Reutilization of flare gas for energy recovery in oil and gas operations

by

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CERTIFICATION OF APPROVAL

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Approved by,

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MUHAMMAD AFDHALUDDEN BIN AZMI

Abstract

Flaring is the controlled burning of natural gas in the course of routine oil and gas production operations. This burning occurs at the end of a flare stack or boom. During flaring, the burned gas generates mainly water vapor and carbon dioxide. Gas being flared may come from a variety of sources. It may be excess to that which can be supplied commercially to customers, unburned process gas from the processing facilities, vapors collected from the tops of tanks as they are being filled and from process upsets, equipment changeover or maintenance. Occasionally, a production shutdown may require the temporary flaring of all the gas stored on or arriving at a facility, to release high pressure and avoid a tragic situation occurring.

Flaring constitutes a hazard to human health, and is a contributor to the worldwide emissions of carbon dioxide. Flaring emits methane and other volatile organic compounds as well as sulfur dioxide and other sulfur compounds, which are known to worsen asthma and other respiratory problems. It is in the company's interest to minimize the amount of gas being flared.

This project is aim to evaluate potential energy recovered from gas reutilization facility. The concept used in this project is to store the flaring gas in storage tank. After achieving certain amount, the gas will be flow into gas reutililzation facility consist of microturbine and compressor. The simulation of gas reutilization is being done using Aspen Hysys 2006 simulation software. Assuming natural gas flowing at constant rate of 0.75 MMSCFD, an amount of 217kW to 225kW of energy is produced.

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CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Flaring is the controlled burning of natural gas in the course of routine oil and gas production operations. This burning occurs at the end of a flare stack or boom. A complete flare system consists of the flare stack or boom and pipes which collect the gases to be flared. The flare tip at the end of the stack or boom is designed to assist entrainment of air into the flare to improve burn efficiency. Seals installed in the stack prevent flashback of the flame, and a vessel at the base of the stack removes and conserves any liquids from the gas passing to the flare. Depending on the design, one or more flares may be required at a production location. During flaring, the burned gas generates mainly water vapor and carbon dioxide. Efficiency combustion in the flame depends on achieving good mixing between the fuel gas and air, and on the absence of liquids.

Gas being flared may come from a variety of sources. It may be excess to that which can be supplied commercially to customers. It may be unburned process gas from the processing facilities. It may be vapors collected from the tops of tanks as they are being filled. Sometimes, the gas may be from process upsets, equipment changeover or maintenance. Occasionally, a production shutdown may require the temporary flaring of all the gas stored on or arriving at a facility, to release high pressure and avoid a tragic situation occurring.

Venting is the controlled release of gases into the atmosphere in the course of oil and gas production operations. These gases might be natural gas or other hydrocarbon vapors, water vapor, and other gases, such as carbon dioxide, separated in the processing of oil or natural gas. In venting, the natural gases associated with the oil production are released directly to the atmosphere and not burned. Safe venting is assured when the gas is released at high pressure and is lighter than air. Because of the strong mixing potential of high-pressure jets, the hydrocarbon gases discharged mix well with the air down to safe concentrations at which there is no risk of explosion.

Venting is normally not a visible process. However, it can generate some noise, depending on the pressure and flow rate of the vented gases. In some cases, venting is the best option for disposal of the associated gas. For example, in some cases, a high concentration of inert gas is present in the associated gas. Without a sufficiently high hydrocarbon content, the gas will not burn and flaring is not a viable option. Sometimes the source of inert gas may come from the process systems. The purging of process systems with inert gas may, in itself, justify venting as the safest means of disposal.

It is in the company's interest to minimize the amount of gas being flared. The aim of minimizing flaring can be achieved through a variety of mechanisms which may range from marketing initiatives to maintenance strategies to new technologies. The following discussion, and the case studies which illustrate it, serve to explain how different solutions are appropriate in different circumstances. Ideally, the associated gas will be sold to a customer as a fuel or petrochemical feedstock. However, unlike oil, gas is not an easily transportable fuel.

In the situation where the associated gas cannot be commercialized, only three options remain: vent it, flare it, or re-inject and store it in the underground formations from which the oil is being recovered. Reinjection is a practicable option for some oil fields, but not in all cases. In some situations, the geological nature of the underground formations is such that the injected gas would migrate back to the oil production wells too easily, leading to inefficient and energy intensive gas recycling. Even for formations where reinjection is geologically practicable, the oil field itself may be too small in economic terms to support the additional reinjection infrastructure.

