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Research Article

THERMODYNAMIC AND ECONOMIC ANALYSES OF POWER GENERATION FROM GAS TURBINE EXHAUST

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ABSTRACT:
This paper presents the development of a thermodynamic model of natural gas production processes on the offshore platform by applying Organic Rankine Cycle (ORC) technology to the plant. This research considered the thermodynamic performance and economic feasibility of using ORC for electricity production from exhaust gas generated by gas turbine engines which were used as prime movers to drive natural gas compressors. According to the Process & Instrumentation Diagram (P&ID), the process of recovering waste heat from Booster Compression and Sales Gas Compression and Export modules from the entire gas production processes of the plant has been modeled in DWSIM program which is an open-source chemical process simulation. The simulation result showed that the exhaust gas had a temperature at 527 °C at Booster Compression and 504 °C at Sale Gas Compression and Export. The ORC was designed as a simple cycle with no degree of superheating and subcooling due to limited area of the offshore platforms. We have selected the most suitable working fluid for ORC in order to get the highest turbine power and efficiency. From the simulation, Toluene was identified as the most suitable working fluid which provided the highest turbine power and efficiency at 1.9 MW and 24.33%, respectively. So, the installation of 4 cycles of ORC for offshore platform will get total energy at 7.6 MW. To demonstrate the commercial feasibility of this project, a detailed economic analysis has been performed. The results showed that the ORC technology has the net present value (NPV) is 40.141 million Baht, the payback period (PB) is around 16.49 years, the internal rate of return (IRR) is 8.18% per year (from the minimum attractive rate of return or MARR at 8% per year) and the benefit cost ratio (B/C ratio) is 1.10. All indicators show economically favorable results, thus, indicating that this research is economically feasible and worth for the investment.

Keywords: *Offshore petroleum production, Waste heat recovery, Organic rankine cycle, Working fluid, DWSIM*

1. INTRODUCTION

Petroleum industry, especially petroleum refineries and offshore platforms release a lot of waste heat to the environment primarily in the form of exhaust gases from combustion. The release of exhaust gas is a waste of energy and causes harmful impact to the environment [1]. The quantity of waste heat from exhaust is extensive and the temperature of the exhaust gas is still relatively high when compared to the ambient temperature thus the exhaust gas

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possess high potential for waste heat recovery applications. However, energy from waste heat can rarely be used directly therefore they must be converted to electrical energy using a thermodynamic heat engine. Organic Rankine Cycle (ORC) is one of the most common and cost-effective methods of converting waste energy into electrical energy [1, 2]. It is a heat engine that converts heat into electricity using a thermodynamic cycle known as Rankine Cycle with organic substances as working fluid. The ORC is suitable as a power conversion cycle of renewable and alternative energy source due to its simple structure and ease of maintenance. The ORC has a structure similar to the Steam Rankin Cycle (SRC) consisting of evaporator, turbine, condenser, and pump but it uses organic fluids instead of water as working fluid. Organic fluids with low boiling points can be converted to saturated or superheated vapor when heated from a low-temperature heat source. This makes it possible to use a variety of heat sources as the evaporating temperature is much lower than water. Thus, ORC can generate electricity using low temperature and a variety of heat sources by the selection of appropriate organic fluid that evaporates the heat source temperature. There have been a number of studies related to ORC over the years [1-7].

Thurairaja, et al. [3] stated that Organic Rankine Cycle (ORC) is known as one of the best methods of recovering low grade energy (low temperature source), but the right working fluid must be selected for the system for better performance. This work focused on the performance assessment of ORC for various working fluids considering various practical limitations such as equipment availability, fluid availability, safety and environmental impacts, and economic feasibility.

