INTEGRATION OF REFINERY FLARE GAS SYSTEM WITH FUEL GAS NETWORK FOR POWER GENERATION

Jayasinghe Arachchige Amila Indika

(128362R)

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Engineering

Department of Mechanical Engineering

University of Moratuwa
Sri Lanka

February 2017

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Signature: .... Date: ....

Dr. R. A. C. P. Ranasinghe

Senior Lecturer, Department of Mechanical Engineering, University of Moratuwa

ABSTRACT

The high price of crude oil, strict environmental regulations and increasing demand for energy have made refineries adopt a more holistic approach to integrating energy, economics and environment in their design and operation. In this situation gas flaring can be considered as a major course for wasting energy in oil and gas refineries. It can be modified and use it for power generation and in-house heat generation. In this study a novel methodology is introduced to utilize the flare gas generated in a refinery through utilizing the pressure energy generated within the process. The proposed methodology uses pressure stages to regulate the pressures in predefined values and use either natural gas or LPG to makeup the gas requirement other than the gases from the process and flare system. Especial attention was given to regulate the existing FGN operation and to recover steady flow out for power generation. According to the cases analyzed with different input parameters, there was no observed variations in the vessel pressures and desired gas output flows. The gas flow from the plant values was set to vary up to 1574 g/s and the flare gas flow is varied up to 422 g/s. The profitability of using the flare gas recovered has been analyzed in 6 cases. Accordingly the total profit gain depends on the excess gases generated within the refinery, total gasses used in the process furnaces, total electricity demand and the makeup gas price. Considering LPG as a makeup gas and with the low LPG prices, there is maximum profit gain of 7,141,943 LKR in the situation where the power is generated using flare gas in the peak hours only.

Key words **:** Flare gas system, Fuel gas system, power generation, LPG, Natural gas

ACKNOWLEDGEMENT

I am very much grateful to Dr. H. K. G. Punchihewa, Senior Lecturer, Department of Mechanical Engineering, University of Moratuwa, Dr. R. A. C. P. Ranasinghe Senior Lecturer, Department of Mechanical Engineering, University of Moratuwa and Eng. K. G. H. Kodagoda, Manager (Operations), Ceylon Petroleum Corporation, Oil Refinery for giving me their utmost support and guidance on this research.

I wish to thank Dr. Udaya Chinthaka Jayatilake, Senior Lecturer, Department of Mathematics, University of Moratuwa, for helping me formulating the equations and modeling them. Further I wish to thank Eng. N. D. Premadasa, Engineer, Sri Lanka Sustainable Energy Authority, Eng E.N.P De Silva, Engineer, Ceylon Electricity board, Mr. S.D.L. Sandanayake, Lab Attendant, Department of Mechanical Engineering, University of Moratuwa, for their support and being the resource people for the research. This research was carried out under the supervision of Dr. R. A. C. P. Ranasinghe, Senior Lecturer, Department of Mechanical Engineering, University of Moratuwa. I am grateful to them for their valuable guidance, kind hearted cooperation and encouragement extended to me throughout the study. Finally, I would appreciate everybody, who helped me in numerous ways at different stages of the research, which was of utmost importance in bringing out this effort a success.

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LIST OF ABBREVIATIONS

GGFR	-	Global Gas Flaring Reduction (GGFR)
FGN	-	Fuel gas network
CEB	-	Ceylon electricity board
HRSG	-	Heat recovery steam generation
GTL	-	Gas to liquid technology

CHAPTER 1 : INTRODUCTION

1.1. Background

The essential purpose of a flare system is to be a safety device for the plant which it serves. The use of this device raises a whole series of additional safety concerns connected directly with the act of flaring gas. Flare systems in oil refineries are for to burn excess gasses generated in the oil refining process and to maintain a safe way to dispose toxic gases generated in relief valve pop ups. Mainly in industrial plants, flare stacks are used for burning out the flammable gases generated or released by pressure relief devices during sudden over pressuring situations in plant equipments. On the other hand mostly the excess gasses generated during startups and shutdowns of units are burned in flare stakes. Other than that, sometimes the gases generated in lower pressure operations that is not been able to recover, are also directed to the flare system even though that fuel has a potential of recovering energy. [1]

Figure 1-1 : Flare stacks **[2]**

A large amount of hydrocarbon gases are flared and ventilated by many developing oil producing countries even though the gases have a higher economic value if recovered energy. Many different approaches to increase the energy efficiency of fuel gas systems and blow down systems were studied and implemented to reduce wasting of energy via gas flaring. Those innovations include the following. [2] [3]

- Gas to liquid technology

- Utilizing flare gas with natural gas to generate power
- Compressing the gas and store
- Flare gas re inject to the fuel gas system

Flaring of waste and unwanted gases to the atmosphere is a major concern in the whole petroleum industry including upstream and downstream facilities. According to the recent data, 139 billion cubic meters of gas is flared annually which is equal to 4.6% of world natural gas consumption in 2008. [4] [5]

1.2. Present status

Many production facilities, especially in oil and gas industry, use fuel gas and fuel oil as a fuel source for furnaces to generate required heat for the processes. Using more fuel gas with optimized fuel oil consumption, an optimum fuel gas usage in a furnace can be achieved. But due to furnace capacity restrictions, tube skin temperature limitations and difficulties in keeping steady heat transfer conditions (Heat gain by the process fluid), the fuel gas utilization becomes limited. Hence in many circumstances there is always high fuel oil consumption and an excess fuel gas flow goes to flare system to maintain the required pressures in fuel gas system. Other than that, the gases generated having pressures below the fuel gas system are also blown down to the flare system if not compressed and recovered. Moreover, the relief valve pop ups contribute considerable amount of gases in various pressure levels according to the process condition fluctuations and safety reasons. All those gas contributions lead the flare gas flow fluctuates heavily with time.

1.3. Problem statement

Fuel gas system having an excess fuel gas generation and with continuous gas blow downs to flare systems has a big potential of generating power via excess gas. But the main constraint arises is the heavy fluctuation of the gas flow available to recover due to the dynamic nature of process conditions and gas utilization patterns in furnaces via fuel gas system. On the other hand, the design of a power generation system to utilize excess gas becomes difficult with that kind of heavy fluctuations.

Other than that, most fuel gas systems contain a header with a constant pressure to collect the gas from process and to distribute the gas over the furnace network. So that the gasses generated via very high pressures will be reduced to a common header pressure allowing the furnaces to take constant gas flows to the burners according to the requirements. This leads a possibility to use this header pressure or the pressures the gases generated initially, to make up the flare gas variations. Therefore a critical analysis has to be carryout to identify the possibilities of making up the flare gas by the fuel gas generated in the process and its consequences upon the gas supplies to the process furnaces. Figure 1-2, Figure 1-3 and Figure 1-4 shows the average flare gas generated, total fuel gas from the process and total fuel gas to process heaters in the oil refinery Sri Lanka respectively. Data for the graphs are attached in Annex C.

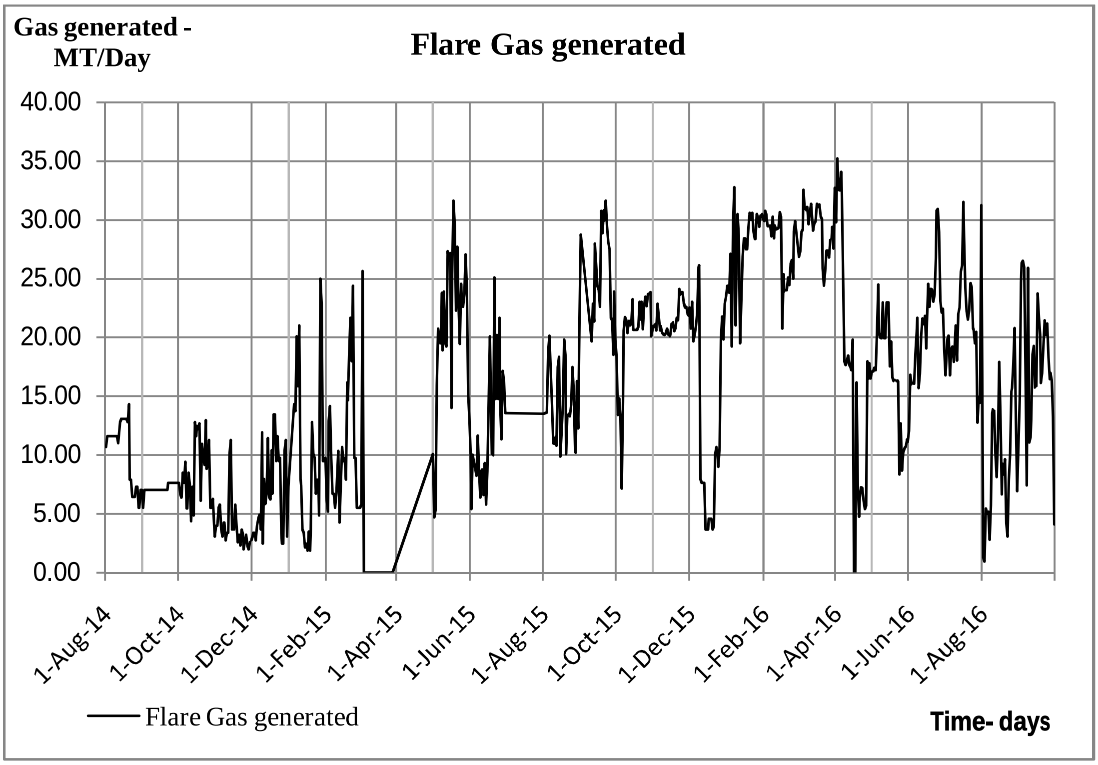

Figure 1-2 : Flare gas generated **[7]**

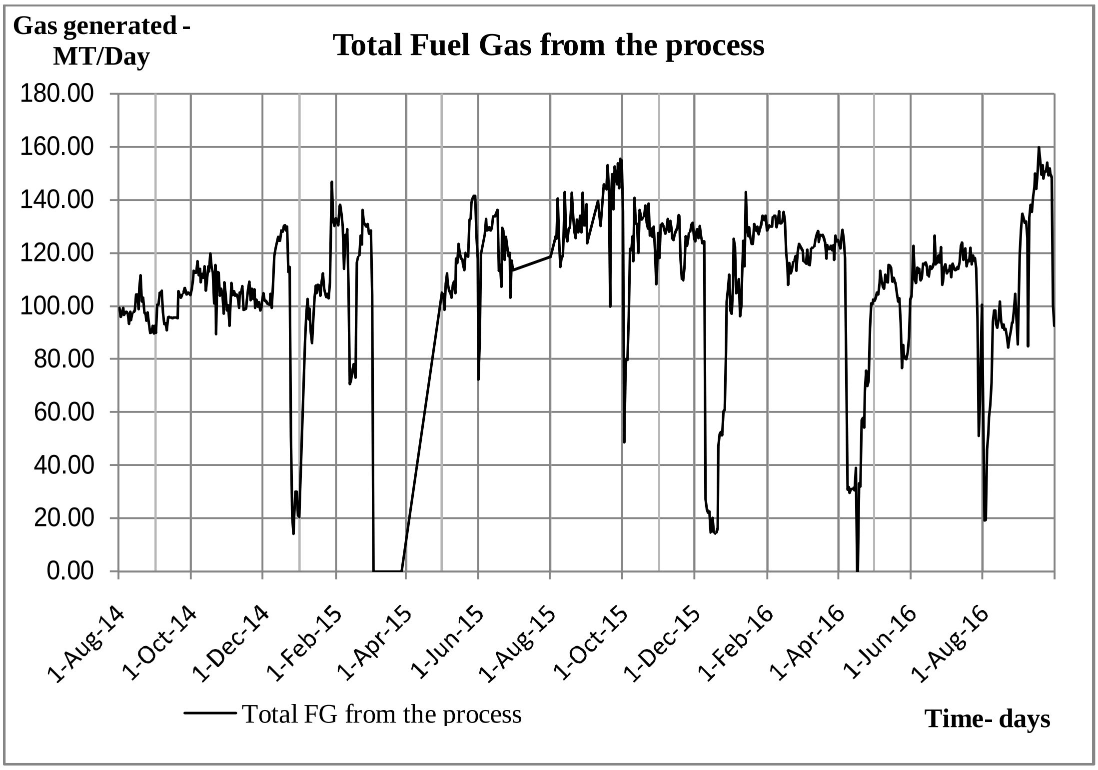

Figure 1-3 : Total Fuel Gas from the process **[7]**

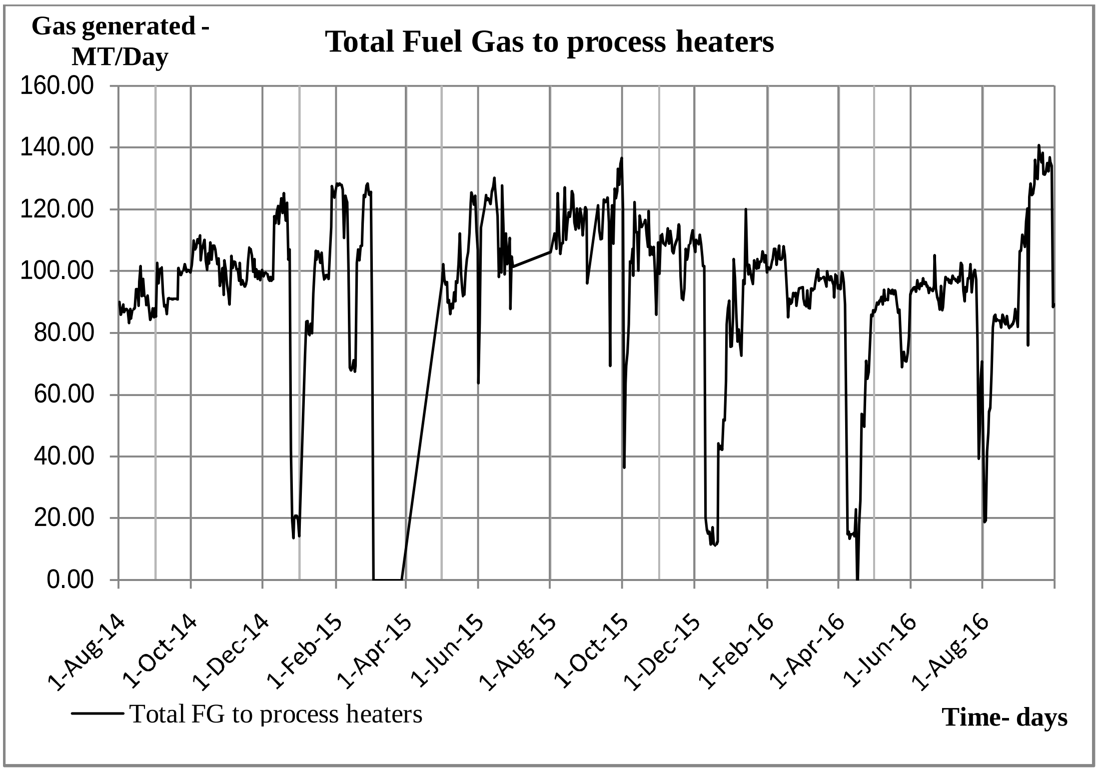

Figure 1-4 : Total Fuel Gas to process heaters **[7]**

1.4. Aim and Objectives

Aim of the research is,

- To identify a pressure vessel arrangement, consisting pressurized fuel gas to makeup blow down gases via flare system which is to be regulated in order to use it as a fuel for separate power generation facility, without disturbing the existing gas supply to the process furnaces.

