UNIVERSITI
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FINAL YEAR PROJECT

"Simulation of Onshore and Offshore Facility Flare Gas Reutilization in an Energy Recovery Scheme"

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Bachelor of Engineering (Hons)

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CERTIFICATION OF APPROVAL

"Simulation of Onshore and Offshore Facility Flare Gas Reutilization in an Energy Recovery Scheme"

By:

Muhamad Fazrin Bin Md Raus

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Approved by,

(Ir. Dr. Mohd Shiraz B. Aris)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

November 2012

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.

(Muhamad Fazrin Bin Md Raus)

ABSTRACT

Since the birth of the oil industry, flaring has been used upstream to depressurize eruptive wells and downstream to burn excess gases in refining and petrochemical plants and also in associated and natural gas treatment plants. Enormous quantities of co-produced gas are flared as a waste by-product and large supplies of gas have emerged. Although this process ensures the safety of the facility by reducing the pressures in the system that is resulted from gas liberation, gas flaring has become a public concern and a priority issue for public authorities because it is first a waste of a non-renewable source. It would be highly desirable to recover energy from flared natural gas to generate electricity especially in the offshore setting where electricity is not readily available. Hence, more attention should be focused on the effective utilization of flared natural gas in oil and gas offshore platforms.

The energy recovery system, as one of the promising techniques, has been attracting increased attention to generate electricity from flared natural gas. In this project, the main aim is to simulate a flare gas recovery system by utilizing the method of generating electricity from microturbine using HYSYS software to evaluate the potential energy that can be recovered from gas flaring. It is concluded that microturbine with recuperator gives out a better energy recovery than microturbine without recuperator and the concentration of methane is a viral factor in the energy recovery scheme.

ACKNOWLEDGEMENT

First and foremost, I thank and praise Allah for His guidance and blessing, definitely without it I would not have been able to complete my final year project lasting for two semesters. It was a long journey of studying, researching, analyzing, comparing and training, in which a lot has happened – many problems were faced and many solutions were implemented. I am infinitely thankful to a lot of people who has helped in the completion of this project. My deepest gratitude goes to Dr. Mohd Shiraz Bin Aris, my supervisor who has guided me through the whole process of project implementation and helped in suggesting the suitable approach and methods to solution of the problems and challenges encountered during the timeframe of the project.

My salutation would be incomplete without giving credit to PETRONAS and Azreel who have given me their corporation in providing me with the essential information related to this research. I sincerely appreciate the contributions handed to me, which certainly have added value to the completion of this project.

Thank you all for all the help and support in completing my final year project

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CHAPTER 1

INTRODUCTION

1.1. Background of Study

Worldwide, final product cost of refinery operations are becoming proportionally more dependent on processing fuel costs, particularly in the current market, where reduced demand results in disruption of the optimum energy network through slack capacity. Therefore, to achieve the most cost-beneficial plant, the recovery of hydrocarbon gases discharged to the flare relief system is vital.

The option to release gas to the atmosphere by flaring is an essential practice in the oil and gas production, primarily for safety reasons. 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 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.

Energy consumption is a key part of most human activities. This consumption involves converting one energy system to another, the input energy propels the work and is mostly converted to heat or follows the product in the process as output energy. Energy recovery systems harvest the output power and providing this as input power to the same or another process. An energy recovery system will close this energy cycle to prevent the input power from being released back to nature and rather be used in other forms of desired work.

In reutilizing the flare gas in an energy recovery schemes, gas is converted successively into thermal energy, mechanical energy, and finally electrical energy for continuous use and distribution. To be specific this project will be discussing more on energy recovered by converting flare gas from a flare system facility into electrical energy.

1.2. Problem Statement

- Industry practice of continuous flaring.
- Waste of valuable natural resources.
- Offshore facility power breakdown

1.3. Objectives and Scope of Study

Main objectives of this study are:

- To evaluate the feasibility of using flare gas recovery system on an onshore and offshore facility.
- To estimate the amount of energy that can be generated using HYSYS software.
- To provide simulation and modeling of flare gas recovery system using HYSYS.

Scope of study of this project is limited to only four aspects which are:

- Flare gas system
- Micro turbine mechanism
- HYSYS software
- Economic consideration of energy management

For this project, a model of an energy recovery system will be simulated by using HYSYS where the amount of energy generated will be estimated to evaluate the feasibility of the system. To establish the desired final result that is the energy that will be generated from this simulation, micro turbine is placed inside the system where Brayton cycle takes place which is the most important part of understanding the energy recovery system.

1.4. Relevancy of the Project

Flaring produces a great number of harmful by-products such as dangerous particles, volatile organic compounds, polycyclic aromatic and many other compounds just as harmful. Rather than wasting the natural resources by combusting it to the atmosphere, converting the flare gas to another type of energy can minimize environmental and economic disadvantages of burning flare gas. Apart from that,

.

1.5. Feasibility of the Project within the Scope and Time Frame

The project is aimed to be completed within 2 semesters that is from May 2012 to December 2012 provided with suitable methodology that supports rapid development that meet user's requirement.

Basically, the project is feasible within the scope and time frame if proper planning is done. Up until now, everything is on track and all of the equipment and materials needed for the project are available within the university campus.

CHAPTER 2

LITERATURE REVIEW

2.1. Flare gas recovery system

Gas flaring has been recognized as an economic waste and a great environmental hazard. Various researchers have written extensively on various issues in the gas sector. (Blasing, Hand and Kimberly, 2007) worked on monthly carbon emissions from natural gas flaring and cement manufacture in the United States. They discovered that emissions amounted to 0.1% of all fossil fuel and carbon emissions had no clear and persistent annual pattern annually. (Akpan, 2009) in his work noted that literature shows that vast amount of these gas are being used by few of our chemical industries. The only way-out for harnessing the nation’s natural gas is to encourage the establishment of gas-based petrochemical complexes that can consume large volume needed to eliminate gas flaring. He recommended that Nigeria can make steady foreign exchange earnings on the long-term by properly harnessing their natural gas through establishing a gas based petrochemical industries. (Hill, Moore, Boone and Randall, 1985) in their work revealed a methodology based on more than two years engineering development on various associated gas sources whereby offshore "associated gas" streams, in great quantities, through gas treatment, gas-liquids recovery, power generation, and residue gas compression can be effectively and economically utilized.

(Abdulkareem and Odigure, 2010) worked on the Economic Benefit of Natural Gas Utilization in Nigeria based on a Case Study of the Food Processing Industry. According to them, their work focused on the measurement of heat radiation from gas flaring as one of the menaces of gas flaring and benefits of substituting conventional fuel and energy types, such as automotive gas oil (automotive gas oil-diesel), low pour fuel oil, and electricity with natural gas in monetary terms using mathematical principles in calculation with a case study of the food processing industry in Nigeria. Results obtained revealed that up to 69% on diesel, 29.85% on low pour fuel oil, and 69% on electricity could be saved by the company, translating to millions of dollars in five years if conventional fuel and energy is substituted with natural gas. (Onwukwe, 2009) worked on gas to liquid technology in Nigeria. His article examined the prospect of Gas-to-Liquid (GTL) conversion technology as a sustainable natural gas utilization option. He noted that this technology will make possible the chemical conversion of natural gas into clean diesel, naphtha, and kerosene and light oils, as marketable liquid products. According to him this conversion will contribute to the elimination of flared gas and reduces the country's overdependence on imported refined petroleum products.

2.2. GTL technology

One of the best solutions for reducing gas flaring is the application of some new environmentally friendly technologies such as gas-to-liquid (GTL) technology. The main issue in Nigeria is to gather gas from more than 1000 wells by building gas collection facilities at the oilfields and constructing an extensive pipeline network to carry gas to an industrial facility where it turns into liquids for transportation (Tolulope, 2004). Among the various alternatives for combustion, there has recently been an increased interest in the development of GTL technology. Such technologies play an important role in bringing gas to markets as both fuel and/or petrochemicals (Iandoli and Kjelstrup, 2007).

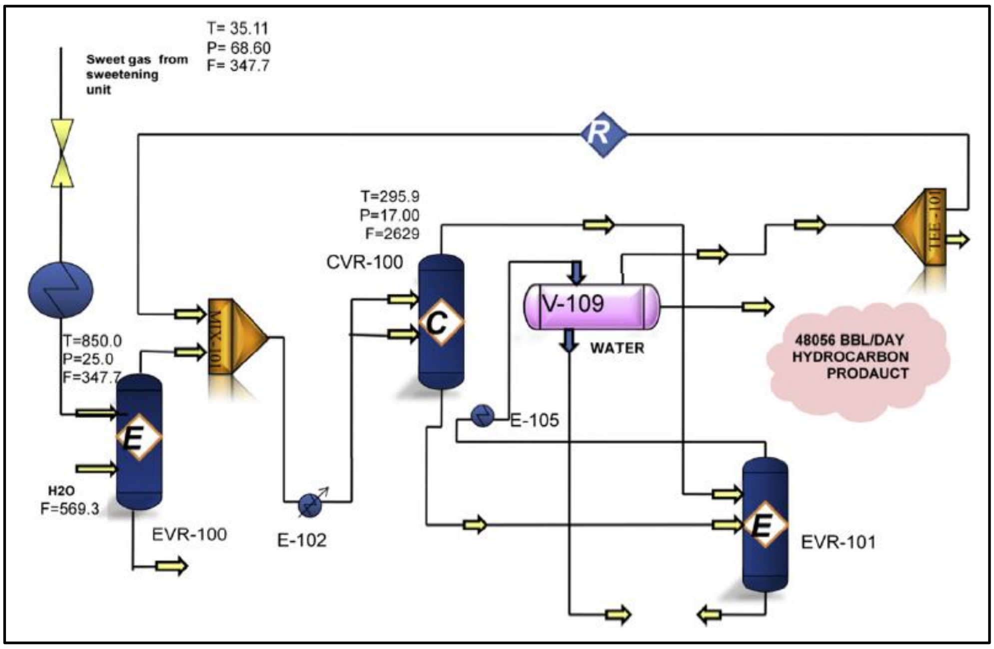
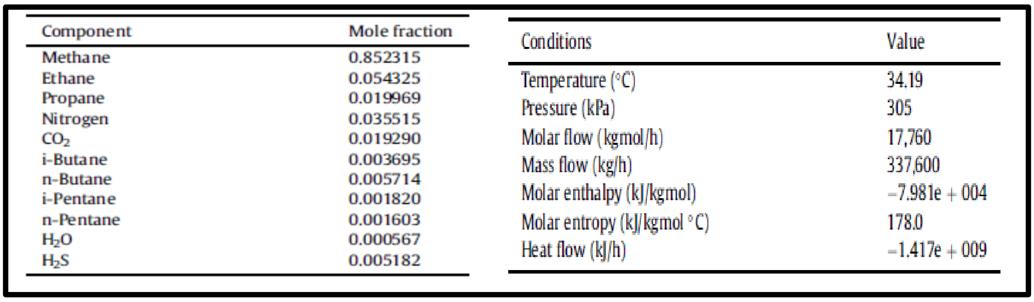