1.2. PROBLEM STATEMENT

Flaring is the controlled burning of natural gas and a common practice in oil/gas exploration, production and processing operations. Flaring constitutes a hazard to human health, and is a contributor to the worldwide emissions of carbon dioxide. Flaring emits methane and other volatile organic compounds as well as sulfur dioxide and other sulfur compounds, which are known to worsen asthma and other respiratory problems. Other emissions include, aromatic hydrocarbons (benzene, toluene, xylenes) and benzapyrene, which are known to be carcinogenic.

As of the end of 2011, 150×10^9 cubic meters of associated gas are flared annually. The amount of natural gas being flared and vented annually is astronomical. It's equivalent to 25 per cent of the United States' annual gas consumption, 30 per cent of the European Union's annual gas consumption, 75 percent of Russia's annual gas exports, and more than the combined gas consumption of Central and South America. In Africa alone, the annual amount of gas flared is equivalent to half the continent's power consumption.

Gas flaring has a global impact on climate change by producing about 400 million tons of greenhouse gas emissions annually. But the negative impacts of gas flaring don't stop there. Residents in nearby communities have experienced chronic health problems, including bronchial, chest, rheumatic, and eye problems.

Thus, a prevention program or initiative to reduce flaring activity need to be practiced by oil and gas industry to avoid worse impact towards human and environment. Oil and gas company are currently pun an effort to minimize their flaring activity. Is a mechanism adopted to ensure that extraction of oil be it on or offshore in drilling does not cause harm to the environment and that the gas is safely and cost effectively recovered and utilize for distribution purposes. This is done to reduce an emission of carbon dioxide and ni-troxide into the atmosphere.

1.3. OBJECTIVE / SCOPE OF STUDY

Parallel with the problem statement, this project is aim to help reduce flaring emission by reutilize natural gas for energy recovery. Other objectives of this study is to evaluate energy recovery potential. Previous researches were done to evaluate energy recovery based on data obtained from Duyong Central Processing Platform.

CHAPTER 2: LITERATURE REVIEW

2. 1 FLARING REDUCTION INITIATIVES

Associated gas flaring is one of the most challenging energy and environmental problems facing the world today. Environmental degradation associated with gas flaring has a significant impact on local populations, often resulting in loss of livelihood and severe health issues. For producer governments, flare reduction is an opportunity to create value from a wasted resource and enable wider access to energy, improved environmental conditions, and economic development for local populations. Successful efforts to reduce flaring will benefit local communities, provincial and national governments, and the entire planet. Below are some success stories of flare reduction program.

- Russia - Flare gas reduction and electricity production with Jenbacher gas engines.

  GE Energy is supplying 12 Jenbacher gas engines to support Russian oil and gas producer Monolit LLC's project to reduce emissions by utilizing previously flared gas at a Western Siberian production facility. At the facility, the waste gas will be separated into liquefied natural gas and other "transportable" products (including propane, butane, and ethane) for the chemical industry. By utilizing the gas from nearby drilling fields at Shapinskoe for onsite power generation, Monolit will avoid the need to transport diesel fuel over long distances, thus delivering significant environmental benefits. Utilization of otherwise flared gas for onsite power generation will help save up to about 536,000 tons of CO2 equivalents per year.

- Kazakhstan - Sour gas re-injection

  Sour gas or natural gas with high levels of H2S is lethal if dispersed into the air. GE has developed technology to handle the high pressure, high sulfur content gas associated with oil production at Karachaganak, Tengiz, and Kashagan oil fields. The associated gas is captured, compressed and re-injected into the formations to sequester the toxic gas while improving oil recovery. This approach utilizes GE's BCL300 series of centrifugal compressors. Since 2000, the deployment of this GE technology for gas re-injection has prevented more than 49 million tons of CO_2 from being released into the atmosphere each year, or the equivalent of the annual CO_2 emissions released by approximately 10 million average cars.

- Argentina - Aeroderivative power generation

  GE Energy developed the Chihuido Power Plant for REPSOL YPF Argentina. The project involves GE's LM2500 gas turbine equipped to operate with low BTU fuel. The project generates about 40 MW of power from the .45 million cubic meters per day of gas that was previously flared.