The objectives are,

- To identify the pressure vessel arrangement that can regulate the excess gas flows via flare system.
- To identify the control system that can regulate the identified pressure vessel network.
- To develop dynamic model to simulated proposed system and asses the desired mass flow rate variations with different input flow fluctuations.
- To assess the steady state conditions of the proposed model with existing refinery data over a two year period.
- To study the economy of using LPG as a makeup flow to generate electricity using recovered gas through proposed system instead of purchasing electricity.

CHAPTER 2 : LITERATURE REVIEW

2.1. Introduction

All most all oil and gas refineries around the world emit huge amount of gases to the atmosphere through flaring. Flaring also has harmful effects on human health and the ecosystems near flaring sites. Other than that, CO_2 emissions from flaring have high global warming potential and it contributes to climate change also. The low quality gas that is flared, releases many impurities and toxic particles into the atmosphere during the flaring process. Acidic rain, caused by sulfur oxides in the atmosphere, is one of the main environmental hazards which results from this process. [6] [7] [8]

Russia, Nigeria, USA and Iran which are main oil producing countries in the world, are listed as main flare gas producers of the world in 2013 by Global Gas Flaring Reduction (GGFR) [4]. Figure 2-1 shows the global gas flaring variation with the oil production capacities throughout the years. After 1996 till 2014 the oil production capacities were increased by 31% and opposite to that the gas flaring amount were decreased by 11%. This may be due to new innovations in flare gas recovery, utilizing excess gas for in house heat and power generation or new process innovations that generate low excess gases. [4] [2]

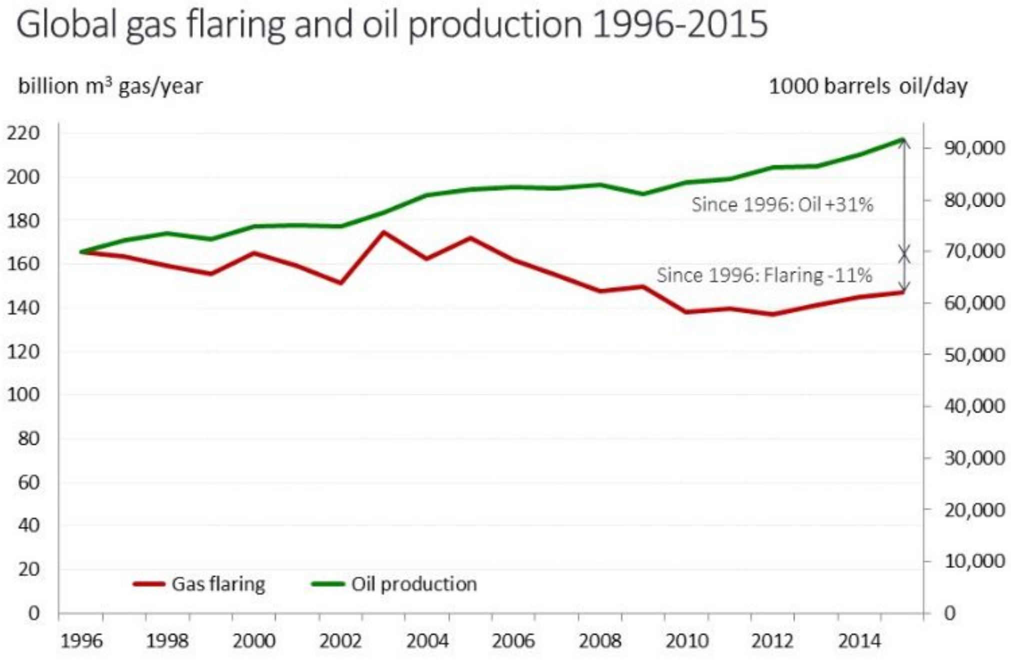

Figure 2-1 : Global gas flaring and oil production 1996-2015 [4]

Figure 2-2 shows top 30 countries that generate high flare gas volumes in 2013 to 2015.

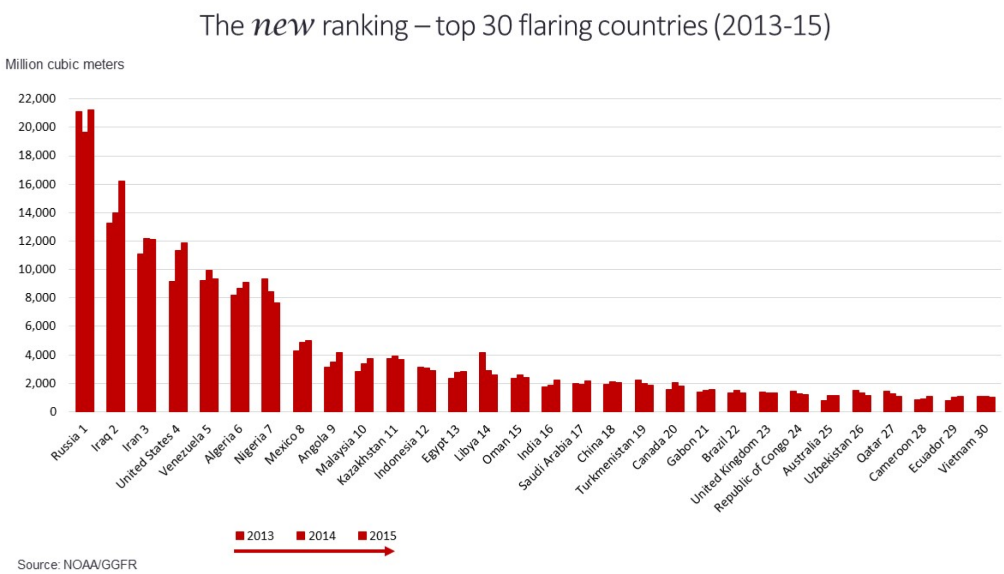

Figure 2-2 : The top 30 gas flaring countries **[4]**

Figure 2-3 and Figure 2-4 shows the gas flaring intensity as the cubic meters of gas produced per barrel of oil produced.

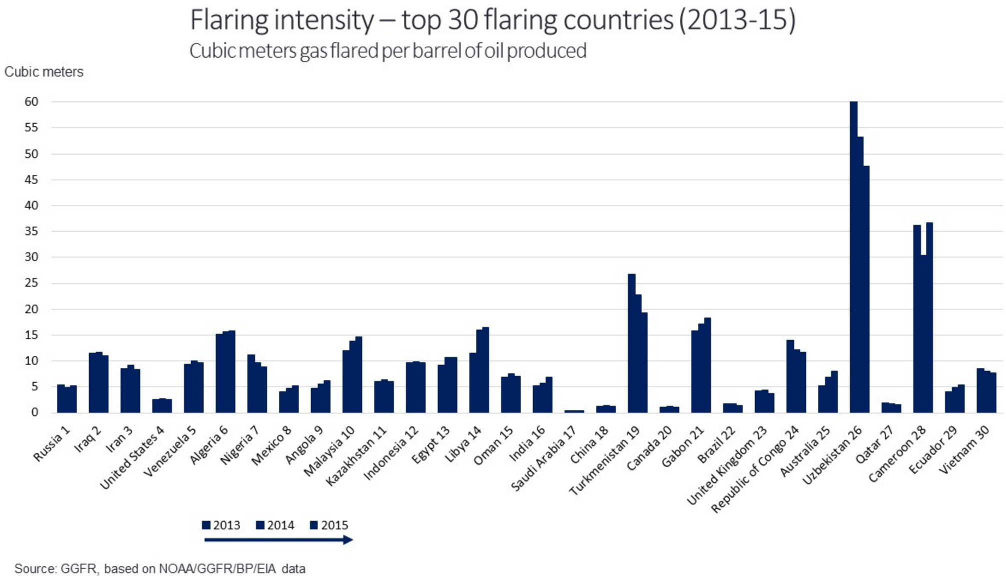

Figure 2-3 : Top 30 countries by flaring intensity [4]

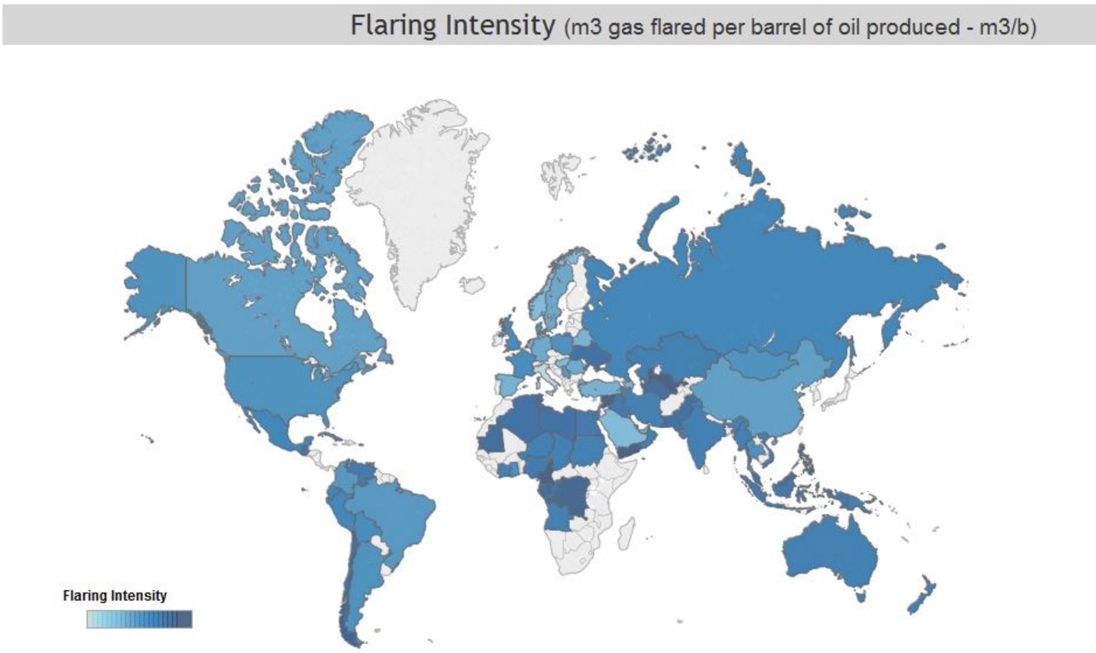

Figure 2-4 : Flaring intensity [4]

As per the researches performed by the World Banks' Global Gas Flaring Reduction Partnership (GGFR), the equivalent of almost one third of Europe's natural gas consumption is burned in flares each year which contributes to about 400 million tons of carbon dioxide emission to the atmosphere. It is roughly 1.5% of the global CO_2 emissions. Mainly environmental and economic considerations promote to use flare gas recovery systems which reduces noise, thermal radiation, air pollution and gas emission [4] [9]. Flaring or ventilating gases to the atmosphere causes to increase the greenhouse gases also. Global Bank estimates that 100 Billion cubic meters of natural gas, equal to annual consumption of gas for Germany and France, is flared to air each year globally. [4] [2]

Since gas flaring has natural, economic and capital wastes, the main intention should be to reduce flare gas generation by improving the process conditions [10]. But for the safety purposes a flare in a refinery facility becomes a compulsory design. After considering that looking for recovery methods and generating electrical power using the waste gas or using it in other applications should be considered. [11] [9]
Excess flare gas can be used via different ways.

- The gas can be re-introduced in to the fuel gas network for own use for the heaters to generate heat.
- For onsite electricity generation.
- As a feedstock for the petrochemical industry.

[10] [2]

Electricity generation using flare gas as a fuel is studied by many studies. Many have discussed about the economic and environmental impacts of flare gas and the necessity to decrease the amount of gas flaring. For example Emeka Ojijiagwo, Chike F. Oduoza and Nwabueze Emekwuru have proposed a study on gas to wire technology in 2016 September [10]. There they studied one unit of the gas turbine having 0.93 MCM of gas consumption capacity and generates 150 MW of electricity daily in the Nigerian oil and gas sector. It was found that 50 turbines are sufficient to consume an average of 46.5 MCM of gas daily to generate 7500 MW of electricity.