Figure 1: Process Flow Diagram of GTL Plant Simulation (Montazer Rahmati & Bargah-Soleimani, 2001)

2.3. Electricity production from purge gas via gas turbine

It has been achieved, as a secondary energy source, from the conversion of other sources of energy like coal, natural gas, oil, nuclear power and other natural sources. Flare gas from refinery can be used as a primary source. An electric utility power station uses a turbine, engine, water wheel or other similar machines to drive an electric generator. A turbine converts the kinetic energy of a moving fluid (liquid or gas) to mechanical energy. Gas turbines are commonly used when power utility usage is at a high demand. 16% of the power was fueled by natural gas (Razak, 2007). Gas turbines can be burned to produce hot combustion gases that pass directly through a turbine, spinning the blades of the turbine to generate power. The electric power industry evolved from a highly regulated, monopolistic industry with traditionally structured electric utilities to a less regulated, competitive industry (Horlock, 2003).



Component	Mole fraction
Methane	0.852315
Ethane	0.054325
Propane	0.019969
Nitrogen	0.035515
CO_2	0.019290
i-Butane	0.003695
n-Butane	0.005714
i-Pentane	0.001820
n-Pentane	0.001603
H_2O	0.000567
H_2S	0.005182

Conditions	Value
Temperature (°C)	34.19
Pressure (kPa)	305
Molar flow (kgmol/h)	17,760
Mass flow (kg/h)	337,600
Molar enthalpy (kJ/kgmol)	−7.981e + 004
Molar entropy (kJ/kgmol °C)	178.0
Heat flow (kJ/h)	−1.417e + 009

Figure 2: Components and Condition of Asalooye Flare Gas (Rahimpour & Jokar, 2012)

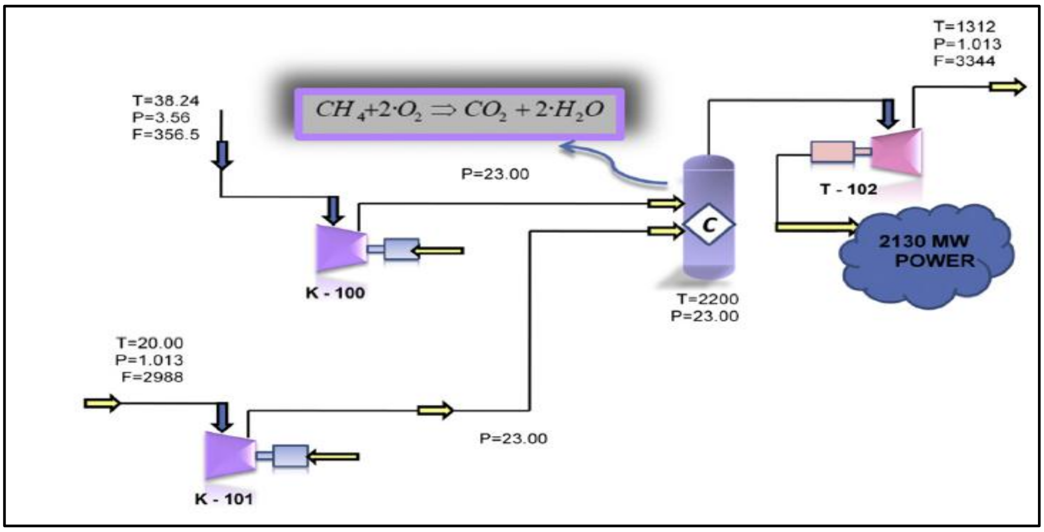


Figure 3: Process Flow Diagram of Power Plant Simulation (Rahimpour & Jokar, 2012)

2.4. Compression method

Piston compressors operate based on the displacement principle. Air is introduced to the piston through the intake valve during the downwards stroke, afterward the intake valve closes at the start of the downwards stroke; consequently, air is compressed and forced out of the pressure valve. The piston is driven by a crank drive with crankshaft and connecting rods (Dale Beggs, 1984).

Piston compressors are available with one or more cylinders and one or more stages. Multi-cylinder compressors are used for higher outputs, multistage compressors for higher pressures. The gas compressed in the cylinder in the first stage (low pressure stage) is cooled in the intermediate cooler and then compressed to the final pressure in the second stage (high pressure cylinder). In single action compressors, one compression action with one rotation of the crankshaft take place while double acting compressors, include two compression actions with one rotation of the crankshaft (Brown and Compressors, 2005).

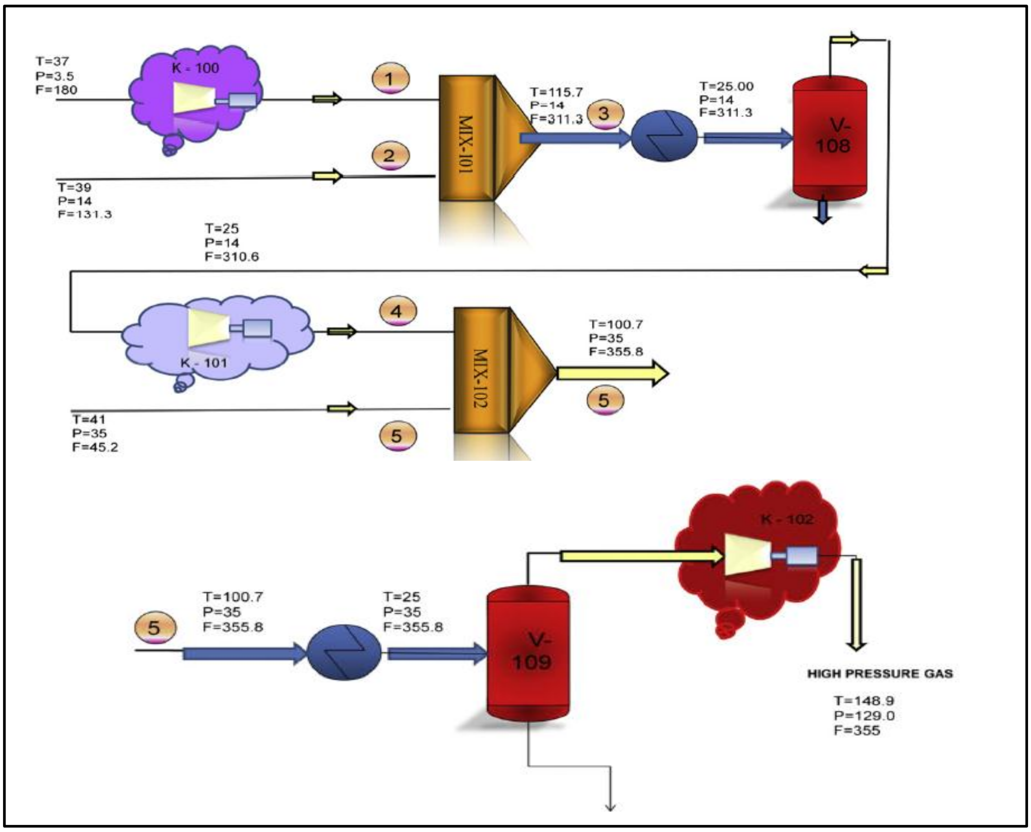


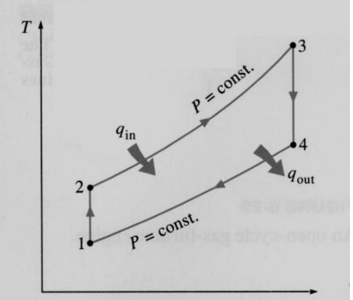
Figure 4: Process Flow Diagram of Compression Unit Simulation (Rahimpour & Jokar, 2012)

2.5. Brayton cycle

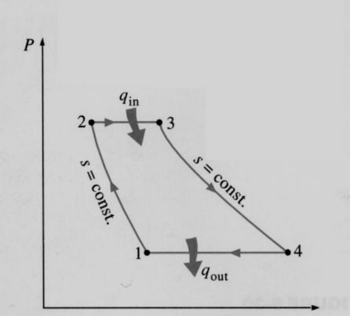
The Brayton cycle is a thermodynamic cycle that describes the workings of the gas turbine engine, basis of the air breathing jet engine and others.

It is named after George Brayton (1830–1892), the American engineer who developed it, although it was originally proposed and patented by Englishman John Barber in 1791.It is also sometimes known as the Joule cycle. The Ericsson cycle is similar but uses external heat and incorporates the use of a regenerator. There are two types of Brayton cycles, open to the atmosphere and using internal combustion chamber or closed and using a heat exchanger.