Quoilin, et al. [1] presented the overview of ORC applications including an overview of the current industry market situation, the costs for ORC modules and commercial ORC manufacturers. It was shown that there was a relationship between system cost per kilowatt and output power as the price of the system per kilowatt tended to decline as the power increases. This work also discussed the selection of working fluid that is most suitable to the temperature of heat source such that the work output and thermal efficiency are maximized. The selection criteria of ideal working fluid for ORC has been established: (1) high latent heat of vaporization, (2) low boiling point, (3) low melting point, (4) high critical temperature, (5) low vapor pressure, (6) low specific heat, (7) low viscosity, (8) environmental friendly with low ozone depletion potential (ODP) and low global warming potential (GWP), (9) fluid availability, and (10) economic feasibility.

Nami et al. [4] discussed the prospect of recovering thermal energy from gas turbine exhaust using ORC. This work investigated two different ORC configurations: cascade and series arrangement. Two types of working fluids were considered: Siloxane (MM, MDM, D5) and Refrigerant (R123, R124). Dowtherm A is used as a heat transfer fluid for process heat demand at high and low temperature. It was found that the working fluids MM and R124 were most suitable for parallel and series arrangements, respectively. For the cascading arrangement, if the process heat demand was changed, there would be no effect on ORC work output as the amount of heat absorption and rejection of the ORC were constant at the evaporating and condensing temperature of the working fluid. However, in the series arrangement, the increase in process heat demand resulted in a reduction of ORC work output. Thermal efficiency of the ORC studied could be improved by using a recuperator to reduce temperature difference and a reduction in compressor pressure to allow more expansion of the working fluid in the turbines.

Khosravi et al. [5] studied the structural design and development of the Organic Rankine Cycle (ORC) with a focus on maximizing exergy performance and minimizing the cost. The selection of working fluids was selected based on their impact on the environment, thermodynamic properties and economic impacts. In this work, R123 and R600 were used as working fluids. The single-fluid, single-pressure ORC, single-fluid, dual-pressure ORC, and dual-fluid, dual-pressure ORC were considered. All of the aforementioned systems employed recuperator as it could effectively increase thermal efficiency of the systems. It was also found that the one pressure system had the highest efficiency out of all three systems. Moreover, at the same efficiency, one pressure system had the lowest cost.

Tartière and Astolfi [7] has also confirmed that the Organic Rankine Cycle (ORC) technology is one of the reliable ways to convert heat into electrical energy, either for renewable energy use or for industrial energy efficiency. ORC systems range from a small (few kW) for domestic combined cycle power plant to a large multi-megawatt geothermal power plant. In this study, data on more than 700 projects from reliable and comprehensive databases of 27 manufacturers were collected to provide an overview of the current situation on ORC deployment in industrial markets. The evolution of each market takes into account the current installed capacity (MW), historical data and macroeconomic trends. It also discusses the criteria for selecting the working fluid that is most suitable for each system by taking into account the heat source temperature and power plant size. This work concluded that the working fluids should consist of hydrocarbons, hydrofluorocarbons and siloxanes for better efficiency of turbomachinery.

The objective of this study was to develop a thermodynamic model of natural gas production processes on offshore platforms and enhanced it with the addition of Organic Rankine Cycle (ORC) for electricity production. The heat source for the ORC was provided from exhaust gas generated by gas turbine engines which were used as prime movers to drive natural gas compressors. This work also considered the thermodynamic performance and economic feasibility to implement such heat recovery system to the existing offshore platform.

2. Simulation Methodology

This research involved in the development a thermodynamic model of natural gas production processes on the offshore platform and applying the ORC technology to the plant. We have developed and modified the model by using DWSIM program version 5.8 update 5 which is an open-source chemical process simulation. DWSIM allows user to better understand the behavior of chemical systems with no cost as it is freely accessible and could be easy to be studied, reviewed, and modified by any interested parties [8].

