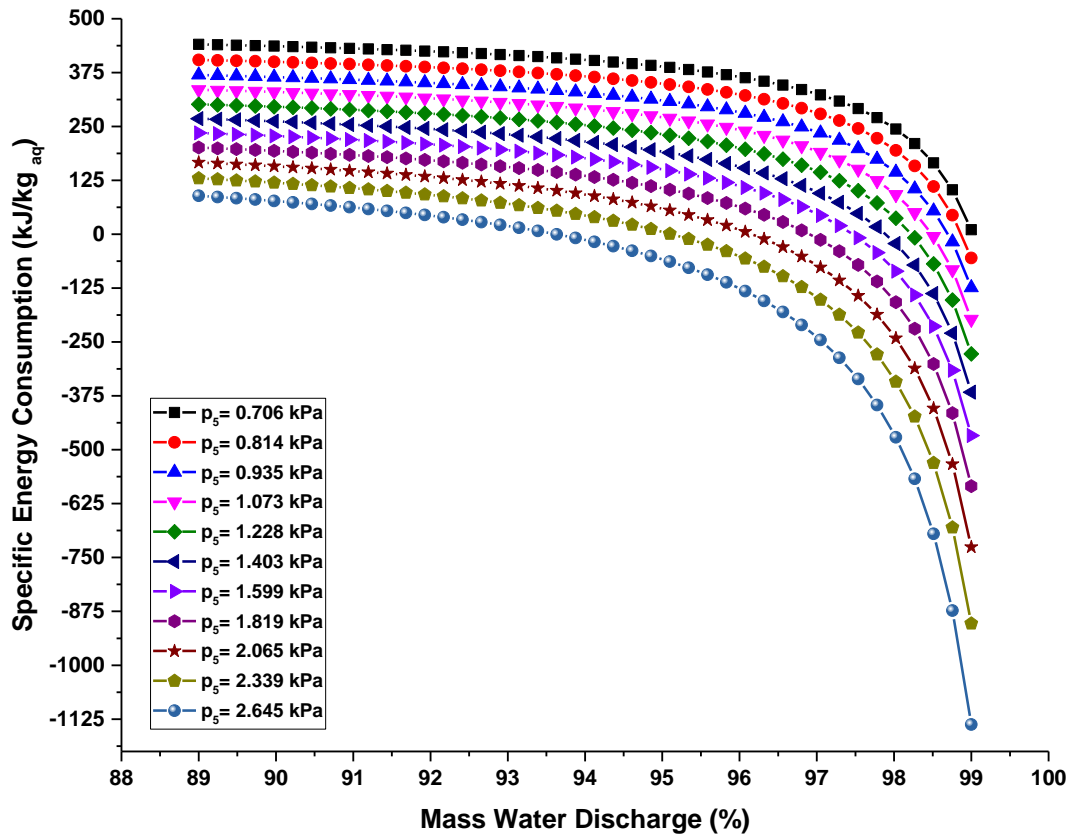
Fig. 6. Graph SEC vs. percentage mass water discharge at different pressure in a cyclone separator

Based on research that has been done before using a refrigeration system [3], the simulation was carried out at a capacity of 50 MW steam power plant and 90% mass water discharge. But the difference is in the research conducted by Kosasih *et al.,* [3] conducted on various pinch point temperature differences (PPTD). Overall, the higher the pressure on the water tank, the lower the SEC value. It can also be seen in Figure 4 shows the relationship between the SEC and cyclone pressure at various mass water discharges showing the tendency of SEC values to get lower. In Figure 7 below show the similarity with the Figure 4.
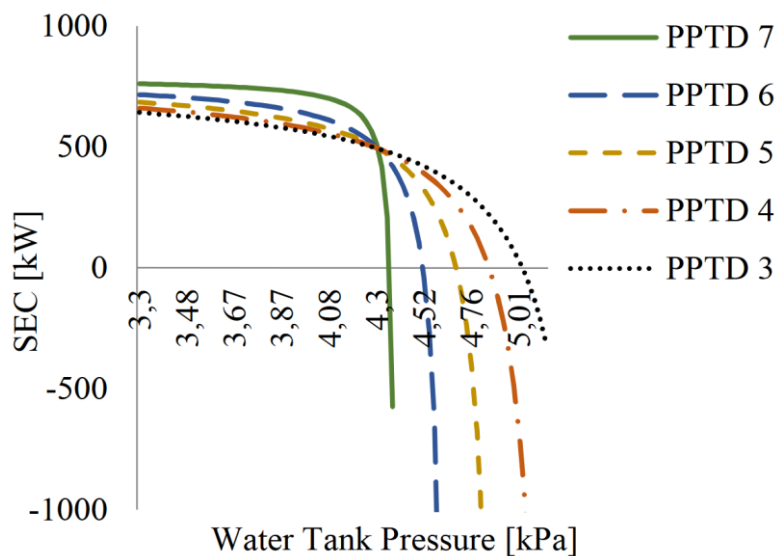

Fig. 7. Graph SEC vs. water tank pressure at different PPTD [3]

4. Conclusions

Based on the simulation results of the 50 MW steam power plant system combined with a desalination plant, can be concluded as follows

   i.   The effect of lowering the condenser pressure is to increase the power of steam turbine 1181.85 kW, and then the cooling water temperature of the condenser decrease from 37.5°C to 32.5°C.
  ii.   The effect of an increase in the pressure in the cyclone separator caused a decrease in aquadest production.
 iii.   The more percentage of mass water discharged to sea at a constant pressure and temperature in the cyclone separator, the less water throttled to cyclone separator. So the aquadest production will be less. However, the SEC will increase. Figure 3 shows the effect of mass water discharge from 98% to 99% show the most significant SEC decrease.
  iv.   The minimum aquadest production 0.86 kg/s $_{aquadest}$ for SEC is -1137.62kW/kg $_{aquadest}$ at 99% of mass water discharge and 2.645 kPa pressure in the cyclone separator and then the higher aquadest production 17.12 kg/s for SEC 440.53kW/kg $_{aquadest}$ for at 89% of mass water discharge and 0.706 kPa pressure in the cyclone separator.

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