A cycle describes what happens to air as it passes into, through, and out of the gas turbine. The cycle usually describes the relationship between the spaces occupied by the air in the system (called volume, V) and the pressure (P) it is under and also temperature (T) with entropy (S). The Brayton cycle (1876), shown in graphic form in Fig. 5 as a pressure-volume diagram, is a representation of the properties of a fixed amount of air as it passes through a gas turbine in operation. These same points are also shown in the engine schematic in Fig. 6.



(a) T-s diagram



(b) P-υ diagram

Figure 5: T-S and P-V Diagram of an Ideal Brayton Cycle (Waleed Mohamed, 2010)

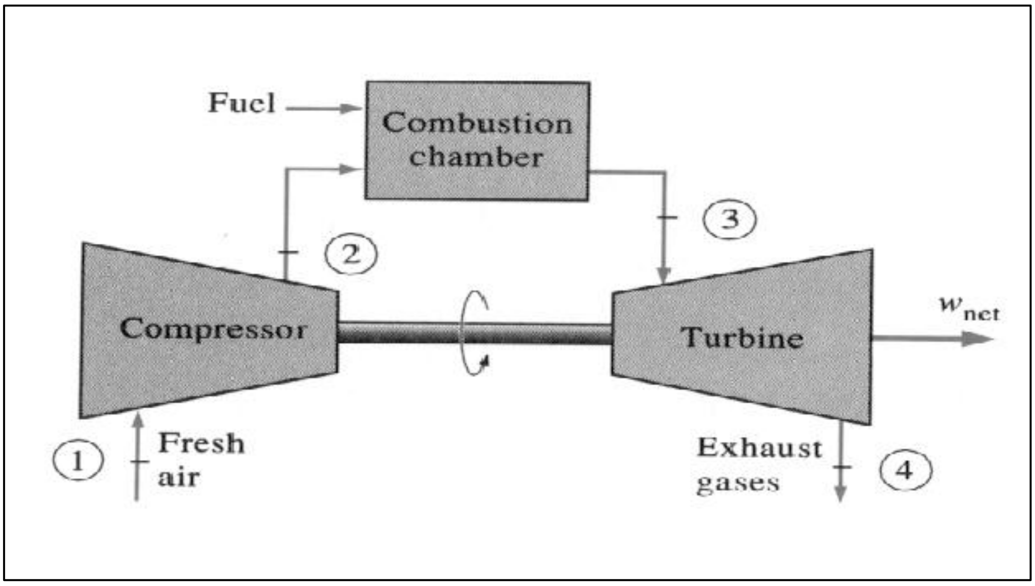


Figure 6: Gas Turbine Schematic Diagram Showing Relative Points of the Brayton Cycle (Waleed Mohamed, 2010)

Air is compressed from point 1 to point 2. This increases the pressure as the volume of space occupied by the air is reduced. The air is then heated at constant pressure from 2 to 3 in Fig. 6. This heat is added by injecting fuel into the combustor and igniting it on a continuous basis. The hot compressed air at point 3 is then allowed to expand (from point 3 to 4) reducing the pressure and temperature and increasing its volume. In the engine in Fig. 6, this represents flow through the turbine to point 3’ and then flow through the power turbine to point 4 to turn a shaft inside a magnetic coil. When the shaft is rotating inside the magnetic coil, electrical current is produced. The exhaust gases leaving the turbine in the open cycle are not re-circulated.

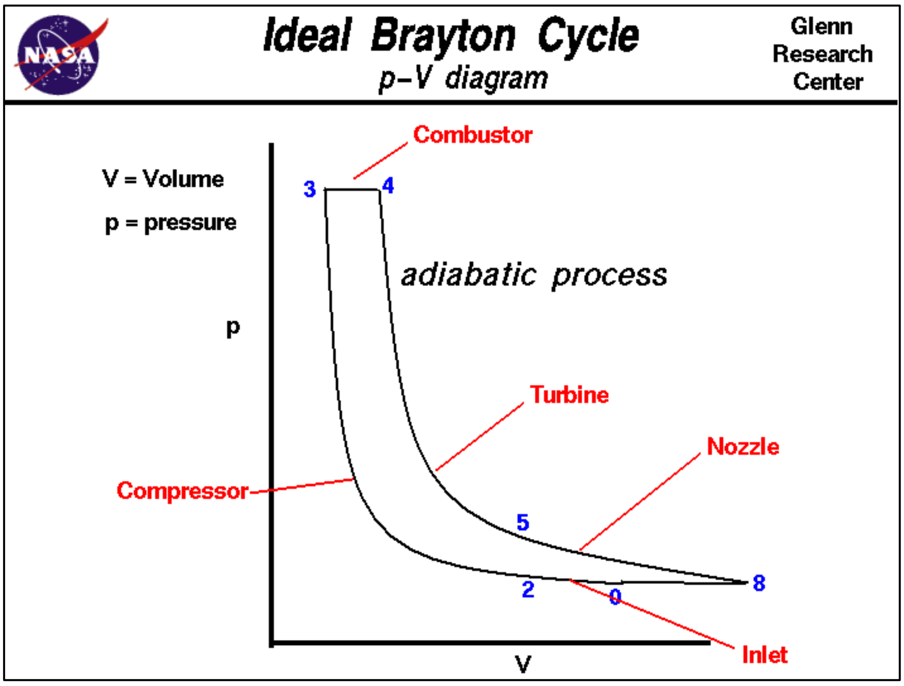


Figure 7: P-V Diagram (Tom Benson, 2008)

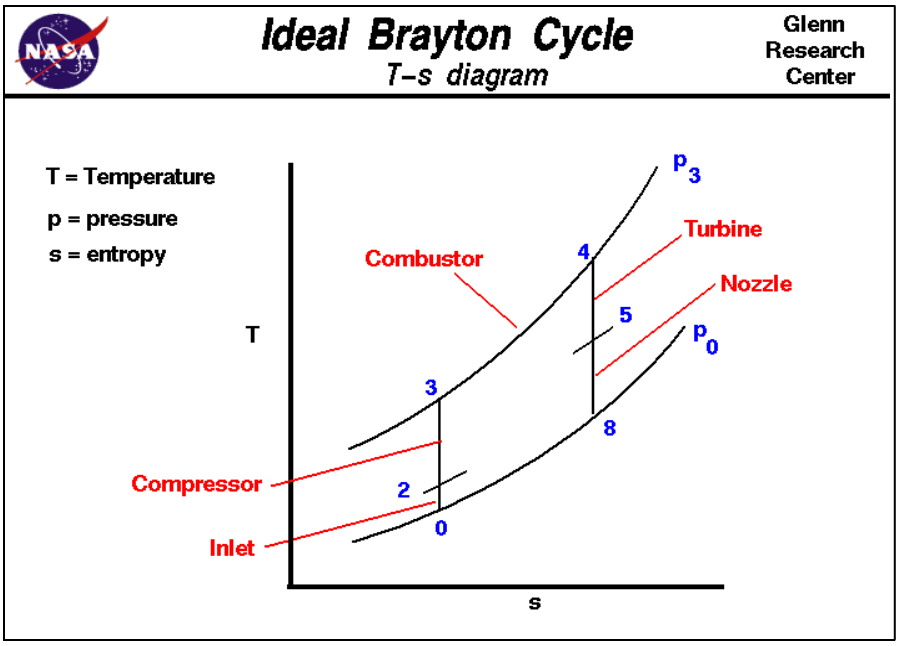


Figure 8: T-S Diagram (Tom Benson, 2008)

The P-v and T-s diagrams of an ideal Brayton cycle are shown in Fig. 7 and Fig. 8. Notice that all four processes of the Brayton cycle are executed in steady-flow devices; thus, they should be analyzed as steady-flow processes. When the changes in kinetic and potential energies are neglected, the energy balanced for steady-flow process can be expressed, on a unit-mass basis as

(qin – qout) + (win - wout) = hexit - hinlet Eqn. 2.1

Therefore, heat transfers to and from the working fluid are

qin = h3 – h2 = cp(T 3 – T2) Eqn. 2.1a

and

qout = h4 – h1 = cp(T4 - T1) Eqn. 2.1b

Then the thermal efficiency of the ideal Brayton cycle under the cold-air-standard assumptions becomes

$$nth, Brayton = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{c_p(T_4 - T_1)}{c_p(T_3 - T_2)} = 1 - \frac{T_1(T_4/T_1 - 1)}{T_2(T_3/T_2 - 1)}$$ Eqn. 2.2

Process 1-2 and 3-4 are isentropic, and P2 = P3 and P4 = P1. Thus,

$$\eta th,Brayton = 1- \frac{1}{r_p^{(k-1)/k}}$$ Eqn.2.4

$$r_p = \frac{P_2}{P_1}$$ Eqn. 2.5

is the pressure ratio and k is the specific heat ratio. Equation 2.5 shows that under the cold-air-standard assumptions, the thermal efficiency of an ideal Brayton cycle depends on the pressure ratio of the gas turbine and the specific heat ratio of the working fluid.

2.6. Cogeneration

Cogeneration (also known as Combined Heat and Power, or CHP) is the simultaneous production of heat and electrical power. Cogeneration is typically used for large towns, universities, hospitals, hotels, prisons, oil refineries, chemical plants, paper mills, wastewater treatment plants, enhanced oil recovery wells, and numerous other industrial plants with significant heating needs (EDUCOGEN, 2001). Cogeneration has also been adapted on a smaller scale to individual homes or businesses (called micro cogeneration) (EDUCOGEN, 2001).