As DWSIM program can be accessed freely, it is easy to study, review and edit. The DWSIM program is available for Windows, Linux and macOS. It was created by Mr. Daniel Medeiros on Microsoft.NET and Mono Platforms and features a Graphical User Interface (GUI), advanced thermodynamic computation, Reaction Support and Petroleum Modeling / Hypothesis Building Tool. DWSIM also can simulate Steady-state, Vapor – liquid, Vapor – liquid-liquid, Solid – liquid and liquid electrolyte processes with a thermodynamic model.

The reliability of the DWSIM program has been confirmed by Tangsriwong et al. [9]. This work emphasized on the comparison of simulation results calculated by the commercial software Aspen Plus vs. the open-source software DWSIM (an open-source sequential modular steady state simulator) [10]. Finally, simulation results from DWSIM and Aspen Plus were compared with the heat and mass flow diagram which was used as reference. It was found that the discrepancy between simulation and reported values was in general less than 5%. It has been demonstrated that free and open-source software like DWSIM could potentially perform similar tasks as commercial software. It can be concluded that DWSIM could serve as an alternative process modeling software especially for offshore petroleum production.

After the reliability of DWSIM program has been tested, we have created a process flowsheet based on Process & Instrumentation Diagram (P&ID) of an offshore natural gas production facility and then it was modified with the ORC to convert waste heat from the gas turbine cycle into electricity.

The efficiency of electricity generation with the ORC system depends on the temperature and amount of waste heat. Generally, the electricity generation from ORC system has an overall thermal efficiency of approximately 15-25%, depending on the saturation temperature at the evaporation and the condensation temperature at the condenser. Turbine power output, pump power input, new work output and thermal efficiency can be described in the following equations [10].

$$\dot{W}_t = \dot{m}_{wf}\left(h_{t,i} - h_{t,o}\right) \tag{1}$$

$$\dot{W}_P = \dot{m}_{wf}\left(h_{p,o} - h_{p,i}\right) \tag{2}$$

$$\dot{W}_{net} = \dot{W}_t - \dot{W}_P \tag{3}$$

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} \tag{4}$$

where $\dot{Q}_{in}$ = Total heat input (kW)
$\dot{W}_t$ = Turbine work output (kW)
$\dot{W}_p$ = Pump work input (kW)
$\dot{W}_{net}$ = Net work output (kW)

$\dot{m}_{wf}$	= Mass flow rate of working fluid (kg/s)
$h_{t,i}$	= Specific enthalpy of working fluid at turbine inlet (kJ/kg)
$h_{t,o}$	= Specific enthalpy of working fluid at turbine outlet (kJ/kg)
$h_{p,i}$	= Specific enthalpy of working fluid at pump inlet (kJ/kg)
$h_{p,o}$	= Specific enthalpy of working fluid at pump outlet (kJ/kg)
η_{th}	= thermal efficiency (%)

2.1 The first law of thermodynamics [11]

The first law of thermodynamics or conservation of energy principle states that energy cannot be created or destroyed; it can only be transformed and transferred. The definition of thermal efficiency is defined as the ratio of network output divided by the total heat input as shown in Equation 5.

$$\text{Thermal efficiency} = \frac{\text{Net work output}}{\text{Total heat input}} \quad (5)$$

2.2 The second law of thermodynamics [11]

The second law of thermodynamics describes the quantity that determines the direction of a process and the driving force of physical or chemical change. This quantity is known as entropy. The change in entropy resulting to a reversible system is directly proportional to the heat transferred into the system (q_{rev}), but inversely to the temperature (T) of the system can be found in Equations 6-7.

$$dS = \frac{dq_{rev}}{T} \quad (6)$$

$$\Delta S = \int_i^f \frac{dq_{rev}}{T} \quad (7)$$

2.3 Exergy analysis

Exergy is a quantity that combines the enthalpy and entropy of a system. It is a maximum useful work of a system with respect to the reference ambient temperature. Exergy analysis can inform which process has an inefficient use of energy and can quantify the amount of energy lost. The expression for exergy of a steady-flow device with negligible kinetic and potential energy change is given in Equation 8.