- Nigeria - Fast track gas compression projects and power generation projects

  GE Oil and Gas is developing compression island approaches for various flow stations in the Niger Delta. These reciprocating compressor units will compress natural gas for delivery into local power generation or pipelines. The Ebocha compression project gathers up low and high-pressure gas from the oil and gas separation units for redelivery into the pipeline grid. Another Nigerian project used GE aeroderivative technology including LM2500 gas turbines for the Crawford Channel LPG and associated gas-gathering project.

2. 2 MICROTURBINE – RECUPERATED AND UNRECUPERATED

Microturbine is a new technology being used for energy generation applications. Microturbine is a combuston turbine that produce both heat and electrical energy. Microturbine systems have many advantages over reciprocating engine generators, such as higher power density (with respect to footprint and weight), extremely low emissions and few, or just one, moving part. Microturbines also have the advantage of having the majority of their waste heat contained in their relatively high temperature exhaust, whereas the waste heat of reciprocating engines is split between its exhaust and cooling system. However, reciprocating engine generators are quicker to respond to changes in output power requirement and are usually slightly more efficient, although the efficiency of microturbines is increasing.

Microturbines operate with most commercial fuels, such as gasoline, natural gas, propane, diesel, and kerosene as well as renewable fuels. Microturbine designs usually consist of a single stage radial compressor, a single stage radial turbine and a recuperator.

Microturbine generators can be divided into two types: recuperated and unrecuperated microturbine. In unrecuperated microturbine, compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work. Simple cycle microturbines have low efficiency up to 15%. However, unrecuperated microturbine is cheaper, higher reliability and more heat available for cogeneration applications than recuperated microturbines. On the other hand, recuperated microturbines use a sheet-metal exchanger that recovers some of the heat from an exhaust stream and transfer it to the incoming air stream, boosting the temperature of the air stream supplied to the combustor. Further exhaust heat recovery can be used in a cogeneration configuration. Recuperated microturbines can achieve up to 80% efficiency.