There are two types of cogeneration plants. One type of cogeneration plant is called bottoming cycle cogeneration. It generates heat first and electricity second. These plants exist only in heavy industries such as glass or metals manufacturing where very high temperature furnaces are used. The most common type of cogeneration plant is called topping cycle cogeneration and produces electricity first and heat second. Typical configurations for topping cycle cogeneration plants are (EDUCOGEN, 2001):

1) A gas turbine or diesel engine producing electrical or mechanical power followed by a heat recovery boiler to create steam to drive a secondary steam turbine. This is called a combined-cycle topping system. Combined cycle is useful for maximizing power production when no process steam or hot water is needed.
2) The second type of system burns fuel (any type) to produce high-pressure steam that then passes through a steam turbine to produce power while the exhaust provides low-pressure process steam. This is a steam-turbine topping system and is useful when a fuel source is readily available at low cost and only low-pressure process steam is needed.
3) A third type employs hot water from an engine jacket cooling system flowing to a heat recovery boiler, where it is converted to process steam and hot water for space heating. This type is useful for many engines which require significant cooling because a high temperature cooling water stream is available to further heat into process steam.

4) The fourth type is a gas-turbine topping system. A natural gas turbine drives a generator. The exhaust gas goes to a heat recovery boiler that makes process hot water or steam. This type is useful for producing large amounts of both power and steam and is the type here at LSU.

Cogeneration is important for numerous reasons. The first is that capturing the waste heat from power generation can result in an increase in efficiency from below 50 % for conventional power generation to 70 - 90 % for cogeneration. This offers significant potential savings in energy costs. Additional electricity generated can also be sold back to the grid in a 3 deregulated electricity market, opening up more opportunities for energy savings (EDUCOGEN, 2001).

Cogeneration is also more environmentally friendly than traditional fossil fuel power plants. First, CHP is more efficient, reducing total fossil fuel consumption and thereby reducing emissions to the atmosphere. Second, natural gas (a clean burning fossil fuel) is often used in cogeneration with steam injection to minimize emissions. For a typical gas turbine topping-cycle cogeneration plant, typical CO2 emissions reductions are 356 g/kW-hr, typical NOx reductions are 2.9 g/kW-hr, and typical SO2 reductions are 23.2 g/kW-hr as compared to a traditional fossil fuel plant (EDUCOGEN, 2001).

Gas turbine analysis including material, energy, and entropy balances as well as detailed design equations can be found in Bathie (1996). Individual units including compressors, turbines, and combustion chambers are examined first before proceeding to overall gas turbine problems. Numerous problems were solved using both ideal gas and real gas models. Heat recovery steam generator (HRSG) design and operation is the key to the increased efficiency of cogeneration as compared to traditional power generation. Various works by Ganapathy (1991, 1993, and 1996) were consulted as well as Karthikeyan et al. (1998). HRSG modeling and simulation were studied including unfired and fired modes. One very important concept is the selection of temperature profiles in HRSG, especially the pinch and approach temperatures.

The next step is the combining of gas turbines and HRSG into a cogeneration system. Kim et al. (1994) examined the off-design performance of a gas turbine cogeneration facility. The gas turbine process was modeled using performance maps for compressors and turbines. HRSG performance is examined by modeling of the heat transfer process. The study focused on 5 tracking important operating parameters as the load on the turbine changed. Ahner (1988) modeled and solved several cases for an industrial cogeneration plant. The heat rate and other important parameters of the system were examined for various power generation conditions and process heat requirements.

CHAPTER 3

METHODOLOGY

This research will need several methods in order to get a good result.

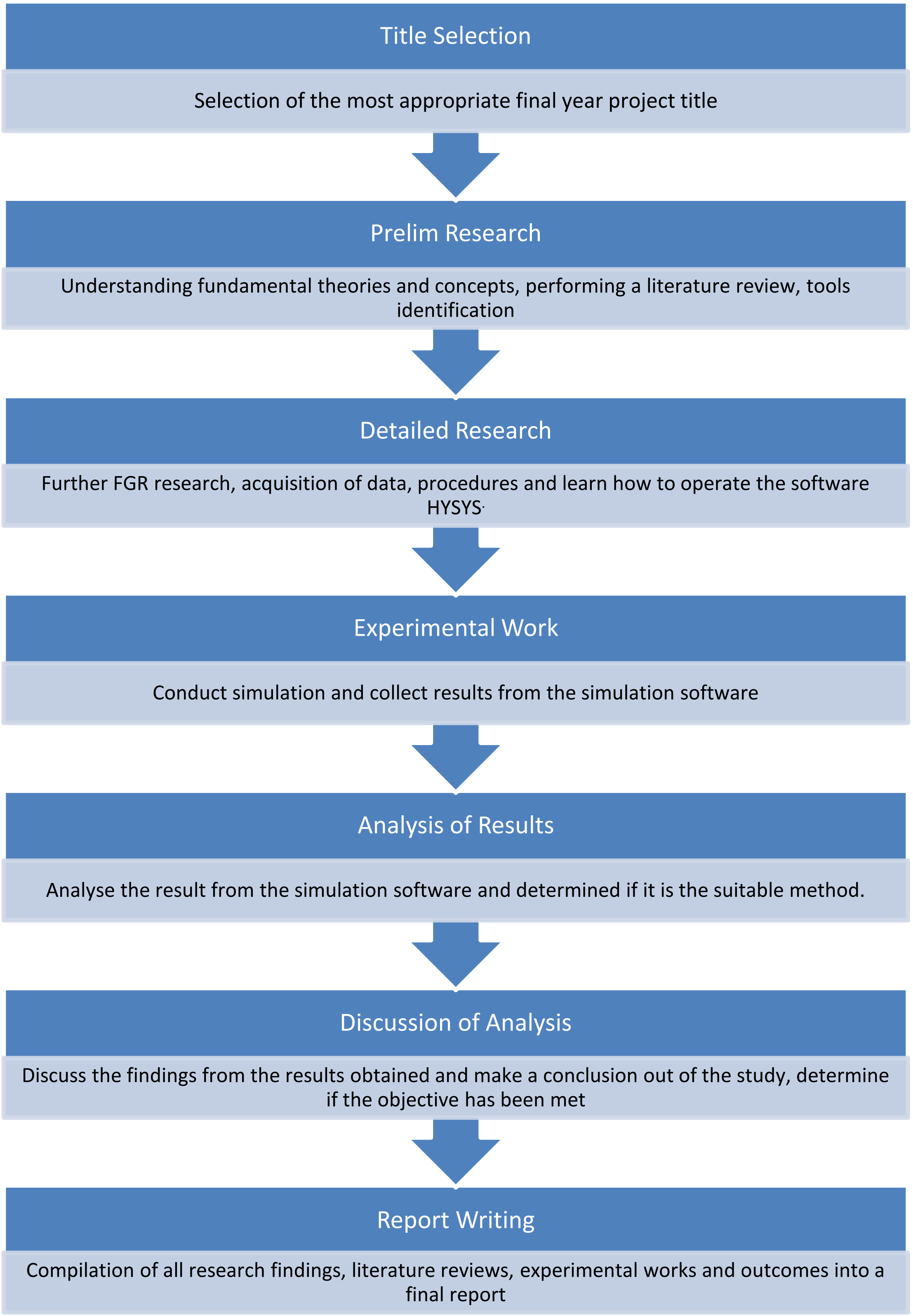
3.1. Research Methodology

For research part, journals, books, and technical papers will be used to get a better understanding about this project.it will make the author to be familiar and a clear view about the research scope that will be carried out. Most of the sources are from Society of Petroleum Engineers (SPE) technical papers that can be found online. Other than that, oil and gas news has been used as well for the source. Book related to the project from University of Technology PETRONAS library has helped this research a lot.

After the reading has been done, a Gantt chart will be drawn which consist of several milestone and project activities so that the time will be allocated in the right way.

The existing flare gas recovery system will be studied in order to provide a feasible model in an energy recovery scheme. All information will be compared and analyzed in detail. Afterward, this paper will reveal a better solution for current problem such as safety and cost.

3.2. Project Activities



Title Selection

Selection of the most appropriate final year project title

Prelim Research

Understanding fundamental theories and concepts, performing a literature review, tools identification

Detailed Research

Further FGR research, acquisition of data, procedures and learn how to operate the software HYSYS

Experimental Work

Conduct simulation and collect results from the simulation software

Analysis of Results

Analyse the result from the simulation software and determined if it is the suitable method.

Discussion of Analysis

Discuss the findings from the results obtained and make a conclusion out of the study, determine if the objective has been met

Report Writing

Compilation of all research findings, literature reviews, experimental works and outcomes into a final report

3.3. Experimental work and Analysis

For the second part of the project, the main focus is on optimizing results based on the data acquired from the first part of the project. All simulation done in HYSYS will be based on the actual flare gas data obtained from field. The result from the simulation will be compared with theoretical results using thermodynamics. This is to ensure the reliability of the results acquired.

It is necessary to know the parameters of the gas such as the natural gas properties and its gas components before it can be used as fuel in the micro turbine to generate electricity. In this study, the natural gas properties and gas components taken from a gas field was identified as follows.

Components	Mole Fraction
Methane	0.83141295
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
CO_2	0.03637937
H_2O	0.00001309
N_2	0.00495610
H_2S	0.00000010

Table 1: Natural Gas Composition (Carigali, Important Daily Report, 2012)

Pressure (Bar)	69.17
Temperature (^{0}C)	23.70
Molar Flow (MMSCFD)	1.50

Table 2: Natural Gas Condition (Carigali, Important Daily Report, 2012)

The main part of data that is required from the field is the gas compositions and its condition as it is crucial in the simulation. The chemical reaction in the natural gas combustion process will solely consider for Methane, CH_4 as follows:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$; ΔH = -800 kJ/mol (Exorthermic process)

What is meant by the equation above is that the combustion reaction will contribute 800 kJ of energy when there is a complete combustion. As the process components are all gases, the selected fluid package would be the Peng Robinson in the HYSYS simulation. When all necessary data are in place, the physical system can be modeled and the result can be obtained.