$$\Delta Ex = \Delta H - T_0 \Delta S \quad (8)$$

where	ΔEx	= Exergy difference between two states (kW)
	ΔH	= Enthalpy difference between two states (kW)
	ΔS	= Entropy difference between two states (kW/K)
	T_0	= Ambient temperature (K)

The exergy balance is given in Equation 9

$$\sum \text{Exergy input} = \sum \text{Exergy output} + \sum \text{Exergy stored} + \text{Irreversibility} \quad (9)$$

Exergy efficiency (η_{ex}) can be calculated from Equation 10.

$$\eta_{EX} = \frac{\text{Energy output}}{\sum \text{Exergy input}} \quad (10)$$

The selection of the working fluid in the organic force cycle is very important because it is a variable that has a significant impact on system performance. The desirable working fluid of ORC should possess the following properties: (1) compatible evaporation and condensation temperature with heat source and sink, (2) high vapor density, (3) low viscosity, (4) high heat transfer coefficient, (5) acceptable evaporation pressure, (6) positive condensation pressure, (7) high temperature stability, (8) the melting point lower than the lowest ambient temperature, (9) non-toxic and non-flammable, (10) Low Ozone Depletion Potential (ODP), (11) low global warming potential

(GWP), (12) good available and low cost. Based on these selection criteria, the following working fluids have been chosen in this study: Dodecane, Toluene, Benzene, and Cyclohexane [11]. More details about theory and methodology used during model development are described elsewhere [2].

3. Simulation Results

According to the plant flow diagram, the offshore petroleum production process consists of 9 modules as shown in Fig. 1. The entire natural gas production processes have been modeled in DWSIM. To recover the waste heat released from exhaust gas, the ORC systems were added to the Booster Compression and Sales Gas Compression and Export modules [2].

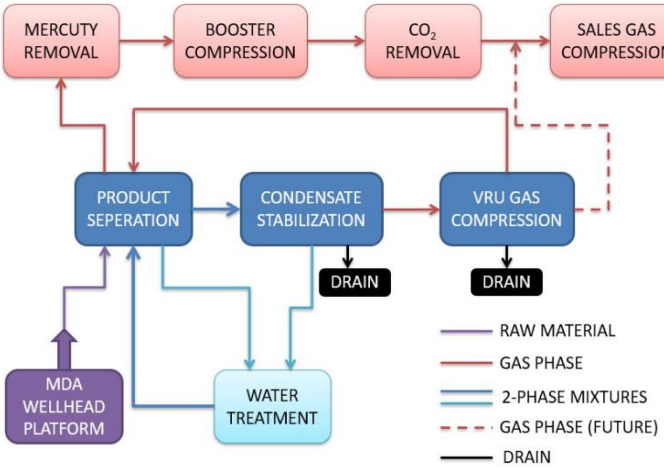

Fig. 1. Plant flow diagram of offshore petroleum production process [2].

Booster Compression, one of the main systems, is used to pressurize the gas product. The Booster Compression receives gas product from previous processes involving the separation of gas product, condensate, and unwanted impurities out of the feed streams. After gas compression, the gas is fed to Carbon Dioxide (CO_2) Removal and Sales Gas Compression, respectively. CO_2 Removal is performed as a filtering process that takes out the unwanted CO_2 from the gas product. After this process, the gas pressure will decrease, thus it is necessary to use Sale Gas Compression to increase the pressure again after the CO_2 Removal process. Sales gas compression process is also used to pressurize the gas for exporting from offshore platform via transmission pipe to onshore distribution stations.

According to the received process flowsheet, the specific design and arrangement of gas turbine engines that drive the gas compressors at Booster Compression and Sale Gas Compression and Export were not available. Therefore, it was necessary to assume generic design and specification commercially available. In this work, gas turbine engines from Siemens were selected because the design data and equipment specification were readily accessible.