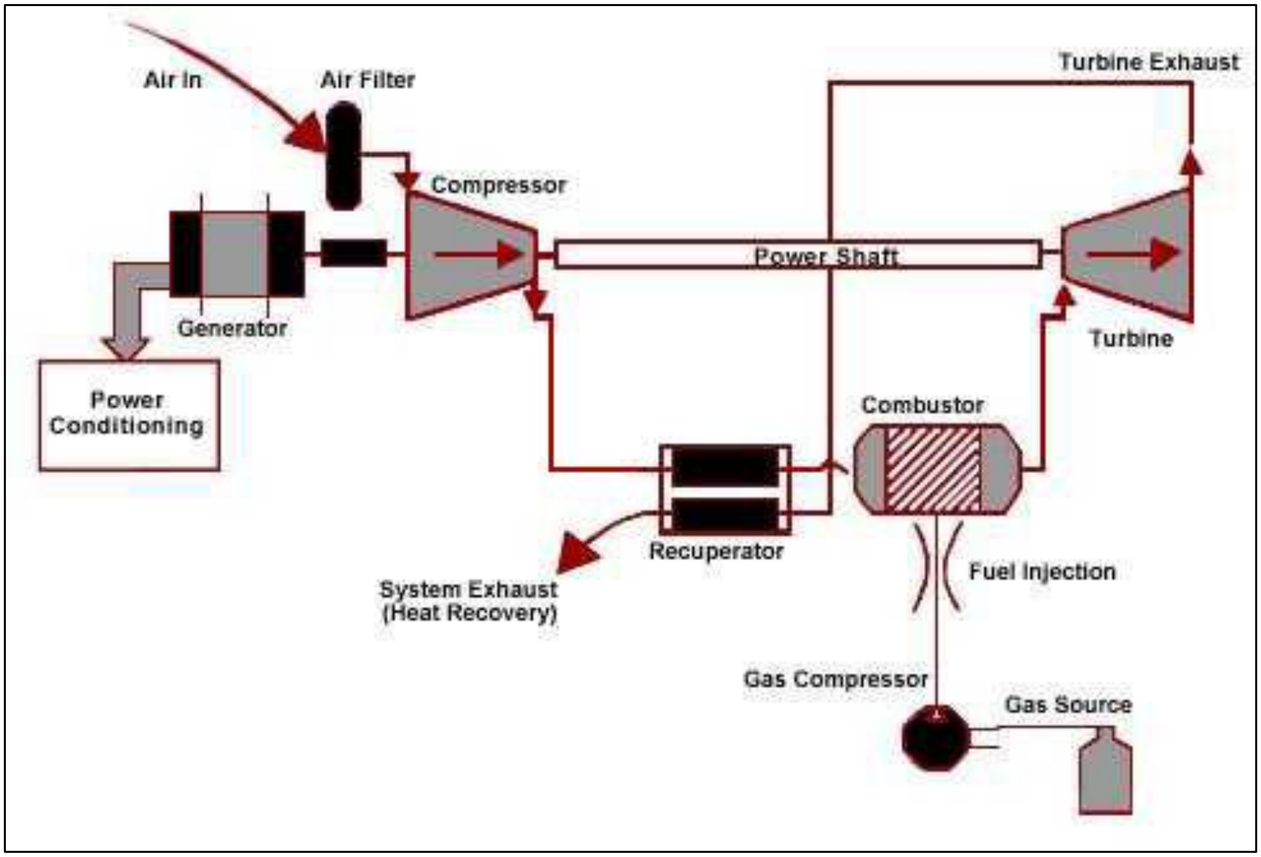

Figure 1: Recuperated microturbine schematic diagram

Typical microturbine efficiencies are 25 to 35%. When in a combined heat and power cogeneration system, efficiencies of greater than 80% are commonly achieved.

2. 3 BRAYTON CYCLE

The Brayton cycle is named after George Brayton; is a thermodynamic cycle that describes the workings of a gas turbine engines. Brayton cycle is usually run as an open system. However, for the purposes of thermodynamic analysis that the exhaust gases are reused in the intake, it is assumed as a closed system.

In Brayton engine, ambient air is channel into a compressor to be pressurized (isentropic process). Then, it is directed over a mixing chamber where fuel is mixed known as an isobaric process. The mixture is then burnt in an expansion container and energy is released, causing the heated air and combustion products to expand through a piston (isentropic process). This expansion causes the turbine blade to spin, which turns a shaft inside a magnetic coil. Electric current is created when the shaft is rotating inside the magnetic coil.

Gas turbine engine, which apply Brayton cycle consist of three components:

1. Compressor
2. Combustion chamber
3. Turbine

Ideal Brayton cycle:

- Isentropic process - air is channel into the compressor, where it is compressed.
- Isobaric process - the compressed air then flow through a combustion chamber, mixing with fuel, burned and heating the air.
- Isentropic process - the heated, compressed air then gives up its energy, expanding through a turbine. Work done by the turbine is used to run the compressor.
- Isobaric process - heat rejection to the atmosphere.