Micro turbines are versatile technical solutions for the production of electrical and thermal power. This term is applied to a new group of small gas turbines being used to provide on-site power and becoming an attractive option to feed the load of small users, especially when co-generation can be exploited.

Most micro turbines with a power range from 20 kW to 250 kW are based on technologies that were originally developed for the use in auxiliary power systems, aircrafts or automotive turbochargers.

Micro turbine 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. Those designed with foil bearings and air-cooling operates without oil, coolants or other hazardous materials. Micro turbines 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 micro turbines is increasing. Micro turbines also lose more efficiency at low power levels than reciprocating engines. Micro turbines offer several potential advantages compared to other technologies for small-scale power generation, including: a small number of moving parts, compact size, lightweight, greater efficiency, lower emissions, lower electricity costs, and opportunities to utilize waste fuels. Waste heat recovery can also be used with these systems to achieve efficiencies greater than 80%.Because of their small size, relatively low capital costs, expected low operations and maintenance costs, and automatic electronic control, micro turbines are expected to capture a significant share of the distributed generation market.

Daily operations provide a wide range of possible parameters in the flow line. Hence, the simulated HYSYS arrangements using default parameters are not always accurate all the time. Therefore, in order to obtain better estimation, parameters need to be varied to complement with fluctuating conditions in the flow line. The default parameters used in HYSYS simulation are as follows:

Temperature: 23.70 ^{0}C

Pressure **:** 8.013 Bar

Molar Flow **:** 0.75 MMSCFD

CHAPTER 4

RESULTS AND DISCUSSION

Micro turbine generators can be divided in two general classes:

- **Recuperated micro turbines**, which recover the heat from the exhaust gas to boost the temperature of combustion and increase the efficiency, and
- **Un-recuperated** (or simple cycle) **micro turbines**, which have lower efficiencies, but also lower capital costs.

While some early product introductions have featured un-recuperated designs, the bulk of developers' efforts are focused on recuperated systems. The recuperator recovers heat from the exhaust gas in order to boost the temperature of the air stream supplied to the combustor. Further exhaust heat recovery can be used in a cogeneration configuration. The figure below illustrates a recuperated micro turbine system.

For this project, two models of micro turbines are created for comparison purposes which are:

1. Micro turbine without recuperator
2. Micro turbine with recuperator

This section explains on the result obtained from HYSYS simulation utilizing the actual flare gas data from field which are Temperature, Pressure, Molar Flow, and Gas Composition.

1. Micro turbine without recuperator.

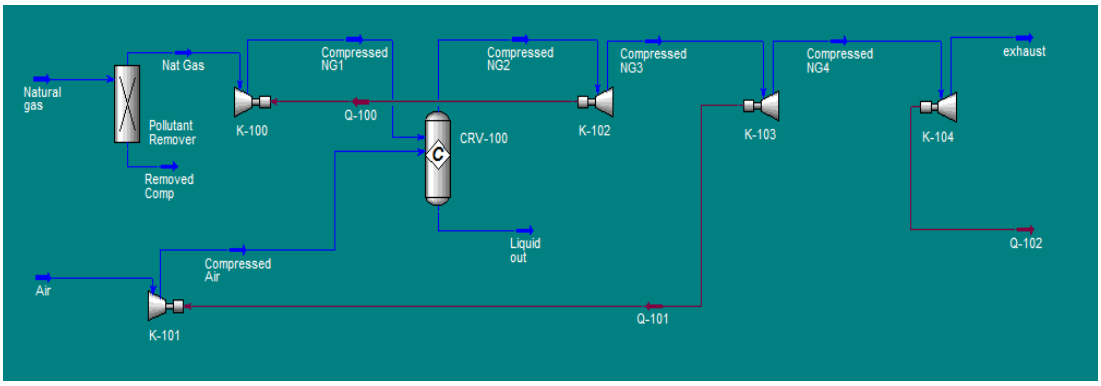


Figure 9: HYSYS Simulation for Micro turbine without Recuperator

- HYSYS results : **217 kW**

2. Micro turbine with recuperator.

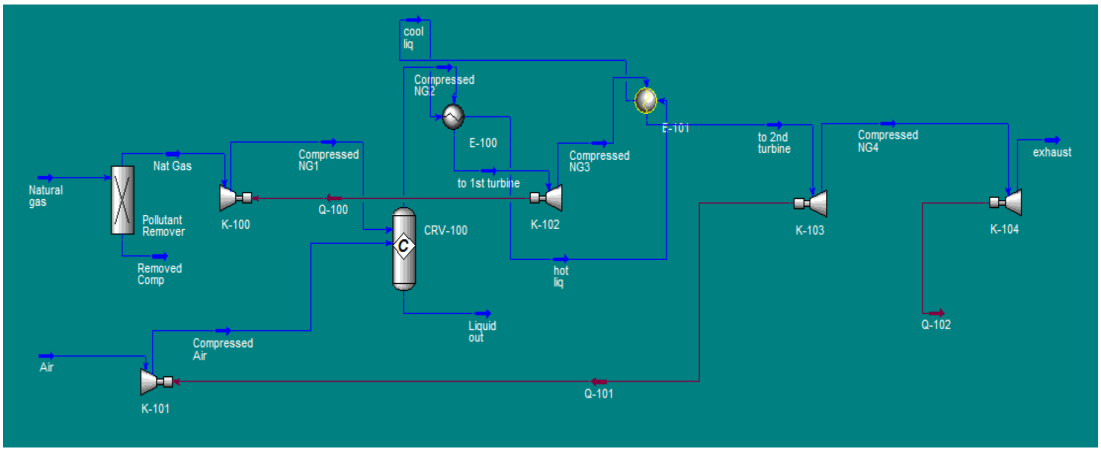


Figure 10: HYSYS Simulation for Micro turbine with Recuperator

- HYSYS result : **301 kW**

Contaminants such as hydrogen sulphide, carbon dioxide and water vapour that exist together with the natural gas have to be removed in order to utilize the flare gas with micro turbine. From the simulation, 217 Kw and 225 kW of electrical power could be harnessed from the volume of natural gas that currently being flared which is at 0.75 MMscfd.

Both option of the micro turbines show positive net power output. However, micro turbine with recuperator has the highest power output since its capability to absorb and preheat the incoming gas before expansion process, hence; it is the best option available. In addition, most micro turbines available on the shelves are already equipped with recuperator due to its higher efficiency.

The basic operation of recuperator is similar to that of heat exchanger which allows the heat transfer of two different fluids. In the case of micro turbine, the recuperator acts as the heat exchanger between outlet gas from combustion chamber and the working fluid. As the gas from outlet temperature from the combustion chamber is to high i.e. 2000ºC, it needs to be cooled down to around 1000ºC due to the metallurgical limit of the turbine blade that can only cater for gases with maximum temperature of 1000ºC.

Apart from that, from the results obtained, efficiencies play a big role in the simulation where all the system in the simulation possesses seventy five percent of efficiency; considering efficiencies in the system will results in lower power output generated. Inefficient system will also give some effects on power and heat loss along the way.

Furthermore, a sensitivity analysis is done to see which default parameters will affect the overall operation of this flare gas recovery system. Temperature, pressure, and molar flow are used as the base reference and each value of the parameter will be varied and calculated with percentage deviations from the original value.

The range of percentage deviation is between -60% to 60%. The results are then presented in graph form to evaluate the sensitivity for each parameter. The graphs are shown below.

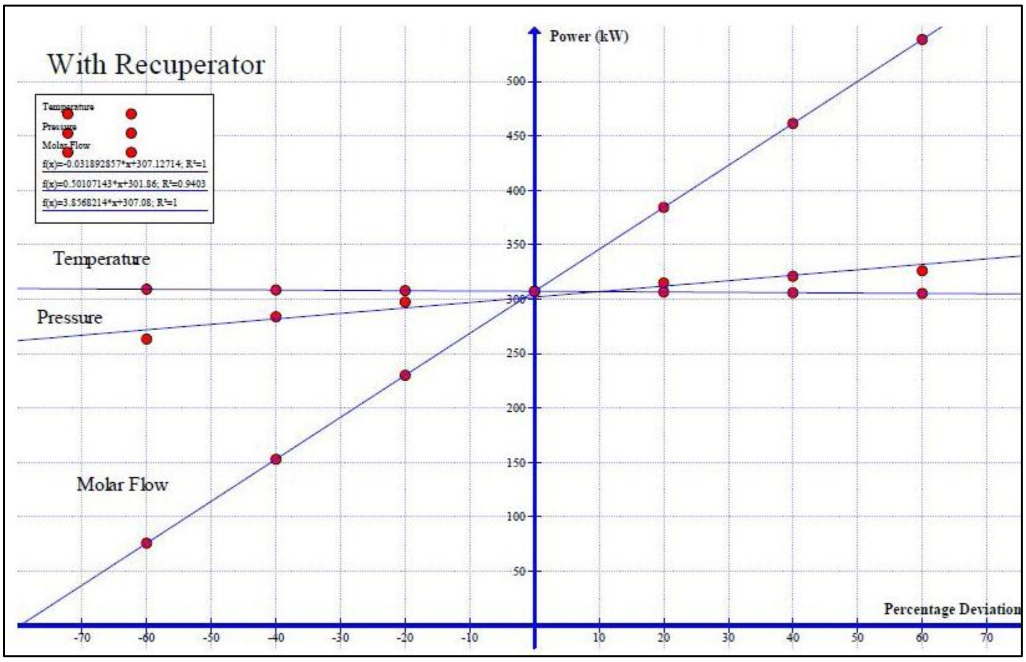


Figure 11: Sensitivity Analysis for Micro Turbine with Recuperator

Equations for the parameters:

- Temperature : y = -0.03x + 301.12
- Pressure : y = 0.50x + 298.86
- Molar Flow : y = 3.86x + 301.08

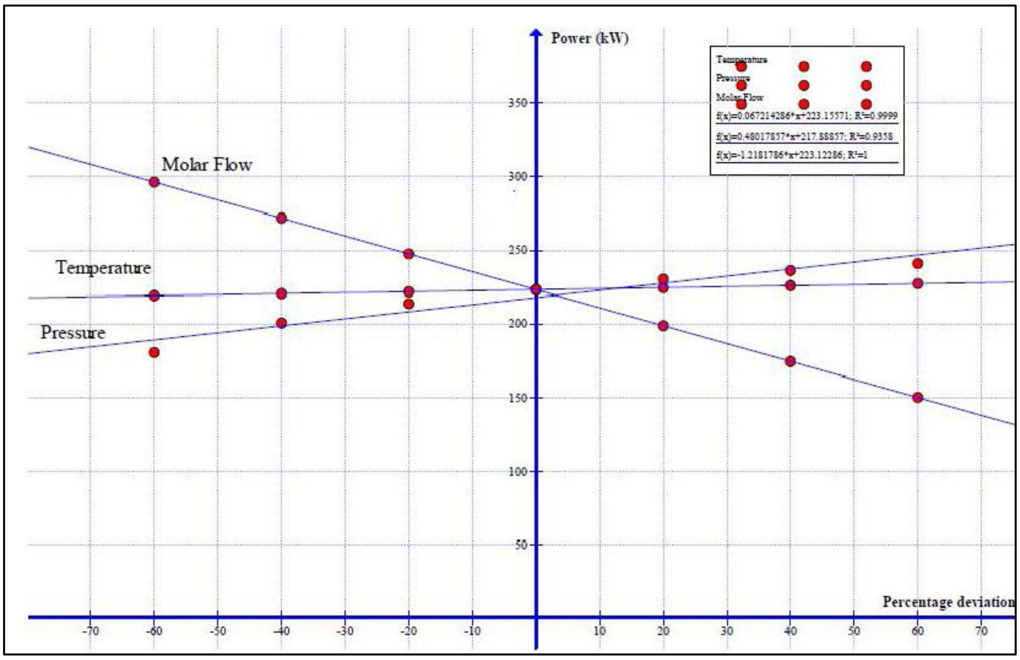


Figure 12: Sensitivity Analysis for Micro Turbine without Recuperator

Equations for the parameters:

- Temperature : $y = 0.07x + 225.16$
- Pressure : $y = 0.48x + 217.89$
- Molar Flow : $y = -1.22x + 225.12$

Gradient of the graph indicates the sensitivity of the parameters. As shown in the graph, we can see that molar flow is the most sensitive parameter compared to others while temperature is the least sensitive. It means that, slight changes of molar value in the flow line will affect power output significantly. Whereas changes in temperature will not affect power output much. So, in order for us to obtain constant power output to supply to the field, we need priority attention to the volume of the gas in the flow line.

It is important to see if the same technology could be implemented in the other platforms all around Malaysia with the assumption of using a typical range of methane concentration from 50 percent till 80 percent. The flow rate and gas parameters of natural gas available were assumed to be equal to the simulation before. The gas compositions were added into the simulation and the summary of power generated was as follows:

Composition	Molecular Formula	Percentage (%)
Methane	CH_4	70-90
Ethane	C_2H_6	0-20
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8
Oxygen	O_2	0-0.2
Nitrogen	N_2	0-5
Hydrogen Sulphide	H_2S	0-5

Table 3: Typical Composition of Natural Gas (Pipeline and Gas Journal, 2005)

Gas Component	**Mole Fraction (%)**			
Methane	**50**	**60**	**70**	**80**
Ethane	7.5	8.3	9.80	9.70
Propane	1.10	1.22	1.80	1.86
Butane	0.15	0.25	0.35	0.45
Power Generated (kW)	192	197	206	215

Table 4: Comparison of Power Generated According to Methane Percentage

It is summarize that Methane content as the major gas component in the natural gas is the main contributor for electricity generation. (Farzaneh, H, 2011) explained in his work where the thermal efficiency of Brayton Cycle reaches its maximum point as methane concentration increased. Thus, an energy recovery program from the natural gas should highlight on the methane content to see if it will yield a high power output.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This project has investigated the energy potential from flare gases in the oil and gas facilities. Micro turbine together with the gas conditioning techniques has been selected to convert the energy in the natural gas into electricity.

Both options of the micro turbines show positive net power output. However, micro turbines with recuperator has the highest net power output since its capability to absorb and preheat the incoming gas before expansion process, hence, it is the best option available. In addition, most micro turbines available on the shelves are already equipped with recuperator due to its higher efficiency.

Sensitivity analysis done on both options shows that Molar Flow is the most sensitive parameter to power output generated. It indicates that the volume of gas coming to the Flare Gas Recovery System should be given priority compared to other parameters i.e. temperature, pressure. Slight changes on the volume of the gas in the flow line will give significant effect to the net power output in the micro turbines.

The main objective of this project is to estimate the amount of energy that can be generated in an energy recovery system plus the feasibility of having such system on an onshore or offshore facility with the aid of HYSYS software. In order to achieve the objectives, all the experimental framework are carefully prepared, which is believe can be completed within the time frame of the research, and also taking into consideration of the availability of the equipment and, materials.

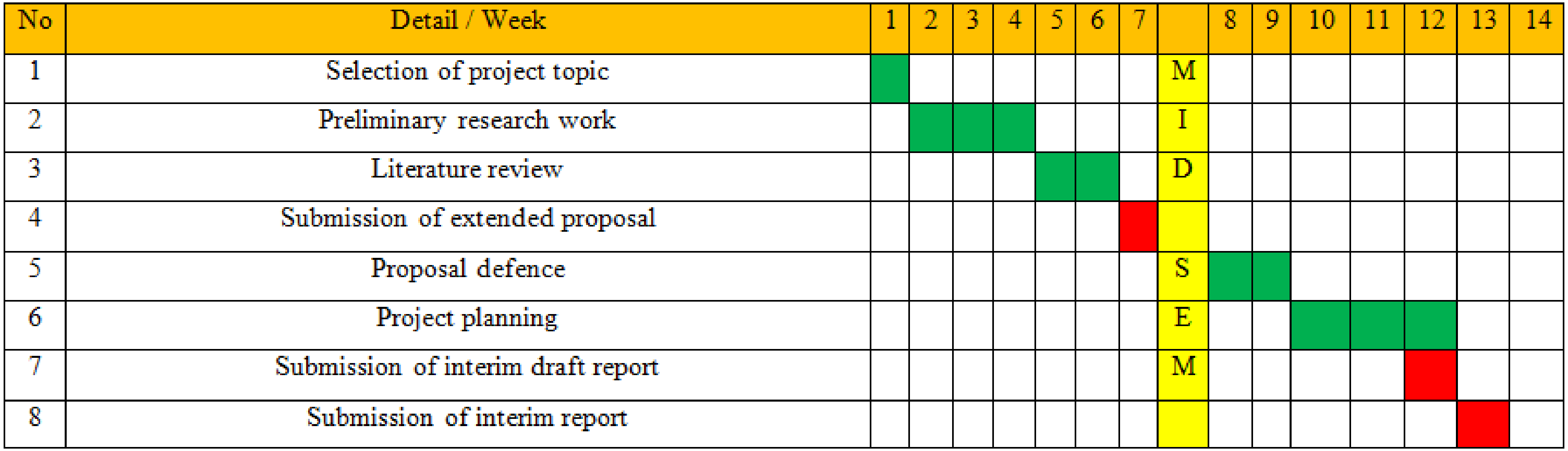
This project has investigated the energy recovery potential with the aid of HYSYS software simulation. However, since the volume and compositions of natural gas varies with time, it is recommended to study these effects in real time where dynamic model functions of simulators can be used. It is also hoped that this project can be expanded for future studies in flare gas reutilization in an energy recovery scheme in Malaysia.