In the simulation, the data of gas turbine-driven compressor was chosen by considering the most suitable power required by gas compressors at Booster Compression process and Sale Gas Compression and Export process which were 14,024.4 and 9,678.18 kW, respectively. Then, we had chosen the Siemens Mechanical Driving Sets that match the power required, acceptable weight, and installation area. Specifically, the SGT-400 Version 15 MW and the SGT-400 Version 11 MW were selected from the Booster Compression and the Sale Gas Compression and Export modules, respectively.

The input conditions for the calculation at Booster Compression and Sale Gas Compression and Export is shown in Tables 1 and 2, respectively.

Table 1: Input conditions for the simulation at Booster Compression.

Properties	Data
Mass flow rate of inlet air (kg/s)	44
Temperature of inlet air (°C)	30
Pressure of inlet air (bar)	1.01325
Compressor pressure ratio	18.9:1
Compressor adiabatic efficiency (%)	90
Heater heat added (kW)	52226.7
Heat exchanger effectiveness (%)	71.7
Turbine generated power (kW)	33552.7
Turbine adiabatic efficiency (%)	87.5
Expander outlet pressure (bar)	1.01325
Expander adiabatic efficiency (%)	100

Table 2: Input conditions for the simulation at Sale Gas Compression and Export.

Properties	Data
Mass flow rate of inlet air (kg/s)	33.8
Temperature of inlet air (°C)	30
Pressure of inlet air (bar)	1.01325
Compressor pressure ratio	16:1
Compressor adiabatic efficiency (%)	90
Heater heat added (kW)	35854.6
Heat exchanger effectiveness (%)	74
Turbine generated power (kW)	23460.6
Turbine adiabatic efficiency (%)	87.5
Expander outlet pressure (bar)	1.01325
Expander adiabatic efficiency (%)	100

After that, the input conditions based on specification from Siemens were assigned into the program. The simulation result showed that the operating temperatures of the gas heaters which are 1176.97 °C at Booster compression and 1093.3 °C at Sale Gas Compression and Export, respectively. The temperature of exhaust gas entering the ORC evaporator (or gas cooler from the view of the upper cycle) is 527 °C at Booster Compression and 504 °C at Sale Gas Compression and Export, respectively. The values of heat exchanger effectiveness have been included in Tables 1 and 2 accordingly.

The exhaust gas from gas turbine engines at Booster Compression and Sales Gas Compression and Export modules was treated as heat source while the seawater was treated as heat sink. Then, the following working fluids namely Dodecane, Toluene, Benzene, and Cyclohexane were chosen as working fluids for the ORC cycle as their critical temperatures were closer to the exhaust gas temperature than other organic fluids in order to achieve better thermal efficiency and work output as well as to reduce thermal irreversibility in the evaporator. The characteristics of each working fluid are shown in Table 3.

Table 3: The characteristics of each working fluid from DWSIM.

No.	Fluid	Formula	T_{cr} (◦C)	P_{cr} (bar)	V_{cr} ($m^3/kmol$)	Boiling point (◦C)
1.	Dodecane	$C_{12}H_{26}$	384.85	18.20	0.75	216.30
2.	Toluene	$(C_6H_5)CH_3$	318.60	41.08	0.32	110.64
3.	Benzene	C_6H_6	288.90	48.95	0.26	80.09
4.	Cyclohexane	C_6H_{12}	280.35	40.73	0.31	80.78

The ORC was designed as a simple cycle with no degree of superheating and subcooling due to limited floor area of the offshore platforms. The mass flow rate is fixed at 10 kg/s for all working fluid. The process flow diagram of the designed ORC is shown in Fig. 2. The simulation results of the designed Organic Rankine Cycle with different working fluids are shown in Table 4.