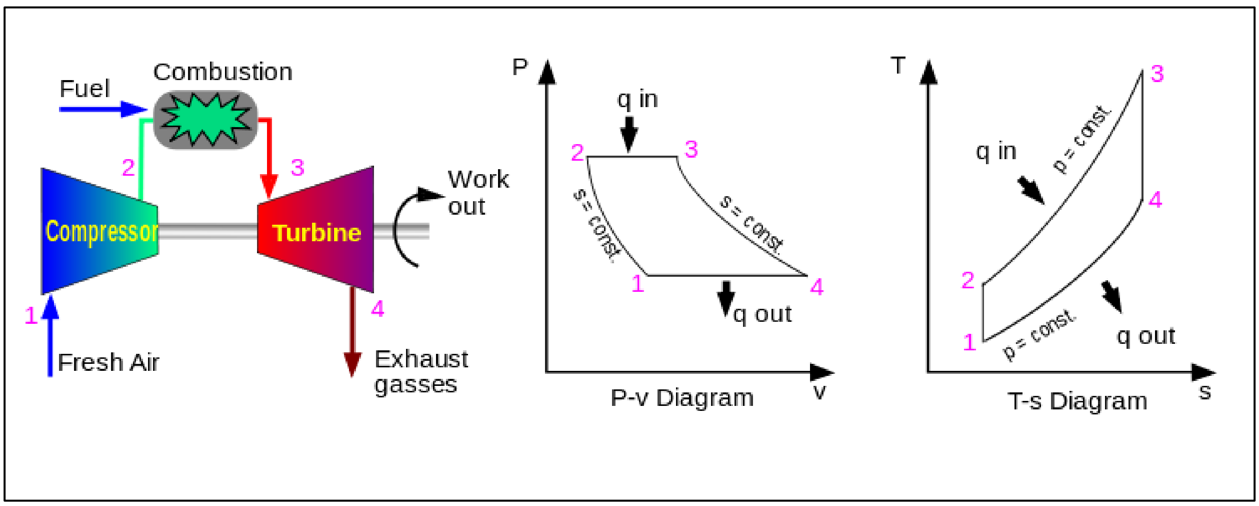

Figure 2: Brayton cycle

The **T-s and P-v diagrams** of an ideal Brayton cycle are shown in figure above. All four processes of the Brayton cycle are performed in steady flow equipment so they should be evaluated as steady-flow processes. Energy balance for a steady-flow process can be express if the variations in kinetic and potential energies are ignored. Theoretical formula for Brayton cycle is as follow:

$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = h_{exit} - h_{inlet}$$

The heat transfer is:

$$q_{in} = h_3 - h_2 = C_p(T_3 - T_2)$$
$$q_{out} = h_4 - h_1 = C_p(T_4 - T_1)$$

The thermal efficiency is:

$$\eta_{th}, Brayton = \frac{w_{net}}{q_{in}}$$

$$= 1 - \frac{q_{out}}{q_{in}}$$

$$= 1 - \frac{C_p(T_3 - T_2)}{C_p(T_4 - T_1)}$$

$$= 1 - \frac{T_1\left(\frac{T_4}{T_1} - 1\right)}{T_2\left(\frac{T_3}{T_2} - 1\right)}$$

Since process 1 to process 2 and process 3 to process 4 are isentropic, we can assume that

$p_2 = p_3$ and $p_4 = p_1$

Thus,

$$\frac{T_2}{T_1} = (\frac{P_2}{P_1})^{\frac{(k-1)}{k}} = (\frac{P_3}{P_4})^{\frac{(k-1)}{k}} = \frac{T_3}{T_4}$$

Substituting these equations into thermal efficiency equation (above) give

$$\eta_{th}, Brayton = 1 - \frac{1}{(\frac{p2}{p1})^{\frac{(k-1)}{k}}}$$

2. 4 HYSYS SOFTWARE

HYSYS is a powerful engineering simulation tool, has been created with respect to the program architecture, interface design, engineering capabilities and operations. The various components that comprise HYSYS provide a powerful approach to steady state modeling. At a fundamental level, the comprehensive selection of operations and property methods allows us to medel a wide range of process.

HYSYS is widely used in universities in engineering course, especially chemical-based subject. However, related with oil and gas industry, HYSYS is capable to be used in research, development, modeling and design oil and gas plant. HYSYS serves as a platform to model upstream process, refining and chemical process, gas processing system and other complex process related to oil and gas industry.

Releven with the project objective, HYSYS is essential to aid natural gas simulation. Various component and system in HYSYS itself is enough to run gas-to-electric model simulation. User need to arrange component as per desired and enter required data into the program. HYSYS will run the simulation and give precise result as long as data and component arrangement are in correct order.

CHAPTER 3: METHODOLOGY

problem statement

- Problem statement identification to determine the goal for this project

Literiture review

- A literature review discusses published information of current gas reutilization system, related theory and its associated area

conceptual facility design

- Conceptual idea to design a gas reutilization facility based on research conducted regarding this project

pre-condition of gas

- Natural gas parameter and condition need to be determined to suit requirements of gas reutilization facility

theoritical calculation

- determine possible output for the system

HYSYS simulation

- Simulation using reliable software to estimate as real output as possible

result verification

- comparison of theoritical calculation and HYSYS simulation to determine percentage error between both concept

3. 1 CONCEPTUAL DESIGN OF GAS UTILIZATION FACILITY

A new conceptual design called "Gas Utilization Facility" is introduced to reutilize gas for energy recovery. Additional equipment are required in the system such as gas storage tank, recuperated gas turbine, and generator. Basic idea is to install the facility before flare stack, intercept the gas in flaring system, and store it temporarily in gas storage tank before it is burned in gas turbine to power the generator. Then the electricity produced from the generator will be used to support the electricity appliances at designed oil and gas plant.