Economic analysis showed that there is an annual net profit of £2.68 billion gained from flare prevention and overall environmental protection. [10]

2.2. Advantages of flare gas recovery

- Reduced flare emissions
- Improved community relations
- Recovered gas for facility fuel gas
- Reduced utility steam consumption
- Increased flare tip life
- Reduced noise and light pollution
- Quick payback

[12] [2] [13]

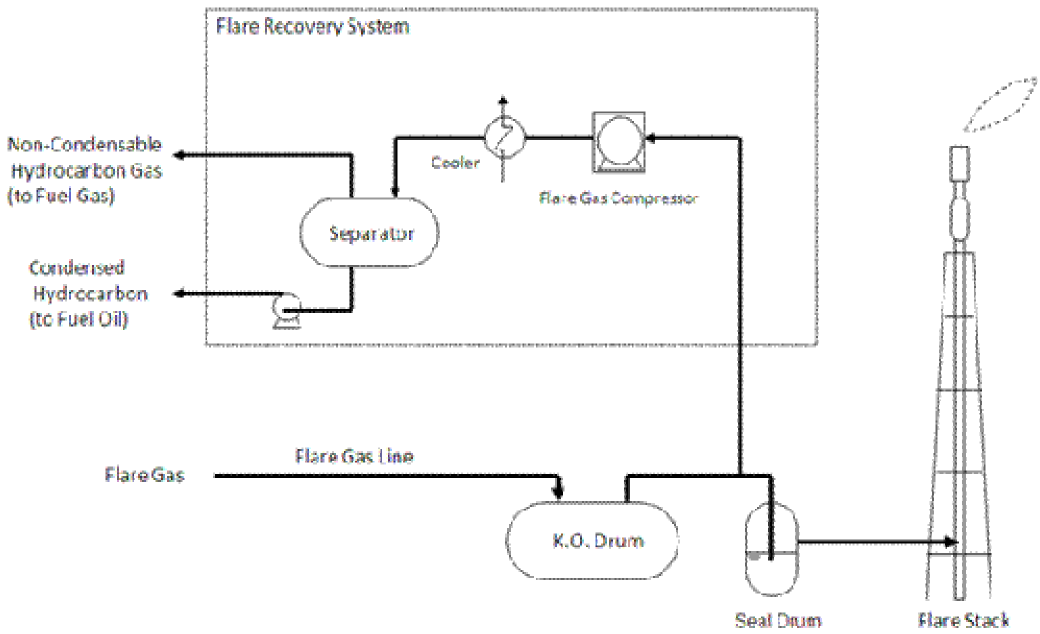

Figure 2-5 : A simple flare gas recovery system **[13]**

2.1. Environmental impacts of gas flaring

Gas flaring releases hazardous chemicals and heavy metals, which negatively affect the environment and badly affects to the health of people and animals. During this process, mainly the emission of carbon dioxide, sulfur oxides and methane takes place. Those cause to trigger global warming and climate changes due to the effect of carbon dioxide, and oxides of sulfur and nitrogen mixed with water vapor present in the atmosphere [11]. Sulfur oxides mixing up with water and oxygen produces acid rains. Acid rains can be toxic to the human body. It can also be experienced on the roofs within the flaring area which gets rusted quickly. Steady acid into the environment creates lowering the pH level in the affected areas and increases the rate of extinction of flora and also make water bodies unhealthy for water species. Noise and vibration emits during gas flaring has also a significant effect on environment. [2] [13]

2.2. Economic impacts

Gas flaring is a form of waste of natural resource. It carries huge impact upon the economy of the world. Eventually it reduces the revenue generation by wasting valuable assets. On the other hand, soil infertility occurs through the deposits of acids on the soil which reduces the pH of the soil surface. It is a huge problem that is associated with gas flaring. This reduces the activities of those microorganisms that are sensitive to low pH and decreases the decomposition of plant residue and nutrients. This phenomenon also reduces plant intakes. So that, acidification of soil causes poor farm harvests and high cost of food items. [11] [9]

2.3. Health and safety

Gas flaring causes for generating byproducts of burning and sometimes escapes of gases without burning when some sudden eruptions of huge gas releases in a refinery occur. Byproducts of gas flaring are mostly the carbon dioxide, nitrogen dioxide, Sulfur dioxide benzene, xylene, toluene and many carcinogen compounds. [14] [11] Those are linked with leukemia, chronic bronchitis, asthma as well as infertility. Other gases released like H_2S, is a highly toxic gas that causes to have neurological diseases with the longer period exposure with an even a small concentration. Benzene particularly is known as one of the top 20 toxic chemicals and the exposure of the human body to benzene leads to headache, drowsiness and can lead to death. Other effects associated with gas flaring include low birth weight, bone marrow damage, anemia, decreased immune system and internal bleeding. [1] [11] Particularly, toluene is highly associated with severe nervous system damage. Other than that, it was found that long exposure to moderate or even low amount can cause liver damage, as well as kidney and lungs damage. Long term exposure to those gases or byproducts can even result to memory loss, vision and hearing disabilities.

2.4. Commercially available flare gas recovery options

According to most definitions, gas flaring is a safety practice that consists of burning off the disposed gases lost through the safety valves of the plant, mostly in oil refineries and oil fields, and it also includes the gas discharged in to the blowdown system during unsteady running conditions. The excess gas minimization initiation has first to be taken to reduce gas flaring since there is an energy loss caused by the amounts of volatile organic compounds and highly reactive VOCs released to the flare. In order to improve energy efficiency three different highlighted technologies to recover the flare gas are widely implemented. Those are as below. [10] [15] [16]

- GTL (Gas to Liquid) technology.
- Use as a fuel in gas turbines in order to produce electrical energy.
- Gas compression method which consists in compressing the recovered flare gas and injecting it into the fuel gas header.

2.5. GTL technology

Gas to Liquid (GTL) technology is one of the best environmentally friendly solutions to reduce gas flaring. 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 petrochemicals. [15] Initiation of Gas to liquid technology is dates back to the start of the 20th century. It is an alternative technology for the production of liquids from crude oil. The cost of crude oil in 20th century causes to initiate this technology and improvements. There are a number of GTL technology formats available and some are under development. Most technologies make diesel or other distillate fuels and some make gasoline. According to the recent analysis only the diesel from petrochemical feedstock versions have been proven economically feasible. [8] [15] On the other hand, due to the relatively low thermal efficiency of GTL, it produces significantly greater CO_2 emissions than crude oil refining. According to the literature with current technology, nearly 10 mmBtu of natural gas is required to produce an average barrel that is 70% diesel and 30% naphtha. So it implies that GTL is only 56% efficient. In contrast, crude oil refining can reach a thermal efficiency close to 90%. [15]

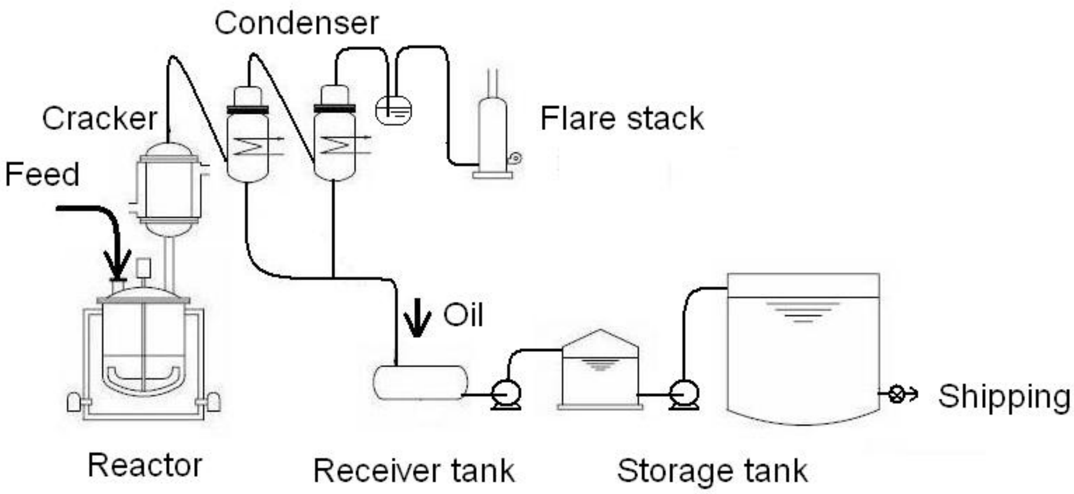

Figure 2-6 : GTL Process **[17]**

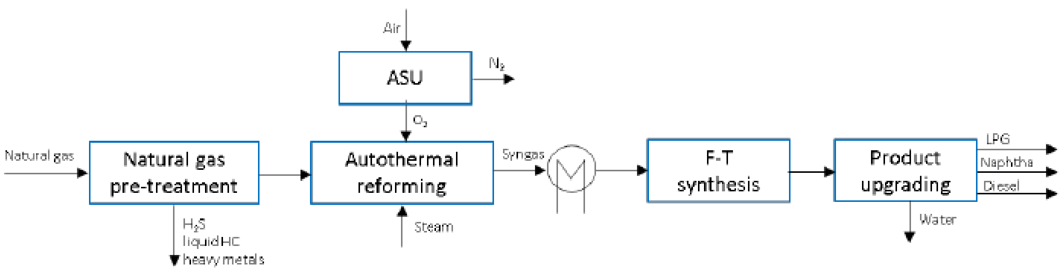

Figure 2-7 : GTL Simple process flow diagram **[17]**

2.1. Compression method

Another method for reducing and recovering flare gas is compression and injection it into the refinery pipelines. Piston compressors are mostly used in this method that operates based on the displacement principle. In order to implement there should always be a lagging of fuel gas requirement for the process plant itself. The flare gas recovery system implemented in a refinery should have a viable technology. The two most used compression method technologies in petrochemical industries are ejector and liquid ring compressor. [18] [19] The ejector exploits the Bernoulli's principle. So that an increase in velocity corresponds to a decrease in pressure happens. In this way, the flare gas is been catch. Afterwards, it is compressed at an intermediate pressure between a Low process pressure value and a high process pressure value with the help of High process Pressure driving fluid. [15]

Liquid ring compressor technology is commonly used in refineries. It is a rotary volumetric machine that uses a secondary fluid to compress the flare gas. One of the most important advantages of using this device with respect to a simple ejector is the chance of removing dangerous species like H_2S that are present in refinery flare gas. It has an axial impeller enclosed in an external case on the impeller. The blades are designed to convey the gas from the inlet port to the discharge port. Here the gas is enclosed by the blades of the impeller and by the liquid fluid. Liquid ring compressors can reach high compression ratios generally up to 1:31 between the suction and the pressure sides. By choosing a right liquid, a gas cleaning process is also can be achieved by removing H_2S. [15] [18]

2.2. Electricity production from purge gases via gas turbines

Main Flare gas reducing method is to convert it into electricity which is one of the most widely used forms of energy. Flare gas from refinery can be used as a primary source to generate electricity or it can be used as a fuel mixed with natural gas or LPG to generate power. An electric utility power station uses gas turbines, engine, water wheel or other similar machines to drive an electric generator. A turbine converts the kinetic energy of a moving fluid to mechanical energy. Gas turbines are commonly used when power utility usage is at a high demand. Gas turbines produce hot combustion gases that pass directly through a turbine, spinning the blades of the turbine to generate power. Other than that the hot flue gas out from the turbine can be used to generate steam via a heat recovery steam generator (HRSG) and use it for power generation through a steam turbine. [20] [10]

2.3. Gas turbines to generate power using excess fuel gases

Gas turbine is a rotary type internal combustion thermal prime mover. The gas turbine plant works on a gas power cycle of the various means of producing mechanical power. The gas turbine has outstanding advantages such as

- Exceptional reliability
- Freedom from vibration
- Ability to utilize grades of fuel not suitable for high performance spark-ignition engines
- Ability to produce large bulk of power from units of comparatively small size and weight

[19] [21]

AS per the Figure 2-8, simple systems consisting of the gas turbine contains a gas turbine driving an electrical power generator.

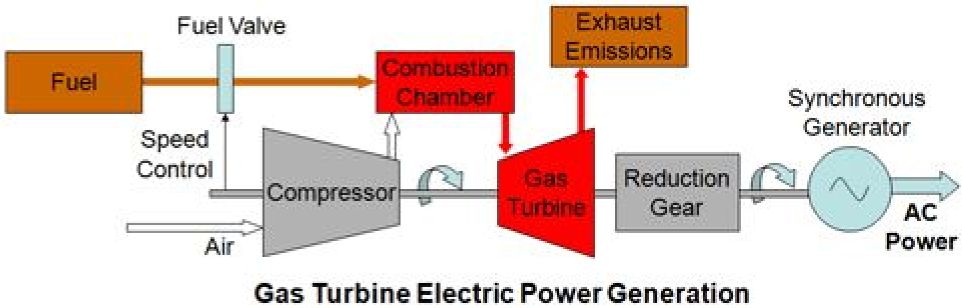

Figure 2-8 : Gas turbine 1 **[22]**

2.3.1. Combined cycle systems

Combined cycle systems are designed to obtain maximum efficiency. Here the hot exhaust gases from the gas turbine are used to generate steam via a HRSG and the produced steam is used to power a steam turbine. After that, both turbines will be connected to the electricity generators.