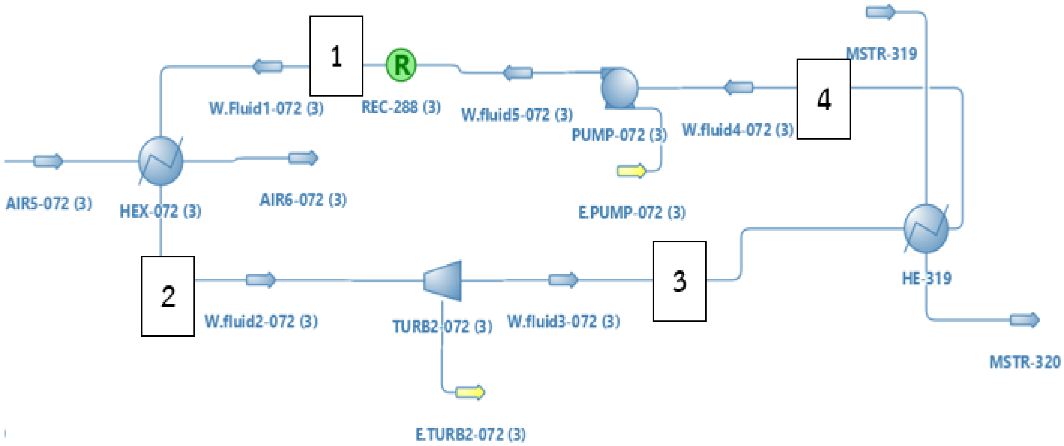

Fig. 2. Process flow diagram of the designed Organic Rankine Cycle.

From Fig. 2, the process flow diagram of the designed Organic Rankine Cycle which uses toluene as the working fluid, the state properties of toluene will be shown in Table 4 and the simulation results of other working fluids are shown in Table 5.

Table 4: State properties of toluene in the designed ORC.

State	Temperature (°C)	Pressure (kPa)	Enthalpy (kJ/kg)	Entropy (kJ/kg·K)	Exergy (kJ/kg)
1	47.29	4008.00	-364.10	-0.95	-70.16
2	323.00	4008.00	392.05	0.64	203.14
3	168.68	10.00	202.17	0.76	-20.42
4	45.75	10.00	-370.01	-0.95	-74.95

Table 5: The simulation results of the designed Organic Rankine Cycle.

Working fluid	Turbine power (kW)	Pump power (kW)	Heat duty (kW)	Efficiency (%)
Dodecane	577.98	32.26	2314.74	23.58
Toluene	1898.83	59.15	7561.48	24.33
Benzene	1602.07	69.89	6432.00	23.82
Cyclohexane	1646.38	65.29	7402.23	21.36

From the simulation, Toluene was identified as the most suitable working fluid which provided the highest turbine power at 1,898.83 kW and thermal efficiency of 24.33%. Therefore, the installation of four cycles ORC (2 cycles for Booster Compression and 2 cycles for Sale Gas Compression and Export) for the offshore platform get total energy at 7,595.32 kW or approximately 7.6 MW.

3.1 Exergy analysis [11]

The exergy destruction calculation is given by Equation 11

$$\dot{X}_{destroyed} = \dot{m}(\dot{X}_2 - \dot{X}_1) \quad (11)$$

where $\dot{X}_{destroyed}$ = the exergy destruction (kW)
$\dot{m}$ = the mass flow rate (kg/s)
$\dot{X}_2 - \dot{X}_1$ = the difference in exergy (kJ/kg)

In order to use the results in Table 5 for the calculation of exergy destruction, we set T_0 = 303 K, h_0 = 104.83 kJ/kg, S_0 = 0.36723 kJ/kg-K. The values of T_0, h_0 and S_0 are from the enthalpy and entropy of saturated liquid state of working fluid and the temperature of water which is the heat sink of the system. The exergy destruction is each device is shown in Table 6.

Table 6: Exergy destruction in each device.