REFERENCES

1. Asalooye Gas, 2010Asalooye Gas Refinery Data from South-Pars Gas Company Asalooye, Iran (2010)
2. Bjorndalen et al., 2005 N. Bjorndalen, S. Mustafiz, M.H. Rahman, M.R. Islam No-flare design: converting waste to value addition Energy Sources, 27 (2005), pp. 371–380
3. Broere, 2008 W. BroereThe Elusive Goal to Stop Flares, Shell World (5 May 2008) http://www.shell.com
4. Brown and Compressors, 2005 R.N. Brown Compressors: Selection and Sizing (third ed.)Elsevier Science & Technology Books (2005)
5. Dale Beggs, 1984 H. Dale BeggsGas Production Operations Oil & Gas Consultants International Inc (1984)
6. Horlock, 2003 J.H. HorlockAdvanced Gas Turbine Cycles (first ed.)Elsevier Science Ltd, Cambridge, U.K (2003) http://www.atlascopco.com
7. Iandoli and Kjelstrup, 2007 L. Iandoli, S. KjelstrupEnergy analysis of a GTL process based on low-temperature slurry FT reactor technology with a cobalt catalyst Energy Fuels, 21 (2007), pp. 2317–2324
8. Mourad et al., 2009 D. Mourad, O. Ghazi, B. NoureddineRecovery of flared gas through crude oil stabilization by a multi-staged separation with intermediate feeds: a case study Korean J. Chem. Eng., 26 (6) (2009), pp. 1706–1716
9. Rahimpour and Alizadehhesari, 2009 M.R. Rahimpour, K. AlizadehhesariEnhancement of carbon dioxide removal in a hydrogen perm-selective methanol synthesis reactor Int. J. Hydrogen Energy, 34 (2009), pp. 1349–1362
10. Razak, 2007 A.M.Y. RazakIndustrial Gas Turbines: Performance and Operability Woodhead Publishing Limited, Cambridge, England (2007)
11. Tolulope, 2004 A.O. TolulopeOil exploration and environmental degradation: the Nigerian experience Environ. Inform. Arch., 2 (2004), pp. 387–393
12. Zadakbar et al., 2008 O. Zadakbar, A. Vatani, K. KarimpourFlare gas recovery in oil and gas refineries Oil Gas Sci. Technol. – Rev. IFP, 63 (2008), pp. 705–711

13. Blasing T, Hand J. And Kimberly B. Monthly carbon emissions for natural gas Gas flaring and cement manufacture in the United States. Tellus B. 2007.59(1) 15 – 28.
14. Akpan, S. The production and utilisation of Natural gas resources in Nigeria: A review. Nigerian annual international conference and exhibition in August of the Society of Petroleum Engineers in Abuja, Nigeria.2009.
15. Hill R, C- E Offshore production systems Inc, Moore, J, Continental oil Co. Of Indonesia, Boone D and Randall C. Associated gas utilisation with liquid recovery. Offshore technology conference. 1985.
16. Abdulkareem, A and Odigure, J. Economic benefit of natural gas utilisation in Nigeria: A case Study of the food processing industry. Energy sources.2010. 5(1) 106 – 114.
17. Onwukwe S. Gas-to-Liquid technology: Prospect for natural gas utilization in Nigeria: Journal of Natural Gas Science and Engineering . 2009. 1(6) 190 – 194
18. 6th Annual World CHP Decentralized Energy Conference and Workshop. “CHP Roadmap.”2005. http://www.internationalchp-de.net/index.html (accessed January 2006).
19. Ahner, D.J. “Benefits of Combined Cycle Cogeneration.” Chemical Engineering Progress.March 1988.
20. Farzaneh, H., *Simulation of Energy Recovery System for Power Generation form Coal Bed Gas of Tabas Coal Mine of Iran.*World Renewable Energy Congree 2011, 2011.
21. Athar, A., Somasundaram, S., Turner, W.D. “System Optimization of the Cogeneration Facility at Texas A&M University – Present Operation and Load.”Journal of Energy Resources Technology.Vol. 115. 1993.
22. Bustami, L. “Design of Heat Recovery Steam Generators.” Louisiana State University. BatonRouge, LA. 2001.
23. EDUCOGEN: The European Educational Tool on Energy-Efficiency through the Use ofCogeneration (Combined Heat and Power). “Educogen – An Educational Tool for Cogeneration, Second Edition.” March 2001. http://www.cogen.org/projects/educogen.htm (accessed January 2006).

APPENDIX I: Final Year Project Gantt Chart

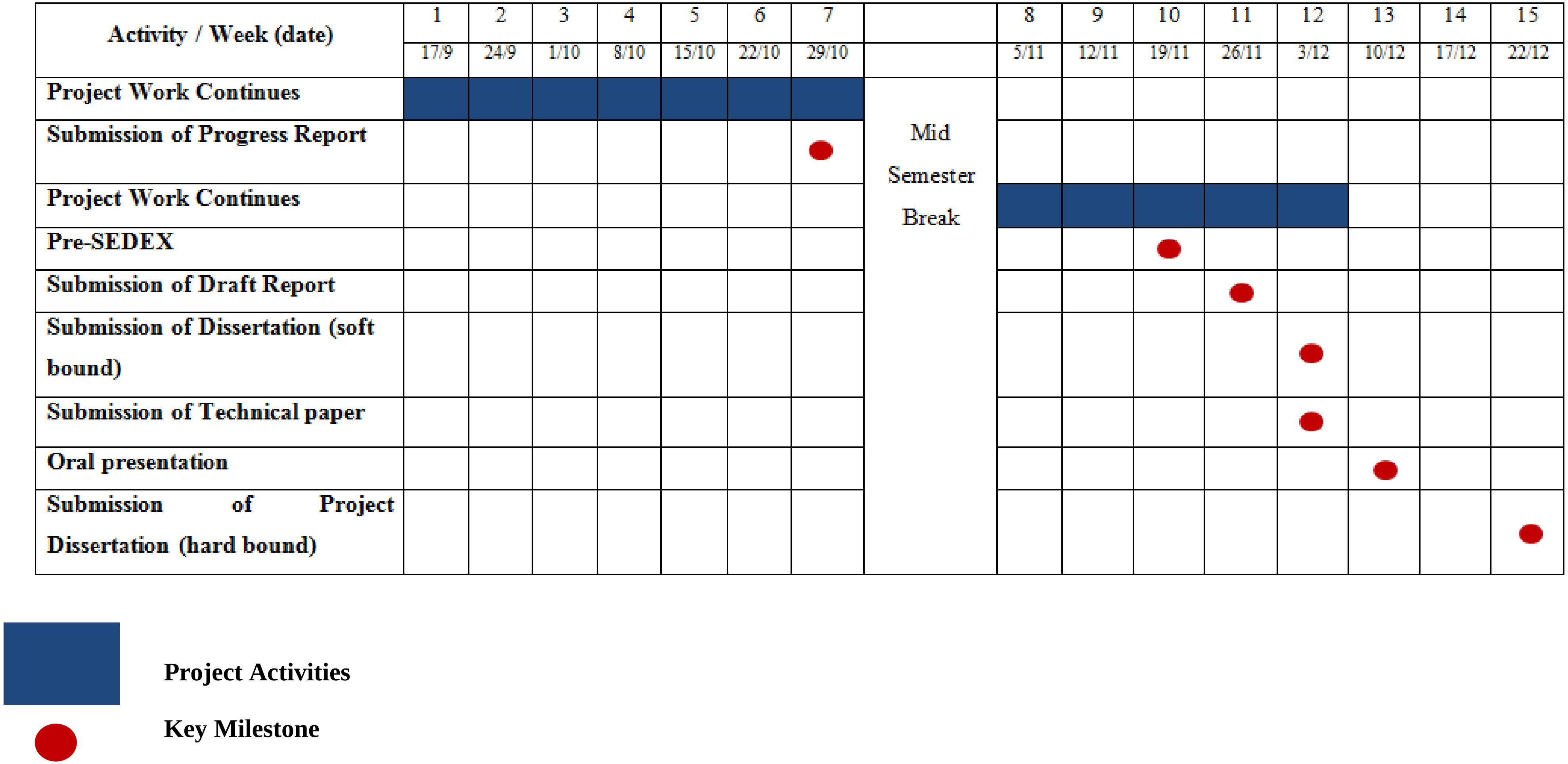


No	Detail / Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of project topic	🟩							M							
2	Preliminary research work		🟩	🟩	🟩				I							
3	Literature review					🟩	🟩		D							
4	Submission of extended proposal							🟥								
5	Proposal defence								S	🟩	🟩					
6	Project planning								E			🟩	🟩	🟩		
7	Submission of interim draft report								M					🟥		
8	Submission of interim report														🟥	

🟩 **Project Activities**

🟥 **Key Milestone**

FYP 1 Gantt Chart



Activity / Week (date)	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
	17/9	24/9	1/10	8/10	15/10	22/10	29/10		5/11	12/11	19/11	26/11	3/12	10/12	17/12	22/12
Project Work Continues	▨	▨	▨	▨	▨	▨	▨	Mid Semester Break								
Submission of Progress Report							●									
Project Work Continues									▨	▨	▨	▨	▨			
Pre-SEDEX											●					
Submission of Draft Report												●				
Submission of Dissertation (soft bound)													●			
Submission of Technical paper													●			
Oral presentation														●		
Submission of Project Dissertation (hard bound)																●

▨ **Project Activities**

● **Key Milestone**

FYP 2 Gantt Chart

APPENDIX II: Flare Gas Data

```
================================================================================
RESAK DAILY REPORT (BASETIME 0:00) 16/10/2012 00:00:00
================================================================================
FQI-2650
        CUMULATIVE      PERIOD
GVOL    1698.5131       1.5584 MMCF
SVOL    147575.4856     125.9864 MMSCF
MASS    7465.894297     6.520485 MM.lbs
ENERGY 160977.1260      139.1327 BBTU

FWA PRESSURE : 1003.196 psig
FWA TEMPERATURE: 74.665 Deg.F
FWA STD DENS : 0.05176 lbs/scf
FWA MASS FR : 6.5248 MM.lbs/d
FWA DP : 190.487 inH20
FWA LINE DENS : 4.18434 lbs/cf
FWA GHV : 1104.360 btu/scf
FWA SVOL FR : 126.0698 MMSCF/d
FWA GVOL FR : 1.5592 MMCF/d
FWA ENGY FR : 139.2254 BBTU/d

FWA METHANE : 83.141295
FWA ETHANE : 9.697911
FWA PROPANE : 1.856903
FWA N-BUTANE : 0.448056
FWA I-BUTANE : 0.587834
FWA N-PENTANE : 0.015655
FWA I-PENTANE : 0.029646
FWA HEXANE : 0.004939
FWA HEPTANE : 0.049899
FWA OCTANE : 0.032335
FWA NONANE : 0.000660
FWA CO2 : 3.637937
FWA N2 : 0.495610
FWA H2O : 0.001309
FWA H2S : 0.000010
================================================================================
```

RESAK DAILY OPERATION REPORT
Date Ending 0600hrs: 16 Oct 2012

A. HEALTH, SAFETY AND ENVIRONMENT

Incident/*Near* Miss	NIL				**UAUC**	**Raised**	**0**	**Resolved**	**0**	**OS**	**0**
Cumulative UAUC	**Monthly**	**34**	**Total (F.Y)**	**1516**	**Cum.O/S UAUC(F.Y)**	**76**					
HSE Talks	**Current Month**	**11**	**YTD**	**3537**	**Today's Talks Topic**	NIL					
Monthly Drill / Loc HSE Mtg	HSE commitee mtg – 12/10/2012 Fire Alarm Drill – 14/10/2012 General HSE meeting – 15/10/12				**Cumulative Weekly**	12					
Last PGI Done	13/10/2012 - Crew D				**Next Planned PGI**	30-10-2012					
Last ESD Check	12/05/2012 @ 0600 hrs.				**Next ESD Check**	14th November 2012					
Weather/Sea state @ 0600HRS	WIND DIR: Easterly, SPEED: 5 KTS, WEATHER: Raining, SWELL: 0.5 – 1.0 m, TEMP: 27.5°C,										
Personnel-On-Board	72										
Standby Boat	Supply vessel : Setia Yakin @ Dulang.										