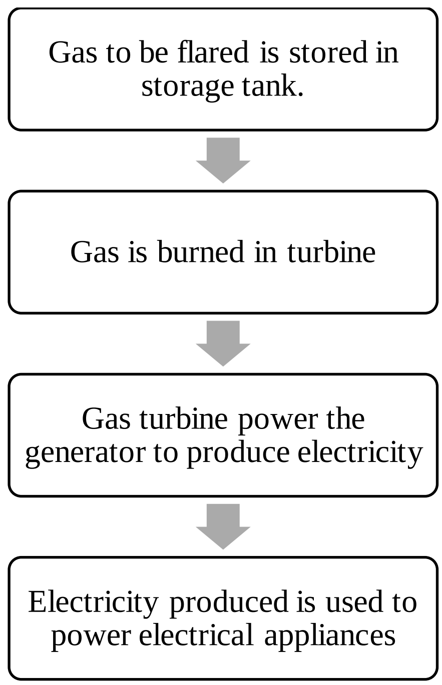

Figure 3 Basic concept of gas utilization facility

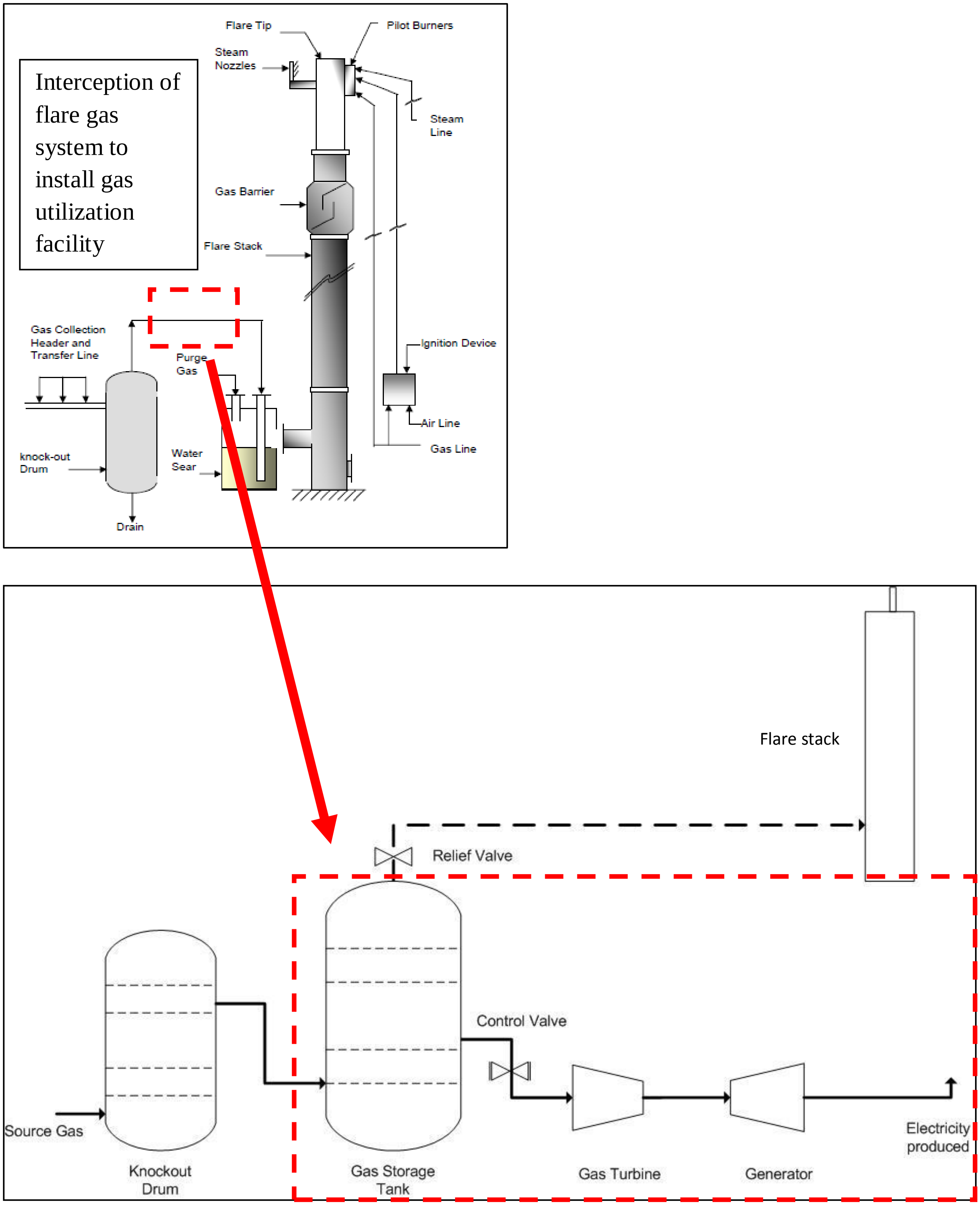

Figure 4 Conceptual design for gas utilization facility

Dry gas from knockout drum will be channelled to gas storage tank. Safety valve or relief valve is connected from gas storage tank to the main line of the flaring system. This is a precaution act in any emergency event when the pressure or volume in the gas storage tank is exceeding the designed parameter, the gas will be flared in normal flaring system. Gas storage tank is important equipment as it will collect the inconsistence flow of gas from offshore platform, store it, and supply constant gas flow to the gas turbine whenever the gas utilization facility is operating.

When gas utilization facility is operating, the gas is collected in gas storage tank will be channelled to gas turbine to be burned. As a result, the gas turbine will power the generator to produce electricity. The electricity produced will be channelled to the main switch board to support electrical appliances of oil and gas plant. The operational period of this conceptual idea is depends solely on gas amount and flow rate. Two options available to operate the facility;

1. Continuously run the operation
   - This type of operation requires continuous gas supply from offshore platform. Electrical appliances is 100% powered by electric generated from suggested gas utilization system.

2. Alternate on-off operation
   - Suitable for inconsistence offshore gas delivery. Gas will be collected at storage tank to meet certain amount before transmitted to gas turbine and generator. Let say, 12 hours is given to collect gas. During this period, electrical utilities is powered normally. Next 12 hours, the electrical utilities is powered by electric generated from this gas utilization system. The process continuous for next cycles.

3.1.1 Storage Tank

Storage tank is an important facility in this suggested system. A storage tank is a container usually for holding liquids and sometimes for compressed gas. Storage tanks are available in various types and size depending on the product to be stored. Oil & gas, petrochemical and fluid-based industry usually used this facility to stored their raw and end-products.