Device	Exergy destruction (kW)
Heat exchanger	2732.98
Turbine	2235.58
Condenser	545.34
Pump	47.94

From Table 6, the exergy destruction occurred in heat exchanger (evaporator) was largest as it involved a large temperature difference of the working fluid at the inlet and outlet. For pump and condenser, the exergy destruction was smaller as the temperature different was correspondingly smaller.

4. ECONOMICS ANALYSIS [12]

For the economic analysis of incorporating the ORC into the existing plant, several methods can be used to evaluate the economic feasibility of a project. Included here are some common methods: Economic Efficiency, Net Present Value (NPV), Payback Period (PB), Internal Rate of Return (IRR) and Benefit Cost Ratio (B/C Ratio).

We have calculated the total capital cost necessary for construction and installation of 4 units of ORCs using toluene as a working fluid with a total turbine power equal of 7.60 MW. The investment cost of the project has been calculated based on a refence project cost of installing a 2 kWe ORC-WHR [13] and a scaling correlation given in Equation 12.

$$C_0 = C_{0,ref}\left(\frac{\dot{W}_{net}}{\dot{W}_{net,ref}}\right)^{0.8} \quad (12)$$

Where C_0 = the cost of ORC system at a given size (Baht)
$C_{0,ref}$ = the cost of ORC system at 2 kWe (Baht)
$\dot{W}_{net}$ = the net turbine power of project (kW)
$\dot{W}_{net,ref}$ = the net turbine power of the reference (2 kW)

The following assumptions have been established for the economic analysis. The figures were based on the 2 kWe ORC-WHR system [13]

- The lifetime period: 20 years
- The operating hour: 8000 hours/year [14]
- The interest rate: 5% per year
- The general inflation: 2% per year
- The minimum attractive rate of return: MARR = 8 %

The investment cost and the expected cost saving after the installation of 4 ORC units at the Booster Compression and Sale Gas Compression and Export section is shown in Table 7 and Table 8, respectively. This cost saving in energy consumption can be converted to monetary value by using barrel of oil equivalent conversion. In this case, one barrel of oil equivalent (BOE) is equal to 1.7 MW-hr [15]. So, the income of this project is 61,120,969.70 THB/year. The net cash flow diagram of the project is shown in Fig. 3.

Table 7: The total investment cost for 4 units of ORC.

Item	Cost (THB)	%
Turbine	77,457,882.70	19.91
Evaporator	90,928,818.82	23.38
Condenser	90,928,818.82	23.38
Fluid pump	30,309,606.27	7.79
Working fluid	13,470,936.12	3.46
Water pump	10,103,202.09	2.60
Piping system	6,735,468.06	1.73
Liquid reservoir	6,735,468.06	1.73
Control system	16,838,670.15	4.33
Misc. hardware	10,103,202.09	2.60
Total Equipment cost (TEC)	353,612,073.20	90.91
Labor cost (10% TEC)	35,361,207.32	9.09
Total installed cost (TIC)	**388,973,280.52**	100.00
Annual cost		
Operation and Maintenance (5%TIC)	19,448,664.03	-
Insurance (0.3% TIC)	1,166,919.84	-
Total annual cost	**20,615,583.87**	-

Table 8: The cost saving of 4 units of ORCs of the project.

Parameters	
Turbine Power	7.60 MW
Energy produced	60762.56 MW-hr/year
Energy saved	37,303.93 (BOE/year)
Money Saved	61,120,969.70 (THB/year)