B. GAS & CONDENSATE PRODUCTION

	FIELD PRODUCTION		
	Monthly Target	Daily Target	Daily Actual
Resak (mmscf)	120 mmscfd	95 mmscfd	162.96 mmscfd
Tangga Barat (mmscf)	119.4 mmscf/d	80 mmscfd	4.74 mmscfd
TOTAL Resak & Tangga Barat Gas (mmscf)			167.70 mmscfd
Resak Condy (bbls / d)	1.6 kbbl/d	1.6 kbbl/d	2432.39 bbls
Tangga Barat Condy (bbls/d)			2.0 bbls
TOTAL Resak & Tangga Barat Condy (bbls)			2434.39 bbls
Effluent Discharge (sm3)			Daily : 114 (HI Flow Totalizer)
Fuel Gas & Flared Gas (mmscf)			Daily : 4.205 mmscfd
Flow rate at 0600hrs / MGL press/MGL Temp.			158.8 mmscf / 82.1 bar / 35.3 deg C
Resak Gas Moisture / Dewpoint			27.55 ppmv
WELLS STATUS	RESAK	RDPA	Flowing well: A1, A- 4L , A-6L,A-9, A-10S, A-13 ,A-14 ,A-16,A-11L , A-17(10 wells flowing) Non-flowing:, 2S , 3L ,3S ,5S , 5L , 6S , 7S , 7L , 8L , 8S, 10L, 15, 11S, 12 , 2L ,4S ,15,19 (18 Strings).
	TOTAL RESAK		Flowing = 10 strings // Not Flowing = 18 strings
REMARKS	A-5L/5S, A-2S/2L, A-7L/7S, A-11S: Low THP A-6S high water cut. A-12 tool (fish) inside the well A-3L/3S (well floating).		

C. STOCK

STOCK	RCPP
POTABLE WATER (LTRS)	94,000 LTRS
DIESEL (LTRS)	35,840 LTRS

D. WELL TEST COMPLIANCE

ITEMS			
PLAN FOR MONTH	10	ATTEMPTED TO DATE	10
BALANCE	0	% ATTEMPTED vs ACCEPTANCE	100% vs.100%
REMARKS			

E. POB

POB		
PCSB-PMO OPS	14	Operations Team
PIONEER/SPJ/SOS	4	Radio operator/General Helper/ Medic .
PFCE	9	PWT installation & NSD activities
HANDAL	1	Crane operator.
PCSB-PMO Support	6	PIE3 / PME3
ALFA MELI	11	Catering crew
CETCO	4	Mercsorb & HiFlow performance monitoring
CORAL	18	Blasting and painting
SERBA DINAMIK	2	GCM. 2 activity.
HG SOLUTION	2	GCM 2 activity

BAKIP	1	Ustaz
TOTAL POB	72	

F. RESAK FIELD OPERATIONAL & CONTRACTOR DAILY ACTIVITIES.

Location	**Description**
RCPP	**Operations :.** • Troubleshoot LCV 2010 C/D not functioning. • Performed well test on new zone for A09 @ 20% choke size. Gas:15.9 mmscfd • Performed 6M PPM on TR-7511 • Continued Data compilation for GCM3 as requested by PRM3 **TRG:** • GCM 2 bundle installation ongoing. Progress 100% completion. Awaiting Gasket before unit could start-up. Duplex Gasket ETA 16/10, Hot Shot by chopper **CETCO/Hg Solution:** • Monitor HiFlow & Mercsorb rental unit performance (24 hrs monitoring). **CORAL :** • Continue blasting activities completed at cellar and sea deck area structure. Progress 28.52%(plan) vs 29.36%(actual) **SERBA DINAMIK:**

Location	Description
	- GCM.2 Bundle installation activity- On standby for start-up. **HG SOLUTION:** - Completed Mercury monitoring for heat exchanger cleaning job. **PFCE :** - Preparation to install the newly fabricated PWT skid at Celllar Deck. Overall progress 2.5%(plan) vs 2.7%(actual)
RDP-A	**T-9 Tioman :** - Drilling well A-12: Plan Days / Actual : 42 / 32.15. Pls refer Drilling report dd 16th Oct for details **PWE** : - Completed zone change and handover well A09 to operations .

G. SAP R3 (MMM) PPM COMPLIANCE

Daily Cumulative PPM/ REM % Completion				
	TOTAL (Sep)	PCNF	TECO	% DONE
PPM	**130**	**0**	0	0 %
REM	0	0	0	0 %
PRM	0	0	0	0 %
Remarks				

H. EQUIPMENT STATUS

	GAS COMPRESSORS			TURBINE GENSETS			CONDY PUMPS			
UNIT	**K2410**	**K2510**	**K2710**	**TG7510**	**TG7530**	**TG7550**	**P3030**	**P3055**	**P3080**	**P3000**
R/Hours	24 hrs	0 hrs	0 hrs	24 hrs	24 hrs	0 hrs	**24**hrs	0	0	0 hrs
REMARK	Running	**OOS: Bundle removed for maint.**	**OOS: engine stall on 17/09/12**	Running	Running	Standby	Running	**Standby**	**Pending gearbox & pump end installation**	Standby

I. AREA OF CONCERN

ITEM DESCRIPTIONS	SINCE	ACTION PARTY	WOR #	ETC	STATUS	URGENCY
PRM-1 (Construction)						
1.Repair collapse cable below bridge	Jun,06	Naazari	91821595	Jan 2012	Package is ready. Job will be executed during shutdown 2008. (last updated 10/3/2008) Still pending and temporary supported by scaffolding. Materials ready at KSB waiting for low POB.	Urgency changed from **Medium to High**
2. Replace badly corroded BRA receiver piping	2011	M Azim		2012 Sept s/down	Still outstanding	High (P1)

ITEM DESCRIPTIONS	SINCE	ACTION PARTY	WOR #	ETC	STATUS	URGENCY
3. LQ Fire Rated Doors Refurbishment / rectification	2011	M Azim			Site survey done in July 2012 by EVOS.	High (P1)
4. Air Accumulator replacement	2011	M Azim				High (P1)
PRM-3 (Rotating & Turbo Machinery)						
1. GCM2 Bundle Installation	June 2012	Irwan		End Sept 2012	Pending bundle delivery; expected 2nd Week of Sept 2012	High (P1)
2. Condensate pump (old & new pumps): piping systems experiencing high vibration	2011	Irwan/Azmi				High (P1)
3. P-3080 installation	March 2012	Irwan/Azmi			**Ready for installation by BAYU (can't proceed due to blasting activities within the vicinity).**	High (P1)
PRM-4 (Mechanical Static)						
1.To replace HVAC filter	Apr 09	PME 4 Nashreen/Azwin	92472155	Jan 2012	AHU Filter replacement as per recommended from the Robotic Duct Cleaning and Santitizing Service report @ 19th Nov - 3rd Dec 2007 >>To get option of material for frame that can be used are Stainless Steel , Cast steel or alluminium. Updated by Nasir PME4 on 16/07/09 Still pending.	Medium
PRM-5 (Electrical)						
Hydraulic starter for Turbo Generator	15/05/11	Erwan Darusis	93062561		**Update on 21/05/2012 :** **Installed SIMOCODE and tested failed. EIC to follow thru with Vendor.**	HIGH (P1)
PRM-6 (Instrument)						
Corriolis meter at V2010 malfunction (due to transmitter faulty).	June 2012	M Fallah			Vendor to rectify the problem is yet to be mobilized.	HIGH (P1)

ITEM DESCRIPTIONS	SINCE	ACTION PARTY	WOR #	ETC	STATUS	URGENCY
OPERATIONS						
Washing Machine	2011	FE- Amir			No latest update received from office.	High (P1)

Classification of Urgency:

High : Outstanding for more than a quarter from planned, potential thread to operation, safety issue and regulatory requirement.

Medium : Potential threat to operation but having alternative to control the potential and still within schedule, temporary substitutable option available but original solution is still needed

Low : All that not above.

J. ACTIVE MOCs

No.	MOC #	TITLE	EXPIRED	STATUS	REMARKS
1					

K. CONTRACTOR AND SUPPORT SERVICE TEAM

Contractor & Support Team onboard	ALFA MELI, CETCO ,CORAL, TRG, HG SOLUTION, SERBA DINAMIK, PFCE

L. RESAK OFFSHORE MANAGEMENT TEAM

Offshore Installation Manager	Hj Amir Shariffudin	**Production / Maintenance Supervisor**	PS – Vacant MS – Hj Sallehuddin.