Common type of storage tank:

- Vertical and Horizontal cylindrical
- Open top and Closed top
- Flat Bottom
- Cone Bottom
- Slope Bottom
- Dish Bottom

Generally in processing plant and especially for liquid fuels, fixed roof tanks, and floating roof tanks are used. Tanks for a particular fluid are chosen according to the flash-point of the substance.

Fixed roof tanks (Cone roofs, dome roofs and umbrella roofs) are meant for liquids with very high flash points such as fuel oil, water and bitumen. These are insulated to prevent the clogging of certain materials, wherein the heat is provided by steam coils within the tanks.

Floating roof tanks are divided into external and internal floating roof tank. It comprises an open- topped cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid. The roof rises and falls with the liquid level in the tank. As opposed to a fixed roof tank there is no vapour space in the floating roof tank to eliminates breathing losses and greatly reduces the evaporative loss of the stored liquid

In order to install a storage tank, there are many regulations and Standards which should be respected. Tanks need to be installed according to the American Petroleum Institute (API) regulations. Tank storage must be differed according to the type or state of the product, whether it is gas, liquid or solid. Oil product can be stored in open or closed tanks with or without heating depends on the density. LPG and light petroleum fractions are stored in pressurized storage tank. Meanwhile LNG is refrigerated and stored in the special container.

3.1.2 Gas turbine & generator

Gas turbines are used to power electrical generators. It is a type of internal combustion engine. It has an upstream rotating compressor coupled to a downstream turbine, and a combustion chamber in-between. Air is supplied into turbine and flows through a compressor that compress it to high pressure air. Energy is then added by mixing air with fuel and being ignited to create a high-temperature flow. This high temperature and high pressure gas enters a turbine, where it expands down to the exhaust pressure, producing a shaft work output. The turbine shaft is used to drive the compressor and other devices such as an electric generator that attached to the shaft.