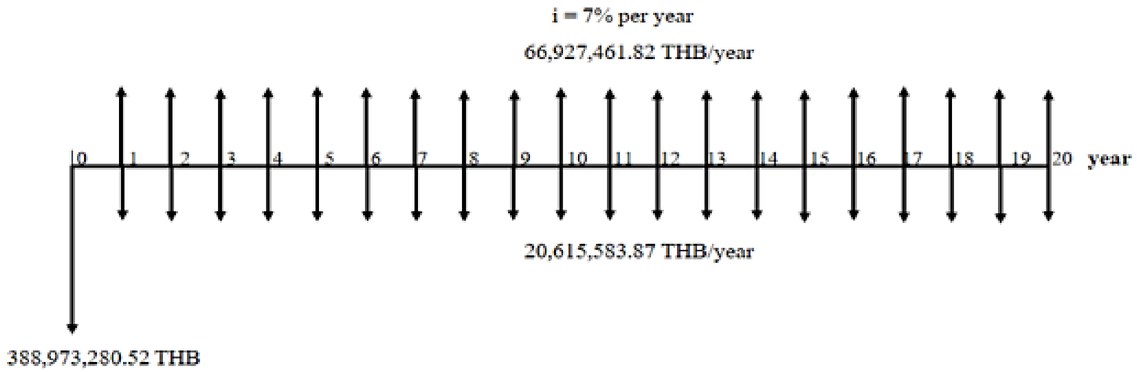

Fig. 3. The net cash flow diagram of the project.

The data in Table 7 was a result from our own estimation. It was originally based on equipment cost from reference [13] and then we used linear extrapolation to scale the equipment cost to our plant size in kW.

The economic analysis using the aforementioned methods has been performed and the results are shown in Table 9. The results showed that the ORC technology has economic efficiency of 106.61%, the net present value (NPV) is 40.141 million Baht, the payback period (PB) is 16.49 years, the internal rate of return (IRR) is 8.18% per year and the benefit cost ratio (B/C ratio) is 1.10. All indicators show economically favorable results, thus, indicating that this research is economically feasible and worth for the investment.

Table 9: Economics analysis of the project.

No.	Methods of evaluation	Acceptable criteria	Project calculation
1	Economic Efficiency	Economic Efficiency > 100%	106.61%
2	Net Present Value (NPV)	NPV > 0	40,141,353.97 THB
3	Payback period (PB)	PB < Lifetime period ; 20 years	16.49 years
4	Internal Rate of Return (IRR)	IRR > MARR; MARR=8%	8.18%
5	Benefit Cost Ratio (B/C Ratio)	B/C Ratio > 1	1.10

5. CONCLUSION

A thermodynamic model of natural gas production processes on offshore platforms has been developed in an open-source chemical process simulation program, DWSIM. The Organic Rankine Cycle (ORC) technology has been applied to the plant in order to recover some of the waste heat from gas turbine exhaust into electricity. The exhaust gas from gas turbine engines at Booster Compression and Sales Gas Compression and Export modules was treated as heat source while the seawater was treated as heat sink. The simulation result showed that the operating temperatures of the gas heaters which are 1176.97 °C at Booster compression and 1093.3 °C at Sale Gas Compression and Export, respectively. The temperature of exhaust gas entering the ORC evaporator (or gas cooler from the view of the upper cycle) is 527 °C at Booster Compression and 504 °C at Sale Gas Compression and Export, respectively. We have selected 4 organic fluids that matched the exhaust gas temperature namely Dodecane, Toluene, Benzene, and Cyclohexane to evaluate the most suitable working fluid for the ORC in order to obtain the highest turbine power and efficiency. The ORC was designed as a simple cycle with no degree of superheating and subcooling due to limited area of the offshore platforms. From the simulation, Toluene was identified as the most suitable working fluid which provided the highest turbine power and efficiency at 1.90 MW and 24.33%, respectively. So, the installation of four cycles ORC for the offshore platform get total energy at 7.6 MW. The economic analysis has been performed. The results showed that the ORC technology has economic efficiency at 106.61%, the net present value (NPV) is 40.141 million Baht, the payback period (PB) is 16.49 years, the internal rate of return (IRR) is 8.18% per year (from the minimum attractive rate of return or MARR at 8% per year) and the benefit cost ratio (B/C ratio) is 1.10. All indicators show economically favorable results, thus, indicating that this research is economically feasible for the investment.

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