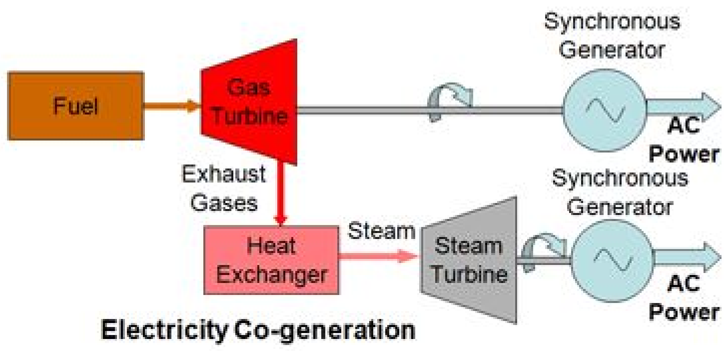

Figure 2-9 : Electricity cogeneration **[22]**

2.3.2. Turbine Power Output

In order to design the turbine for minimum payback period, the size and the weight of the turbine for a given output power is to be minimized. So that the power output per pound of air flow should be maximized. This can be obtained by maximizing the air flow through the turbine which in turn depends on maximizing the pressure ratio between the air inlet and exhaust outlet. The main factor governing this scenario is the pressure ratio across the compressor. This can be as high as 40:1 in modern gas turbines.

2.3.1. Simple cycle turbines system efficiency

In all gas turbines like all cyclic heat engines, a higher maximum working temperature in the machine produces greater efficiency according to the Carnot's Law. In a turbine more energy is lost as waste heat through the hot exhaust gases. The temperatures are typically over 1,000°C. So that the simple cycle turbine efficiencies are quite low. For a heavy plant, design efficiencies are in the range of between 30% and 40%. By increasing the firing temperature, output power at a given pressure ratio can be increased. But there is also a sacrifice of efficiency due to the increase in losses due to the cooling air required to maintain the turbine components at a given range of working temperatures. [23] [25]

2.3.2. Combined cycle turbines

There is a big possibility of recovering waste heat from the simple cycle systems by using the exhaust gases in a HRSG to produce steam and to drive a steam turbine for electricity generation. After the recovery process, the exhaust temperature may be reduced to as low as 140°C (Depending upon the dew point conditions there should be a limitation of minimum temperature achieved to avoid corrosion problems) enabling efficiencies of up to 60% to be achieved in combined cycle systems. In combined cycle systems, increasing pressure ratio has a less effect over the efficiency. It is because most of the improvement comes from increasing in the Carnot thermal efficiency resulting from increasing in the firing temperature. So that simple cycle efficiency is achieved with high pressure ratios while combined cycle efficiencies are achieved through modest pressure ratios and greater firing temperatures. [23] [25]

2.3.3. Fuels used for gas turbine applications

Gas turbines have an advantage with their fuel flexibility. They can be adapted to use almost any flammable gas or light distillate petroleum products such as, natural gas, fuel gases, gasoline, naphtha, diesel and kerosene. Crude and other heavy oils and can also be used to fuel the gas turbines if the fuel viscosity is reduced to an accepted level by heating for burning in the turbine combustion chambers. [25] [23] [15]

2.3.4. Applications

Mainly the power generation facilities use gas turbines. Examples of large scale power generations applications are such as delivering 600 MW or more from a 400 MW gas turbine coupled to a 200 MW steam turbine in a cogenerating installation.

Usually such installations are normally used for remote sites such as oil and gas fields. They do however find use in the major electricity grids also. Low power generating gas turbines are with capacities up to 5 MW. They also can be accommodated in compensating small scale power requirements. [23] [25] [15]

2.4. Waste heat recovery

With the rising of energy costs, depletion of fuel sources and rising energy demand, the wastage of energy has become a critical aspect to reduce. There are many developments and advanced energy systems innovated in recent past that can increase the efficiency and reduce the emissions. Waste heat recovery is the process of recovering energy from potential high energy sources that are normally lost to the environment without any useful work taken. A common utilization of waste heat to steam is via heat recovery steam generator (HRSG). Some of the main most widely used waste heat recovery technologies are listed below. [23] [25] [15]

- Recuperators
- Furnace regenerator
- Heat wheel
- Heat pipe
- Finned tube heat exchangers
- Shell and tube heat exchangers
- Plate heat exchangers

[25] [26] [21] [27]

2.5. Waste heat recovery boilers

Waste heat boilers, are water tube boilers that use medium to high temperature exhaust gases to generate steam. Those are designed to capture the heat wasted due to a heat source like exhaust gas or flue gas from a furnace or a gas turbine. For the case of waste heat steam generator, the hot waste gas passes around consecutive tube bundles. Normally flue gas passes through economizer, evaporator and super heater, while water is flowing inside the tubes and steam is being produced. Waste heat boilers are available in a variety of capacities, allowing for gas intakes from 1000 to 1 million ft^3/min. In cases where the waste heat is not sufficient for producing desired levels of steam, auxiliary burners or an after burner can be added to attain higher steam output. [23] [28] [20]

2.6. Heat recovery steam generator

Heat recovery steam generators are useful for recovering heat from hot flue gases. In general, a heat recovery steam generator (HRSG) is situated next to the hot flue gas exhaust duct of a power plant. In general, whether coming from a diesel engine or a gas turbine, the hot flue gases are led straight into the HRSG. Economizer, evaporator and super heater are the three main components of the HRSG. The preheating of feed water, boiling process and the superheating process is done by economizer, evaporator and super heater respectively. The pinch-point temperature difference plays the most important role for the designing a HRSG.

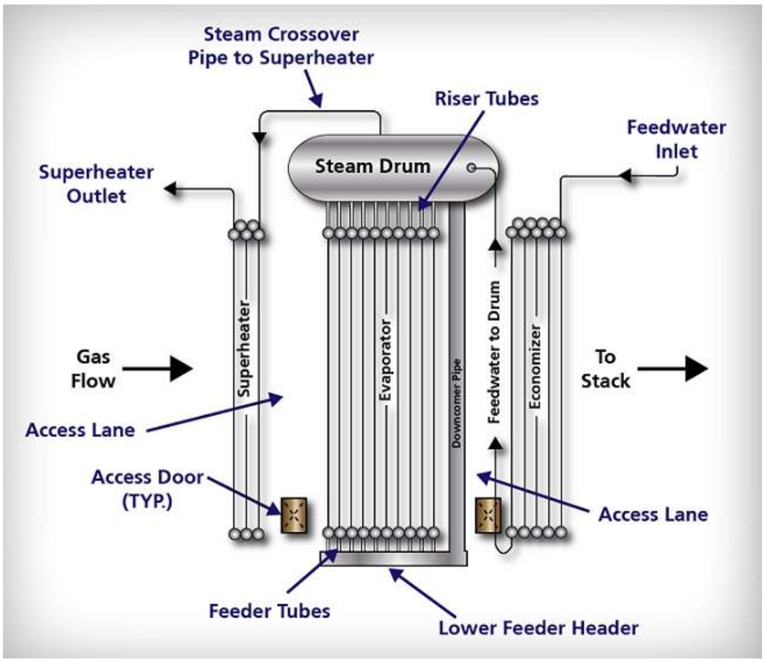

Figure 2-10 : Heat recovery steam generator **[27]**

2.7. Types of HRSG

HRSGs can be classified according to their design, operation and also application.

2.7.1. Fired and Unfired

The steam generation in a HRSG may also be used for process heating apart from its main function of driving a steam turbine. The load condition of the primary waste heat source, could affect the process heating at some times. Therefore some HRSGs are equipped with separate fuel burners at the inlet duct of the HRSG. Usually this is fired with the same fuel as the main engine. They are classified as supplementary fired HRSGs. [27]

2.7.2. Single and multiple pressure operation

Smaller HRSG units are typically designed only with a single pressure level of steam generation in order to decrease complexity and ensure lowest possible costs. Larger units and especially combined cycles aiming at high efficiency would enhance the heat recovery in the HRSG by using multiple (usually 2 or 3) pressure levels of steam generation.

2.7.3. Horizontal and vertical

Based on the position of the waste heat gas flow, the HRSG can be designed horizontally or vertically. Although both the designs carry similar manufacturing costs the different geometry has different advantages and disadvantaged over another.

CHAPTER 3 : METHODOLOGY

3.1. Introduction

In this study, a novel methodology is presented to recover a constant gas flow from the flare gas system with integration of the fuel gas network (FGN) and with excess gas supply either from pressurized natural gas or from LPG produced. Moreover, a change for current FGN in a typical refinery is proposed in order to minimize the fluctuations that can affect the gas flow to process heaters.

3.2. Typical fuel gas and flare gas networks

Figure 3-1 shows the existing layout of a typical fuel gas system and Figure 3-2 shows a typical flare gas system in a refinery. In a typical fuel gas system mostly there is a fuel gas collector that collects the gases generated within the process and then it also acts as a gas distributing vessel to the process heaters via set of knock-out drums in order to separate the condensed hydrocarbons and as to maintain a buffer gas stock for a particular number of selected furnaces. In a situation when the pressure drops below the set value of the gas collector, a make-up gas (LPG commonly) supply will be provided to maintain an uninterrupted gas flow to the process heaters. Gas withdrawn from the FGN is done according to the furnace heat load requirement which can be controlled manually or automatically using a temperature control system.

According to the Figure 3-2 a typical flare gas system mainly consists of a flare stack, a gas collecting drum, and a fuel gas drum especially to maintain a constant gas flow to pilot burners of the flare stack. Flare stack is equipped with a water seal in order to prevent backfiring due to low pressure operation and open ended flame system.

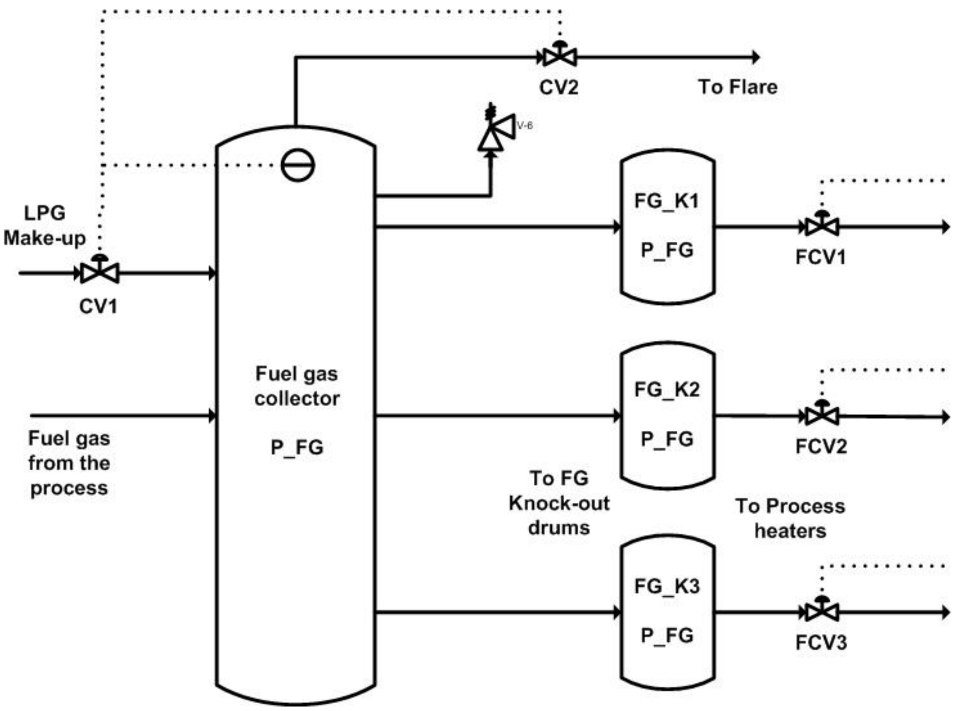

Figure 3-1 : Typical fuel gas network **[14] [7]**

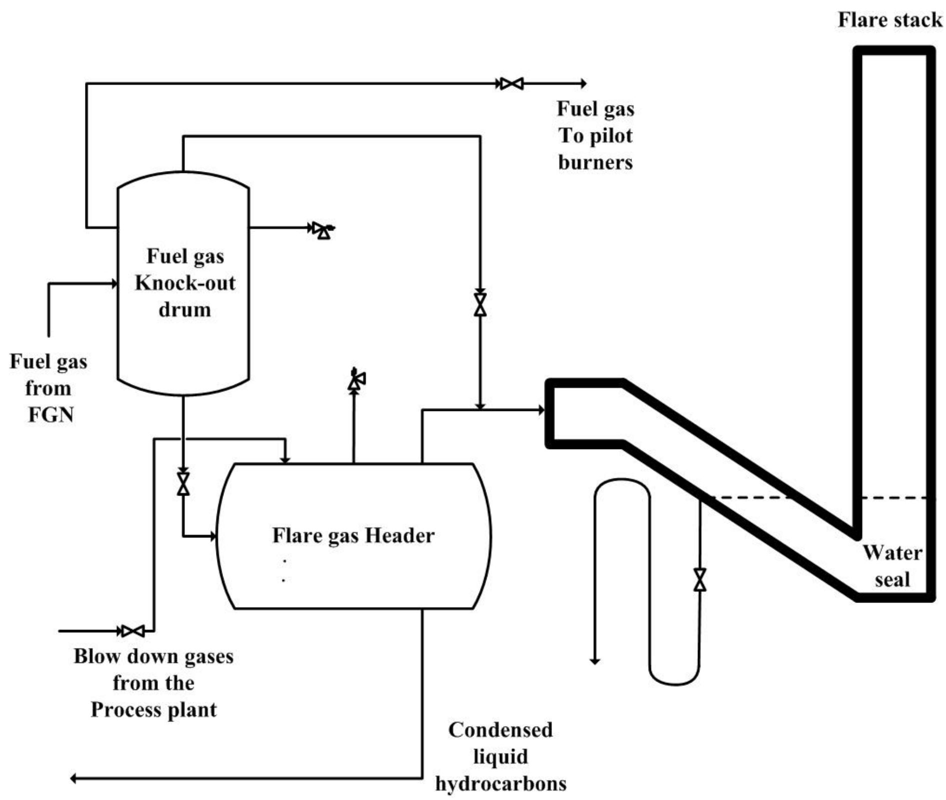

Figure 3-2 : Typical flare gas network **[14] [7]**

3.3. Model objective

The solution for the problem statement in chapter 1.3 is formulated with an objective of minimizing variations of the gas flows to the process heaters if a side stream is taken out from the FGN to balance the pressure reductions occur in flare gas header where a constant mass flow output is taken. The properties of the fuel gas, its behavior with pressure, behaviors of a gas facing different pressures in a pipe line and the effect of the properties of the pipe for a gas flow are considered. The proposed control system is for to obtain the objective of a constant mass flow out put via the fuel gas system and from the flare gas system as described above.