Gas turbine for industrial power generation range in size from small scale to massive, complex structures weighing more than hundred tons accommodated in block-sized buildings. The efficiency of the turbine can be as low as 25% when the turbine is used specially for shaft power. Thus, industrial player more prefer to buy electricity than installing gas reutilization facility. Therefore, Combined Heat and Power (CHP) is used in turbine configurations to increase the efficiency up to 80%. The efficiency of the facility increased when waste heat from the turbine is recovered by a heat recovery generator to power a conventional turbine in a combined cycle configuration.

Another advantage is the ability to be turned on and off within short period of time. Hence, it simply able to supply power during necessary demand. Single cycle power plants are less efficient than combined cycle plants. Subject to the electricity demand and the generating capacity of the region, it is usually used as peaking power plants, which operate anywhere from few hours per day to a several hours per year.

A generator is a device that converts mechanical energy to electrical energy. A generator forces electric current to flow through an external circuit. Mechanical energy supplied to generator is drive by gas turbine.

3. 2 PRE-CONDITION OF GAS AND EQUIPMENT'S REQUIREMENT

It is important to determine parameters of natural gas in this system. Natural gas obtained from offshore platform usually comprise of oil, associated gas, water and other impurities. Thus, before natural gas enters the suggested system, the gas should be free from any liquid particles and acidic materials. Hence, separator and knockout drum are used for that particular purposed.

As for gas turbine, few parameters of gas should be known. Some necessary info for this project are:

- Gas composition
- Temperature
- Pressure
- Flow rate / molar flow
- Gas heating value

Using HYSYS simulation software, few parameters are needed. Natural gas data are taken from Duyong Central Processing Platform, as stated by Fazrin (2012). The data is taken on 1st March 2012.

Pressure: 69.17 bar

Temperature: 23.70 °C

Molar flow: 1.5 MMCFD

Composition:

Table 1: composition of natural gas

COMPONENT	MOLE FRACTION
Methane	0.8314129
Ethane	0.09697911
Propane	0.01856903
N-Butane	0.00448056
I-Butane	0.00587834
N-Pentane	0.00015655
I-Pentane	0.00029646
Hexane	0.00004939
Heptane	0.00049899
Octane	0.00032335
Nonane	0.00000660
CO2	0.03637937
H2O	0.00001309
N2	0.00495610
H2S	0.00000010

In Aspen Hysys 2006 software, Peng-Robinson fluid package was selected and components of natural gas were selected as per above criteria. However, as daily production and operation in oil and gas industry do fluctuate every day. Thus, for simulation purpose, natural gas parameters cannot be assume based on single operation parameter. Thus, the parameter of the natural gas is assume as below:

Pressure: 8.013 bar

Temperature: 23.70 °C

Molar flow: 0.75 MMCFD

For gas utilization facility, the schematic design using Aspen HYSYS 2006 software are divided into two parts; unrecuperated and recuperated microturbine.

CHAPTER 4: RESULT AND DISCUSSION

Two general types of microturbine is recuperated and unrecuperated microturbine. In unrecuperated microturbine, compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work. However, unrecuperated microturbine is cheaper, higher reliability and more heat available for cogeneration applications than recuperated microturbines.

Aspen Hysys 2006 software gives a result of 217kW energy produced from unrecuperated simulation. Recuperated microturbines use a sheet-metal exchanger that recovers some of the heat from an exhaust stream and transfer it to the incoming air stream, boosting the temperature of the air stream supplied to the combustor. Hence, an amount of 225kW energy is produced from recuperated microturbine simulation. The result differ due to different component were used in both simulation.

CHAPTER 5: CONCLUSION

Flaring reduction initiatives have been carried out since long time ago. It takes few years to achieve zero flaring activity or major reduction in flaring volume. This project is aim to help reduce flaring emission by reutilize natural gas for energy recovery. One of the initiative is to reutilize the gas for operational usage such as to support electrical usage. This little initiative can be performed with steady and constant supply of natural gas. Other objectives of this study is to evaluate energy recovery potential. Based on Aspen Hysys 2006 simulation a range of 217kW to 225kW energy is produced for unrecuperated and recuperated microturbine respectively.

Both simulation show positive output power. However, simulation of recuperated microturbine give more energy compared to unrecuperated microturbine simulation since it has the ability to absorb and preheat the incoming gas before expansion process.

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