3.3.1. Data on model formulation

- A set of source streams to the FGN with known characteristics such as compositions, temperatures, pressures and flow rates.
- A set of fuel usage nodes with known energy requirements and acceptable ranges for different specifications such as flow rates, compositions, pressures, temperatures, lower heating values.
- Fluctuation of flare gas flow rate, pressure variation in the flare gas collector drum.
- Expected energy requirement and required gas flow.
- Pressure stages that can compensate pressure reduction in the flare gas collector drum.

3.3.2. Assumptions

- FGN pressure variation do not contribute to any chemical reactions
- No temperature dependency for lower heating value of fuel gases is considered.
- Reference temperature is 40 ^{0}C
- Pressure stages are taken as 18 bar, 12 bar and 7 bar for the steady state case study depending on the refinery gas generation capacities.

- FGN pressure is identified as 3 bar and Flare gas collector pressure is assumed as 5 bar.

3.4. Model development

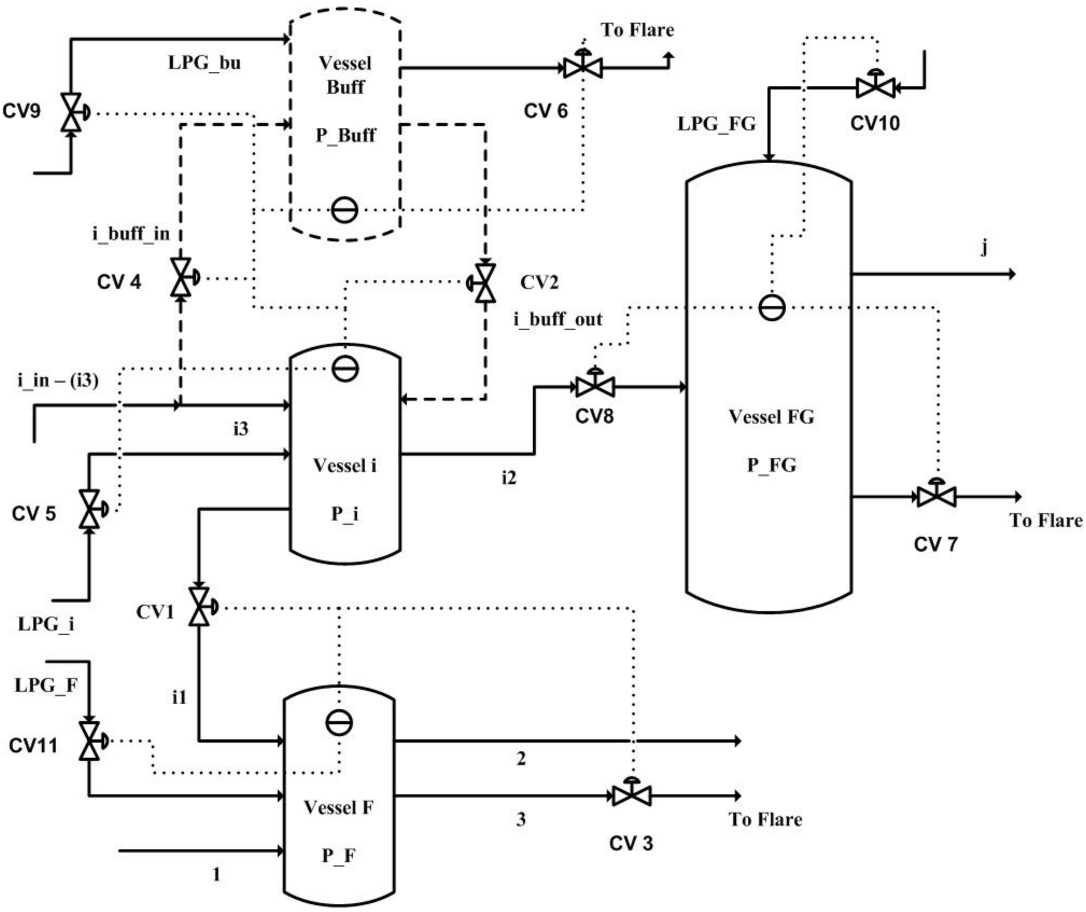

Figure 3-3 : Model schematic

For i = 1, for the main system for pressure reduction in F vessel

3.4.1. Flow numbering

1	-	Flare gas flow
2	-	Gas flow that uses to generate power (Flare gas recovery)

3	-	Excess gas generated due to maintaining set value of F vessel
i1	-	Gas flow that is generated to compensate the pressure fluctuations in the vessel F
LPG_F	-	LPG flow that is used to maintain any fluctuations in vessel F Pressure
i2	-	Fuel gas flow that goes to FG vessel
i3	-	Fuel gas from the process
LPG_i	-	LPG flow that is used to maintain any fluctuations in vessel i
i_in	-	Fuel gas from the process - uses for both vessel i and vessel buff
LPG_buff	-	LPG flow to maintain the pressure fluctuations in Buff vessel
i_buff _in	-	Excess fuel gas flow to vessel Buff from the process
i_buff_out	-	Fuel gas flow to vessel i from vessel Buff
Flow via CV6	-	Excess gas generated due to maintaining set value of Buff vessel
j	-	Fuel gas to the process heaters
LPG_FG	-	LPG flow to maintain the pressure fluctuations in FG vessel
Flow via CV7	-	Excess gas generated due to maintaining set value of FG vessel

3.4.2. Vessel numbers

Vessel F	-	Flare gas collector vessel
Vessel FG	-	Main vessel in FGN that collect fuel gas for plant operations
Vessel i	-	Vessel uses to maintain the pressure fluctuations in F vessel
Vessel Buff	-	Buffer vessel to contain the excess fuel gas generated in the plant

3.4.3. Pressure notations

P_F	-	Pressure in F vessel
P_{FG}	-	Pressure in FG vessel

P_i	-	Pressure in i vessel
P_{Buff}	-	Pressure in buff vessel
P_0	-	Atmospheric Pressure
P_{LPG}	-	LPG pressure

3.4.4. Mass flow notations

m1	-	Mass flow in flow 1
m2	-	Mass flow in flow 2
m3	-	Mass flow in flow 3
mi1	-	Mass flow in flow i1
mi2	-	Mass flow in flow i2
mi3	-	Mass flow in flow i3
m_LPG_i	-	Mass flow in flow LPG_i
m_buff_out	-	Mass flow in flow buff_out
m_buff_in	-	Mass flow in flow buff_in
mj	-	Mass flow in flow j
m_LPG_FG	-	Mass flow in flow LPG to FG vessel
m_LPG_F	-	Mass flow in flow LPG to F vessel

3.4.5. Mass changes in vessels

m_F	-	Mass within the vessel F
m_{FG}	-	Mass within the vessel FG
m_i	-	Mass within the vessel i
m_{bu}	-	Mass within the vessel Buff

3.4.6. Control valves

CV1	-	Flow control valve controlling mass flow i1 considering the pressure in F vessel
CV2	-	Flow control valve controlling mass flow i_buff_out considering the pressure in i vessel

CV3	-	Flow control valve controlling mass flow 3 considering the pressure in F vessel
CV4	-	Flow control valve controlling mass flow i_buff_in considering the pressure in i vessel
CV5	-	Flow control valve controlling mass flow LPG_i considering the pressure in i vessel
CV6	-	Flow control valve controlling mass flow to flare considering the pressure in Buff vessel
CV7	-	Flow control valve controlling mass flow flare considering the pressure in FG vessel
CV8	-	Flow control valve controlling mass flow i2 considering the pressure in FG vessel
CV9	-	Flow control valve controlling mass flow LPG_bu considering the pressure in Buff vessel
CV10	-	Flow control valve controlling mass flow LPG_FG considering the pressure in FG vessel
CV11	-	Flow control valve controlling mass flow LPG_F considering the pressure in F vessel

Other notations

- The value with a dash indicates, first the main value of the parameter then value Specified to the specific component.
- The values with subscript characters are the names corresponding to the specific components of the system
- Equation number is below the particular equation

3.4.7. Gas flow in a pipe line

Fuel gas flow in a stream is Q, in Equation 3-1, and A is a constant. T_b, P_b, P_1 and P_2 are base temperature, base pressure, upstream pressure and downstream pressure of the flow respectively.

$$\frac{dQ}{dt} = A\left(\frac{T_b}{P_b}\right)\sqrt{\frac{\left(P_1{}^2 - P_2{}^2\right)D^5}{GT_fLZf}}$$

Equation 3-1: Volume gas flow rate **[29]**

$$\frac{dm}{dt} = A\rho_g\left(\frac{T_b}{P_b}\right)\sqrt{\frac{\left(P_1{}^2 - P_2{}^2\right)D^5}{GT_fLZf}}$$

Equation 3-2: Gas flow rate by mass

Q	=	Gas flow rate, measured at standard conditions, m 3 /day
f	=	Friction factor, dimensionless
P_b	=	Base pressure, kPa
T_b	=	Base temperature, K (273 + ° C)
P_1	=	Upstream pressure, kPa
P_2	=	Downstream pressure, kPa
G	=	Gas gravity
T_f	=	Average gas flowing temperature, K (273 + ° C)
L	=	Pipe segment length, km
Z	=	Gas compressibility factor at the flowing temperature, dimensionless
D	=	Pipe inside diameter, mm

[29]

3.4.8. Van der Waals equation

Contributes to determine the pressure mass relationship where P, V, R, T, n, m, M are vessel pressure, vessel volume, universal gas constant, temperature, number of moles in the vessel, gas mass in the vessel and the molecular weight of the gas in the vessel respectively. **a** and **b** are constants depending on the gas composition.

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

Equation 3-3 : Van der Waals equation **[30]**

Let $n = \frac{m}{M}$

$$\frac{-b}{M}\frac{dm}{dt}\left(P+\frac{am^2}{V^2M^2}\right)+\left(\frac{dP}{dt}+\frac{2a}{V^2M}\frac{dm}{dt}\right)\left(V-\frac{m}{M}b\right)=\frac{RT}{M}\frac{dm}{dt}$$

Equation 3-4

3.5. Developing the model

3.5.1. Considering the F vessel

Using the Van der Waals equation for Vessel F,

$$\frac{dm_1}{dt}+\frac{dm_{i1}}{dt}+\frac{dm_{LPGF}}{dt}-\frac{dm_2}{dt}-\frac{dm_3}{dt} = \frac{-\frac{dP_F}{dt}\left(V_F-\frac{m_F}{M}b\right)}{\frac{-b}{M}\left(P_F+\frac{am_F{}^2}{V_F{}^2M^2}\right)+\frac{2a}{V_F{}^2M^2}\left(V_F-\frac{m_F}{M}b\right)-\frac{RT_F}{M}}$$

Equation 3-5

The mass balance in vessel F,

$$\frac{dm_1}{dt}+\frac{dm_{i1}}{dt}+\frac{dm_{LPGF}}{dt}-\frac{dm_2}{dt}-\frac{dm_3}{dt}=\frac{\mathbf{dm_F}}{\mathbf{dt}}$$

Equation 3-6

3.5.2. Considering the gas vessel i

Using the Van der Waals equation for Vessel i,

$$\frac{dm_{i3}}{dt}+\frac{dm_{i\_buff\_out}}{dt}+\frac{dm_{LPG\_i}}{dt}-\frac{dm_{i1}}{dt}-\frac{dm_{i2}}{dt} = \frac{-\frac{dP_i}{dt}\left(V_i-\frac{m_i}{M}b\right)}{\frac{-b}{M}\left(P_i+\frac{am_i{}^2}{V_i{}^2M^2}\right)+\frac{2a}{V_i{}^2M^2}\left(V_i-\frac{m_i}{M}b\right)-\frac{RT_i}{M}}$$

Equation 3-7

The mass balance in vessel i,

$$\frac{dm_{i3}}{dt}+\frac{dm_{i\_buff\_out}}{dt}+\frac{dm_{LPG\_i}}{dt}-\frac{dm_{i1}}{dt}-\frac{dm_{i2}}{dt}=\frac{\mathbf{dm_i}}{\mathbf{dt}}$$

Equation 3-8

3.5.3. Considering the FG vessel

Using the Van der Waals equation for Vessel FG,

$$\frac{dm_{i2}}{dt} - \frac{dm_j}{dt} + \frac{dm_{LPGFG}}{dt} - \frac{dm_{cv7}}{dt} = \frac{-\frac{dP_{FG}}{dt}\left(V_{FG} - \frac{m_{FG}}{M}b\right)}{\frac{-b}{M}\left(P_{FG} + \frac{am_{FG}{}^2}{V_{FG}{}^2M^2}\right) + \frac{2a}{V_{FG}{}^2M^2}\left(V_{FG} - \frac{m_{FG}}{M}b\right) - \frac{RT_{FG}}{M}}$$

Equation 3-9

The mass balance in vessel FG,

$$\frac{dm_{i2}}{dt} - \frac{dm_j}{dt} + \frac{dm_{LPGFG}}{dt} - \frac{dm_{cv7}}{dt} = \frac{\mathbf{dm_{FG}}}{\mathbf{dt}}$$

Equation 3-10

3.5.4. Considering the Buff vessel

Using the Van der Waals equation for Vessel Buff,

$$\frac{dm_{i\_buff\_in}}{dt} - \frac{dm_{i\_buff\_out}}{dt} + \frac{dm_{LPGbu}}{dt} - \frac{dm_{cv6}}{dt} = \frac{-\frac{dP_{bu}}{dt}\left(V_{FG} - \frac{m_{bu}}{M}b\right)}{\frac{-b}{M}\left(P_{bu} + \frac{am_{bu}{}^2}{V_{bu}{}^2M^2}\right) + \frac{2a}{V_{bu}{}^2M^2}\left(V_{bu} - \frac{m_{bu}}{M}b\right) - \frac{RT_{bu}}{M}}$$

Equation 3-11

The mass balance in vessel Buff,

$$\frac{dm_{i\_buff\_in}}{dt} - \frac{dm_{i\_buff\_out}}{dt} + \frac{dm_{LPGbu}}{dt} - \frac{dm_{cv6}}{dt} = \frac{\mathbf{dm_{bu}}}{\mathbf{dt}}$$

Equation 3-12

3.5.5. Flow i1

Mass flow via CV1, based on pressure difference across the pipe segment, either 0 or as below depends on the set value of P_F

$$\frac{dm_{i1}}{dt} = A\rho_g \left(\frac{T_{b-i1}}{P_{b-i1}}\right) \sqrt{\frac{\left(P_i^{\ 2} - P_F^{\ 2}\right) D_{i1}^{\ 5}}{G_{i1} T_{f-i1} L_{i1} Z_{i1} f_{i1}}}$$

Equation 3-13

3.5.6. Flow 2

Gas flow for energy recovery obtained based on the pressure difference across the pipe

$$\frac{dm_2}{dt} = A\rho_g \left(\frac{T_{b-2}}{P_{b-2}}\right) \sqrt{\frac{\left(P_F^{\ 2} - P_0^{\ 2}\right) D_2^{\ 5}}{G_2 T_{f-2} L_2 Z_2 f_2}}$$

Equation 3-14

3.5.7. Flow 3

Mass flow to flare via CV3, based on pressure difference across the pipe segment, either 0 or as below depends on the set value of P_F

$$\frac{dm_3}{dt} = A\rho_g \left(\frac{T_{b-3}}{P_{b-3}}\right) \sqrt{\frac{\left(P_F^{\ 2} - P_0^{\ 2}\right) D_3^{\ 5}}{G_3 T_{f-3} L_3 Z_3 f_3}}$$

Equation 3-15

3.5.8. Flow i2

Mass flow to FG via CV8 from Vessel i, based on pressure difference across the pipe segment, either 0 or as below depends on the set value of P_{FG}

$$\frac{dm_{i2}}{dt} = A\rho_g \left(\frac{T_{b-i2}}{P_{b-i2}}\right) \sqrt{\frac{\left(P_i^{\ 2} - P_{FG}^{\ 2}\right) D_{i2}^{\ 5}}{G_{i2} T_{f-i2} L_{i2} Z_{i2} f_{i2}}}$$

Equation 3-16

3.5.9. Flow LPG_F

Mass flow to F via CV11, from LPG pressure based on pressure difference across the pipe segment, either 0 or as below depends on the set value of P_F

$$\frac{dm_{LPGF}}{dt} = A\rho_{g-LPGF}\left(\frac{T_{b-LPGF}}{P_{b-LPGF}}\right)\sqrt{\frac{\left(P_{LPG}{}^{2} - P_{F}{}^{2}\right)D_{LPGF}\ F^{5}}{G_{LPGF}T_{f-LPGF}L_{LPGF}Z_{LPGF}f_{LPGF}}}$$

Equation 3-17

3.5.10. Flow LPG_FG

Mass flow to FG via CV10, from LPG pressure based on pressure difference across the pipe segment, either 0 or as below depends on the set value of P_{FG}

$$\frac{dm_{LPGFG}}{dt} = A\rho_{g-LPGFG}\left(\frac{T_{b-LPGFG}}{P_{b-LPGFG}}\right)\sqrt{\frac{\left(P_{LPG}{}^{2} - P_{FG}{}^{2}\right)D_{LPGFG}\ F^{5}}{G_{LPGFG}T_{f-LPGFG}L_{LPGFG}Z_{LPGFG}f_{LPGFG}}}$$

Equation 3-18

3.5.11. Flow LPG_i

Mass flow to i via CV5, from LPG pressure based on pressure difference across the pipe segment, either 0 or as below depends on the set value of P_i

$$\frac{dm_{LPGi}}{dt} = A\rho_{g-LPGi}\left(\frac{T_{b-LPGi}}{P_{b-LPGi}}\right)\sqrt{\frac{\left(P_{LPG}{}^{2} - P_{F}{}^{2}\right)D_{LPGi}\ F^{5}}{G_{LPGi}T_{f-LPGi}L_{LPGi}Z_{LPGi}f_{LPGi}}}$$

Equation 3-19

3.5.12. Flow LPG_bu

Mass flow to F via CV9, from LPG pressure based on pressure difference across the pipe segment, either 0 or as below depends on the set value of P_{bu}

$$\frac{dm_{LPGbu}}{dt} = A\rho_{g-LPGbu}\left(\frac{T_{b-LPGbu}}{P_{b-LPGbu}}\right)\sqrt{\frac{\left(P_{LPG}{}^{2} - P_{F}{}^{2}\right)D_{LPGbu}\ F^{5}}{G_{LPGbu}T_{f-LPGbu}L_{LPGbu}Z_{LPGbu}f_{LPGbu}}}$$

Equation 3-20

3.5.13. Flow j

Gas flow for process heaters obtained based on the pressure difference across the pipe

$$\frac{dm_j}{dt} = A\rho_{g-j}\left(\frac{T_{b-j}}{P_{b-j}}\right)\sqrt{\frac{\left(P_{FG}{}^2 - P_0{}^2\right)D_j{}^5}{G_j T_{f-j} L_j Z_j f_j}}$$

Equation 3-21

3.5.14. Flow i_Buff_out

Gas flow from the buff vessel obtained based on the pressure difference across the pipe

$$\frac{dm_{i\_Buff\_out}}{dt} = A\rho_{g-i\_Buff\_out}\left(\frac{T_{b-i\_Buff\_out}}{P_{b-i\_Buff\_out}}\right)\sqrt{\frac{\left(P_{i\_Buff\_out}{}^2 - P_i{}^2\right)D_{i\_Buff\_out}{}^5}{G_{i\_Buff\_out} T_{f-i\_Buff\_out} L_{i\_Buff\_out} Z_{i\_Buff\_out} f_{i\_Buff\_out}}}$$

Equation 3-22

3.5.15. Flow i_Buff_in

Flow direction depends on the availability of gas in vessel i for the gas network operation

For all $P_i > P_{i\_set}$

$$\frac{dm_{i\_Buff\_in}}{dt} = \frac{dm_{i3}}{dt}$$

Equation 3-23

Otherwise

$$\frac{dm_{i\_Buff\_in}}{dt} = 0$$

Equation 3-24

3.6. Controlling actions. (Constraints for solving the equations)

For controlling action all the equations in chapter 3.6 are based on Equation 3-1 to Equation 3-24.

3.6.1. Stage 1

Let P_a, P_b, P_c and P_d are defined as a pressure reduction that can minimally affect the mass flow patterns expect from the F and FG vessels. Only the variables having its constraints other than time are stated in chapter 3.6. Here the vessel F pressure is maintained in line with the set pressure of vessel F by introducing the gases from vessel i. LPG or natural gas flow is introduced based on the availability of gases in vessel i and it is introduced in a way that vessel F pressure goes slightly below than the set pressure of vessel F to avoid excess LPG or natural gas intake due to pressure variations in the F vessel. Other than that if the vessel set pressure exceeds the gases in side, it will go to the blow down system (flare system) and all the gas supplies either from LPG, natural gas or from the vessel i will become zero. So that a specified value of gas output from F vessel for power generation can be taken out.

For all $P_F \leq P_{F\text{-set}}$

$$\frac{dm_{i1}}{dt} = A\rho_g \left(\frac{T_{b-i1}}{P_{b-i1}}\right) \sqrt{\frac{(P_i^2 - P_F^2) D_{i1}^5}{G_{i1} T_{f-i1} L_{i1} Z_{i1} f_{i1}}}$$

$$\frac{dm_3}{dt} = 0$$

For all $P_F \leq P_{design}$ and $P_F \leq (P_{design} - P_a)$

$$\frac{dm_{LPG}}{dt} = A\rho_g \left(\frac{T_{b-i1}}{P_{b-i1}}\right) \sqrt{\frac{(P_i^2 - P_F^2) D_{i1}^5}{G_{i1} T_{f-i1} L_{i1} Z_{i1} f_{i1}}}$$

For all $P_F \leq P_{design}$ and $P_F > (P_{design} - P_a)$

$$\frac{dm_{LPG}}{dt} = 0$$

For all $P_F > P_{design}$

$$\frac{dm_{i1}}{dt} = 0$$

$$\frac{dm_{LPG}}{dt} = 0$$

For all $P_F > P_{F\text{-set}}$ and $P_F > (P_{F\text{-set}} + P_a)$

$$\frac{dm_3}{dt} = A\rho_g\left(\frac{T_{b-i1}}{P_{b-i1}}\right)\sqrt{\frac{\left(P_i{}^2 - P_F{}^2\right)D_{i1}{}^5}{G_{i1}T_{f-i1}L_{i1}Z_{i1}f_{i1}}}$$

For all $P_F > P_{F\text{-set}}$ and $P_F < (P_{F\text{-set}} + P_a)$

$$\frac{dm_3}{dt} = 0$$

3.6.2. Stage 2

The situation is same for the vessel FG. The set pressure of vessel FG is controlled by the gas intake from the vessel i. On the other hand LPG or natural gas supply is set to the vessel FG in order to regulate pressure with lack of availability of gases in vessel i. Here also the LPG or natural gas intake pressure of the vessel FG is set slightly below the set pressure of vessel F to avoid excess gas usage due to pressure fluctuations around set pressure of vessel FG in dynamic conditions. Other than that the excess gases that exceed the set pressure of vessel FG will be blown down to the flare system and on that time all gas supplies will be stopped. So that a constant pressure can be maintained in the vessel FG and a desired gas flow out from it can be achieved to the process heaters.

For all $P_{FG} \leq P_{FG\text{-set}}$

$$\frac{dm_{i2}}{dt} = A\rho_g\left(\frac{T_{b-i1}}{P_{b-i1}}\right)\sqrt{\frac{\left(P_i^{\,2} - P_F^{\,2}\right)D_{i1}^{\,5}}{G_{i1}T_{f-i1}L_{i1}Z_{i1}f_{i1}}}$$

$$\frac{dm_{cv7}}{dt} = 0$$

For all $P_{FG} \leq P_{FG\text{-set}}$ and $P_{FG} \leq (P_{FG\text{-set}} - P_b)$

$$\frac{dm_{LPGFG}}{dt} = A\rho_g\left(\frac{T_{b-i1}}{P_{b-i1}}\right)\sqrt{\frac{\left(P_i^{\,2} - P_F^{\,2}\right)D_{i1}^{\,5}}{G_{i1}T_{f-i1}L_{i1}Z_{i1}f_{i1}}}$$

For all $P_{FG} \leq P_{FG\text{-set}}$ and $P_{FG} > (P_{FG\text{-set}} - P_b)$

$$\frac{dm_{LPGFG}}{dt} = 0$$

For all $P_{FG} > P_{FG\text{-set}}$

$$\frac{dm_{i2}}{dt} = 0$$

$$\frac{dm_{LPGFG}}{dt} = 0$$

For all $P_{FG} > P_{FG\text{-set}}$ and $P_{FG} > (P_{FG\text{-set}} + P_b)$

$$\frac{dm_{cv7}}{dt} = A\rho_g\left(\frac{T_{b-i1}}{P_{b-i1}}\right)\sqrt{\frac{\left(P_i^{\,2} - P_F^{\,2}\right)D_{i1}^{\,5}}{G_{i1}T_{f-i1}L_{i1}Z_{i1}f_{i1}}}$$

For all $P_{FG} > P_{FG\text{-set}}$ and $P_{FG} < (P_{FG\text{-set}} + P_b)$

$$\frac{dm_{cv7}}{dt} = 0$$

3.6.3. Stage 3

This is to regulate the pressure of the vessel i to maintain an smooth operation in vessel F and vessel FG. Here the vessel is fed with a gas stream from the process having the pressure above or similar to the set pressure of the vessel i. If the gas exceeds the set pressure of the vessel i, the control system directs the gases from the plant to the buffer vessel. If the pressure drops slightly below the set pressure that is set to avoid excess usage of natural gas, an extra gas input from the outside will be taken in. Depending on the pressure set to the vessel this gas can be natural gas or LPG.

For all $P_i \leq P_{i\text{-set}}$

$$\frac{dm_{ibuffout}}{dt} = A\rho_g\left(\frac{T_{b-i1}}{P_{b-i1}}\right)\sqrt{\frac{\left(P_i^{\,2} - P_F^{\,2}\right)D_{i1}^{\,5}}{G_{i1}T_{f-i1}L_{i1}Z_{i1}f_{i1}}}$$

For all $P_i \leq P_{i\text{-set}}$ and $P_i \leq (P_{i\text{-set}} - P_c)$

$$\frac{dm_{LPGi}}{dt} = A\rho_g\left(\frac{T_{b-i1}}{P_{b-i1}}\right)\sqrt{\frac{\left(P_i^{\,2} - P_F^{\,2}\right)D_{i1}^{\,5}}{G_{i1}T_{f-i1}L_{i1}Z_{i1}f_{i1}}}$$

For all $P_i \leq P_{i\text{-set}}$ and $P_i > (P_{i\text{-set}} - P_c)$

$$\frac{dm_{LPGi}}{dt} = 0$$

For all $P_i > P_{i\text{-set}}$

$$\frac{dm_{ibuffout}}{dt} = A\rho_g\left(\frac{T_{b-i1}}{P_{b-i1}}\right)\sqrt{\frac{\left(P_i^{\,2} - P_F^{\,2}\right)D_{i1}^{\,5}}{G_{i1}T_{f-i1}L_{i1}Z_{i1}f_{i1}}}$$

$$\frac{dm_{LPGi}}{dt} = 0$$

3.6.4. Stage 4

The buffer vessel is set to collect excess gases that are not been able to collect in the vessel i. Here also a set pressure is proposed to avoid the variations of the pressures in the system. Other than that a natural gas of LPG supply depending on the pressures set, is introduced to regulate the pressure set in the buffer vessel. On the other hand the excess gas collected in the vessel is directed to the flare system to avoid over pressurizing the vessel than the pressure set.

For all $P_{bu} \leq P_{bu\text{-}set}$

$$\frac{dm_{cv6}}{dt} = 0$$

For all $P_{bu} \leq P_{bu\text{-}set}$ and $P_{bu} \leq (P_{bu\text{-}set} - P_d)$

$$\frac{dm_{LPGbu}}{dt} = A\rho_g \left(\frac{T_{b-i1}}{P_{b-i1}}\right) \sqrt{\frac{(P_i{}^2 - P_F{}^2) D_{i1}{}^5}{G_{i1} T_{f-i1} L_{i1} Z_{i1} f_{i1}}}$$

For all $P_{bu} \leq P_{bu\text{-}set}$ and $P_{bu} > (P_{bu\text{-}set} - P_d)$

$$\frac{dm_{LPGbu}}{dt} = 0$$

For all $P_{bu} > P_{bu\text{-}set}$

$$\frac{dm_{LPGbu}}{dt} = 0$$

For all $P_{bu} > P_{bu\text{-}set}$ and $P_{FG} > (P_{bu\text{-}set} + P_d)$

$$\frac{dm_{cv6}}{dt} = A\rho_g \left(\frac{T_{b-i1}}{P_{b-i1}}\right) \sqrt{\frac{(P_i{}^2 - P_F{}^2) D_{i1}{}^5}{G_{i1} T_{f-i1} L_{i1} Z_{i1} f_{i1}}}$$

For all $P_{bu} > P_{bu\text{-}set}$ and $P_{FG} < (P_{bu\text{-}set} + P_d)$

$$\frac{dm_{cv6}}{dt} = 0$$

3.6.5. Stage 5

This is the behavior of the pressures of vessels, masses collected in those vessels in set volumes, input flows and output flows. Other than that the condition is set to direct the gas flow from the plant to vessel i, and if the pressure of vessel i is below the set pressure of vessel i, and the gas flow to vessel buff, if the vessel i pressure is reached to the set pressure of vessel i.

For all $P_i \leq P_{i\text{-}set}$

$$\frac{dm_{i3}}{dt} + \frac{dm_{i\_buff\_out}}{dt} + \frac{dm_{LPG\_i}}{dt} - \frac{dm_{i1}}{dt} - \frac{dm_{i2}}{dt} = \frac{-\frac{dP_i}{dt}\left(V_i - \frac{m_i}{M}b\right)}{\frac{-b}{M}\left(P_i + \frac{am_i^2}{V_i^2M^2}\right) + \frac{2a}{V_i^2M^2}\left(V_i - \frac{m_i}{M}b\right) - \frac{RT_i}{M}}$$

$$\frac{dm_{i3}}{dt} + \frac{dm_{i\_buff\_out}}{dt} + \frac{dm_{LPG\_i}}{dt} - \frac{dm_{i1}}{dt} - \frac{dm_{i2}}{dt} = \frac{\mathbf{dm_i}}{\mathbf{dt}}$$

$$\frac{dm_{LPGbu}}{dt} - \frac{dm_{i_{buff_{out}}}}{dt} - \frac{dm_{cv6}}{dt} = \frac{-\frac{dP_{bu}}{dt}\left(V_i - \frac{m_i}{M}b\right)}{\frac{-b}{M}\left(P_i + \frac{am_i^2}{V_i^2M^2}\right) + \frac{2a}{V_i^2M^2}\left(V_i - \frac{m_i}{M}b\right) - \frac{RT_i}{M}}$$

$$\frac{dm_{LPGbu}}{dt} - \frac{dm_{i_{buff_{out}}}}{dt} - \frac{dm_{cv6}}{dt} = \frac{\mathbf{dm_{bu}}}{\mathbf{dt}}$$

For all $P_i > P_{i\text{-}set}$

$$\frac{dm_{i\_buff\_out}}{dt} + \frac{dm_{LPG\_i}}{dt} - \frac{dm_{i1}}{dt} - \frac{dm_{i2}}{dt} = \frac{-\frac{dP_i}{dt}\left(V_i - \frac{m_i}{M}b\right)}{\frac{-b}{M}\left(P_i + \frac{am_i^2}{V_i^2M^2}\right) + \frac{2a}{V_i^2M^2}\left(V_i - \frac{m_i}{M}b\right) - \frac{RT_i}{M}}$$

$$\frac{dm_{i\_buff\_out}}{dt} + \frac{dm_{LPG\_i}}{dt} - \frac{dm_{i1}}{dt} - \frac{dm_{i2}}{dt} = \frac{\mathbf{dm_i}}{\mathbf{dt}}$$

$$\frac{dm_{i3}}{dt} - \frac{dm_{i\_buff\_out}}{dt} + \frac{dm_{LPGbu}}{dt} - \frac{dm_{cv6}}{dt} = \frac{-\frac{dP_{bu}}{dt}\left(V_i - \frac{m_i}{M}b\right)}{\frac{-b}{M}\left(P_i + \frac{am_i{}^2}{V_i{}^2M^2}\right) + \frac{2a}{V_i{}^2M^2}\left(V_i - \frac{m_i}{M}b\right) - \frac{RT_i}{M}}$$

$$\frac{dm_{i3}}{dt} - \frac{dm_{i\_buff\_out}}{dt} + \frac{dm_{LPGbu}}{dt} - \frac{dm_{cv6}}{dt} = \frac{\mathbf{dm_{bu}}}{\mathbf{dt}}$$

CHAPTER 4 : DYNAMIC SIMULATION

The above mentioned methodology is solved, within the constraints in chapter 3.6 and initial conditions defined in chapter 4.1, using MATLAB.

4.1. Initial Conditions

Mass Flow 1 - Flare gas flow

This was taken into 3 cases observed in practical to demonstrate the extreme conditions that the system has to face.

- Case 1 - When gas flow fluctuate heavily with in the upper limit and the lower limit set
- Case 2 - When flare gas flow is 0
- Case 2 - As a sin wave coinciding the flow i3
- Case 3 - As a cosine wave coinciding the flow i3

Mass Flow i3 - Fuel gas from the process

- Case 1 - When gas flow fluctuate heavily with in the upper limit and the lower limit set
- Case 2 - When i3 gas flow is 0
- Case 2 - As a sin wave coinciding the flow1
- Case 3 - As a cosine wave coinciding the flow1

4.1.1. Initial set pressure conditions

All the pressure values were selected according to the generated gas pressures from the process. All the pressure values are gauge pressures.

P_F - 5 bar

P_{FG} - 3 bar

P_i - 18 bar

P_{Buff} - 18 bar

P_0 - 0

$P_{make\text{-}up}$ - 20 bar

4.1.2. Initial gas masses in vessels

All the values are calculated based on the gas properties and the initial set pressures.

m_F - 129.69 kg

m_{FG} - 77.81 kg

m_i - 466.89 kg

m_{bu} - 466.89 kg

All the vessel volumes were taken as 15 m^3 for reference purpose

4.1.3. Properties of pipes

Pipe diameters are set considering the maximum possible flow that can occur

Table 4-1 : Pipe diameters

Pipe connecting vessels	**Flow**	**Diameter - mm**
Vessel i and Vessel F	dmi1dt	73
Out from vessel F	dm3dt	65
Into vessel F	dmLPGFdt	225
Vessel i and Vessel FG	dmi2dt	200
Into vessel FG	dmLPGFGdt	225
Out from vessel FG	dmcv7dt	117
Vessel i and Vessel Buff	dmibuffoutdt	507
Into vessel i	dmLPGidt	225
Into vessel Buff	dmLPGbudt	225
Out from vessel Buff	dmcv6dt	217
Out from vessel FG	dmjdt	110
Out from vessel F	dm2dt	65

Following parameters were taken same for all pipe segments for comparison purpose

f, friction factor	=	0.03
T_b, base temperature	=	313 K
G, gas gravity	=	1.2
T_f, average gas flowing temperature	=	313K
L, pipe segment length	=	0.05 km
Z, gas compressibility factor	=	0.05
a, Van der Waals coefficient for the gas mix	=	0.75
b, Van der Waals coefficient for the gas mix	=	0

4.2. Results

Results were taken from the MATLAB program written based on the above methodology with the initial condition and the cases described in chapter 4.1. The MATLAB simulation is included in the attached DVD ROM.

4.3. Heavy fluctuations in gas to flare and gas from the process

Flare gas flow, gas from the process are to be defined according to the actual situation. LPG or natural gas consumptions are calculated based on the pressure reduction in respective vessels. Here due to the heavy variations in the input gas flows both to the vessel i and vessel F, causes to consume natural gas or LPG from outside both to vessel i and vessel buff. Figure 4-1 shows the variation of input parameters and the makeup gas flows to each vessels. Gas flow 1 is set to vary between 200 g/s to 400g/s and flow i3 vary between 500g/s to 1500 g/s. Makeup flow is also fluctuating heavily.

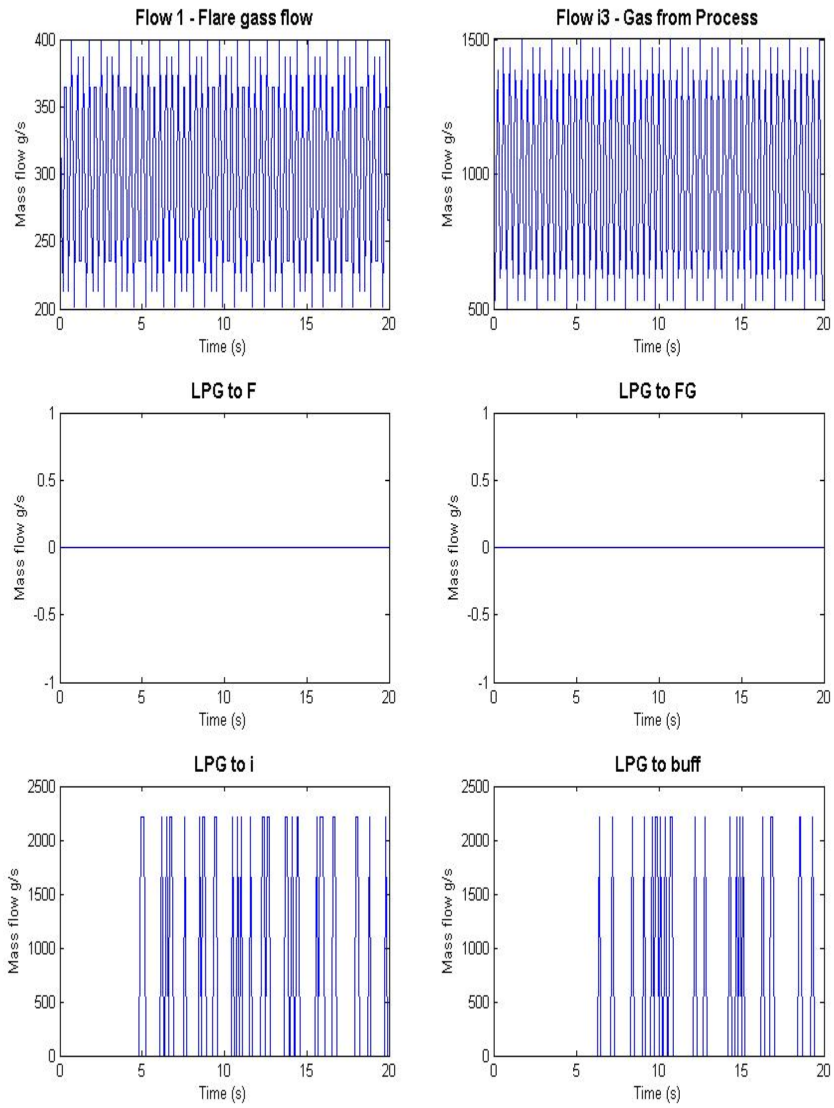

Figure 4-1 : Vessel input parameter variation – Analysis 1

4.3.1. Process parameter variations

Pressure and Mass changes in all 4 vessels are calculated with time. It is important to have steady pressure levels in all the vessels closer to the set values. Here the variation of the pressure in vessel F is in between 5.0002 bar and 4.999 bar, which is an acceptable range for to maintain an steady flow out of the vessel F. Other than that

The Pressure in vessel FG is also in an acceptable range of 2.998 bar and 3.002 bar. The i and buff vessel pressures were dropped to 17.9 bar which is 0.1 bar below the set pressure. However the 0.1 bar drop is previously set to avoid excess usage of LPG or natural gas which will not affect to the desired performance of the system.

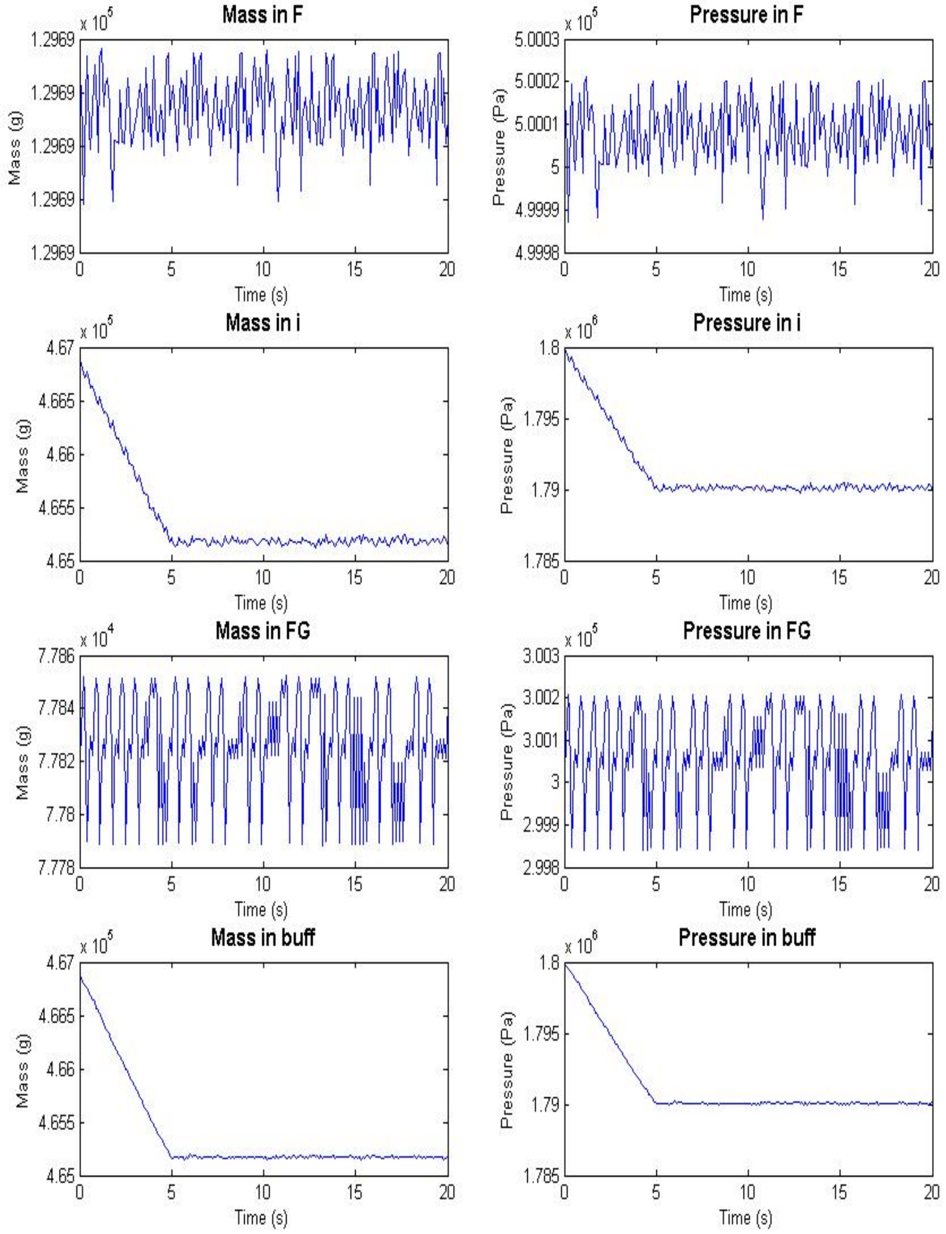

Figure 4-2 : Vessel pressures and mass accumulation variation- Analysis 1

4.3.2. Excess flows from vessels

Excess flows generated will be calculated based on the pressure increases over the set values in vessels. Here no excess flows were detected and all gases were consumed for either to be used in process heaters or to power generation.

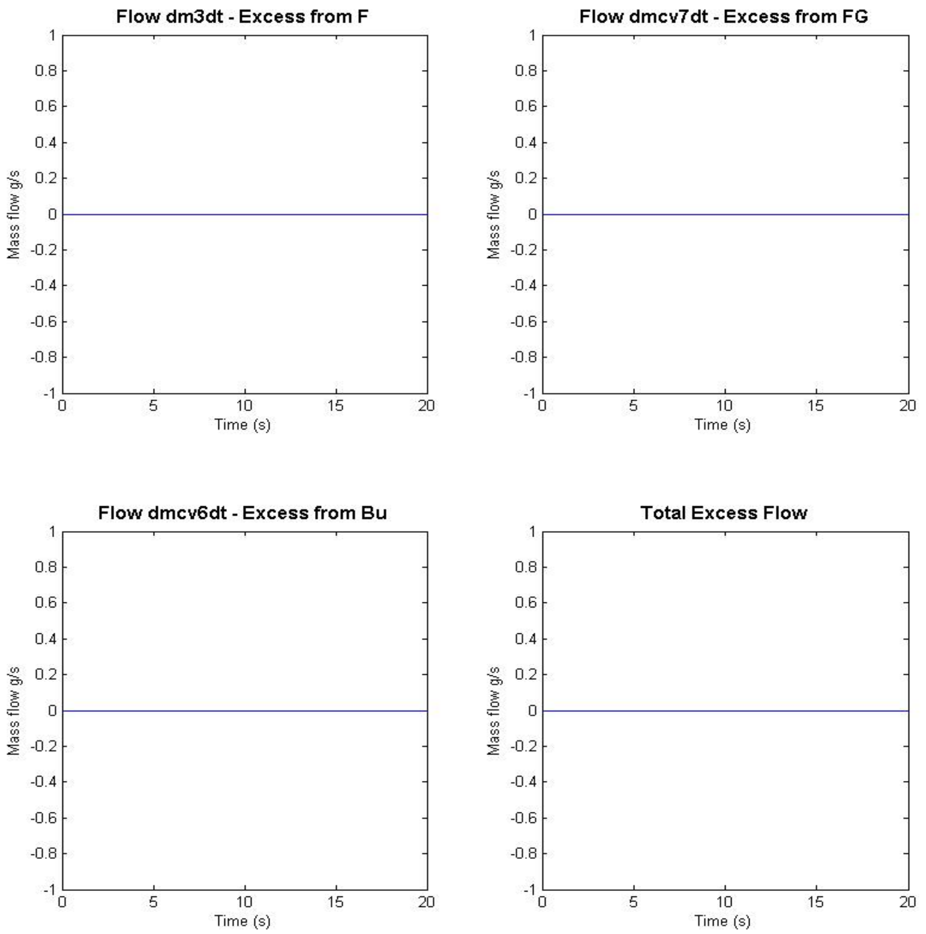

Figure 4-3 : Excess flow generation - Analysis 1

4.3.3. The two main flows to be regulated

The flows are regulated based on pressure differences and the flow rates can be adjusted to the desired values with the changes in pipe diameters. Here the variations are negligible. The desired gas flows can be achieved by adjusting the pipe diameter or the valve positions of the out let gas streams. A flow of 1574 g/s can be taken out to process heaters and a flow of 422 g/s can be taken out of the F vessel for power generation.

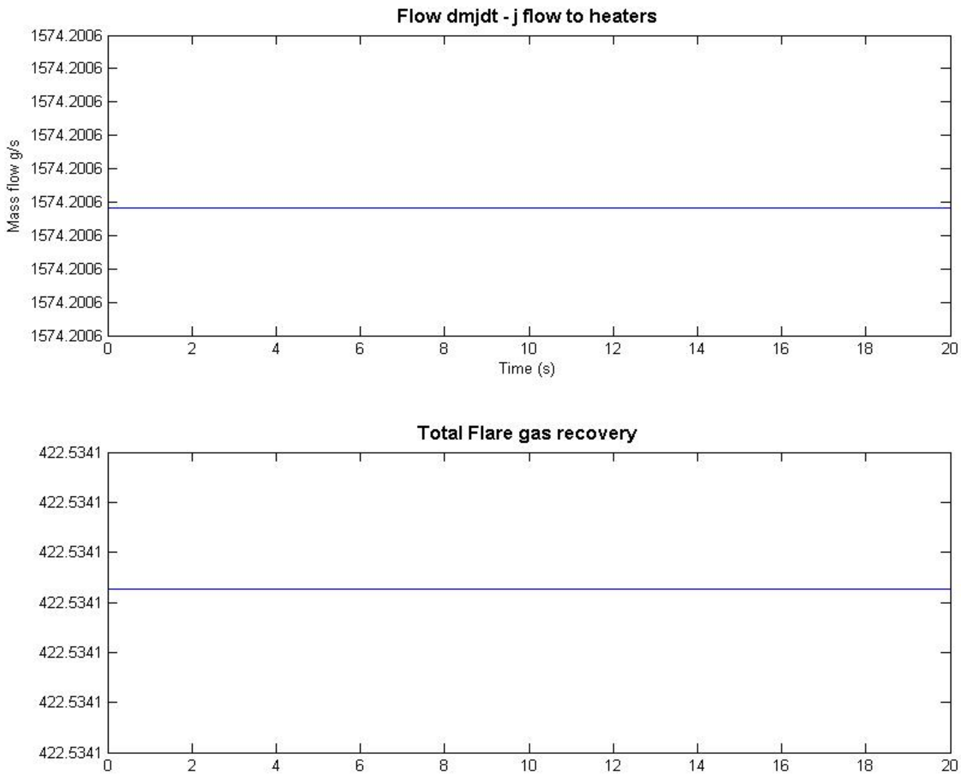

Figure 4-4 : The regulated flows- Analysis 1

4.3.4. Flow 1 and i3 flow rates both are zero

In this situation Both the gas supplies from the process except natural gas or LPG were set to zero, to assess the variations of the pressure in vessels and the gas flows out of the vessels. An increase in natural gas supply was observed in both vessels i and vessel buff than the case of 4.3.3.

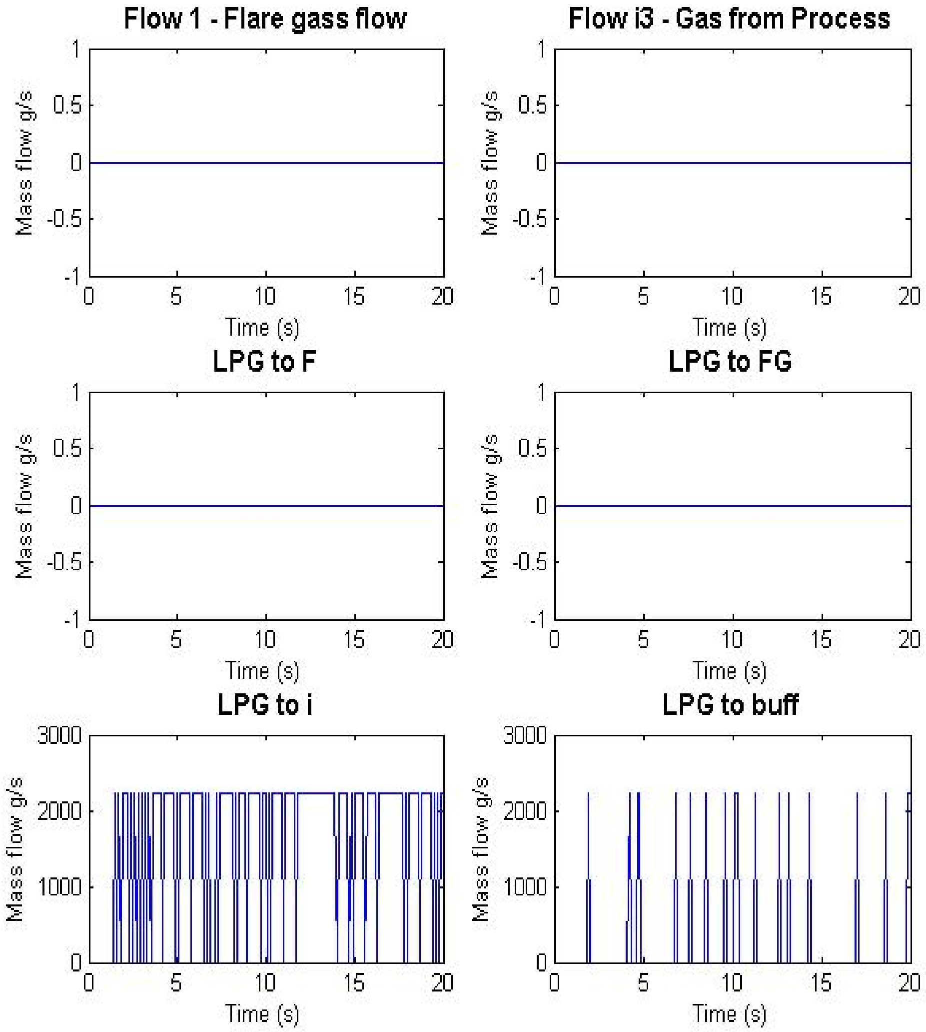

Figure 4-5 : Vessel input parameter variation – Analysis 2

4.3.5. Process parameter variations

The fluctuation of pressure F with time and pressure in vessel FG with time are in acceptable range. As in 4.3.3. the set pressures of vessel i and vessel buff were dropped to 17.9 bar which is also previously set. The pressure variation observed in vessel F fluctuates mostly below the set pressure. This may due to the lack of gas supply from the process and the flare system

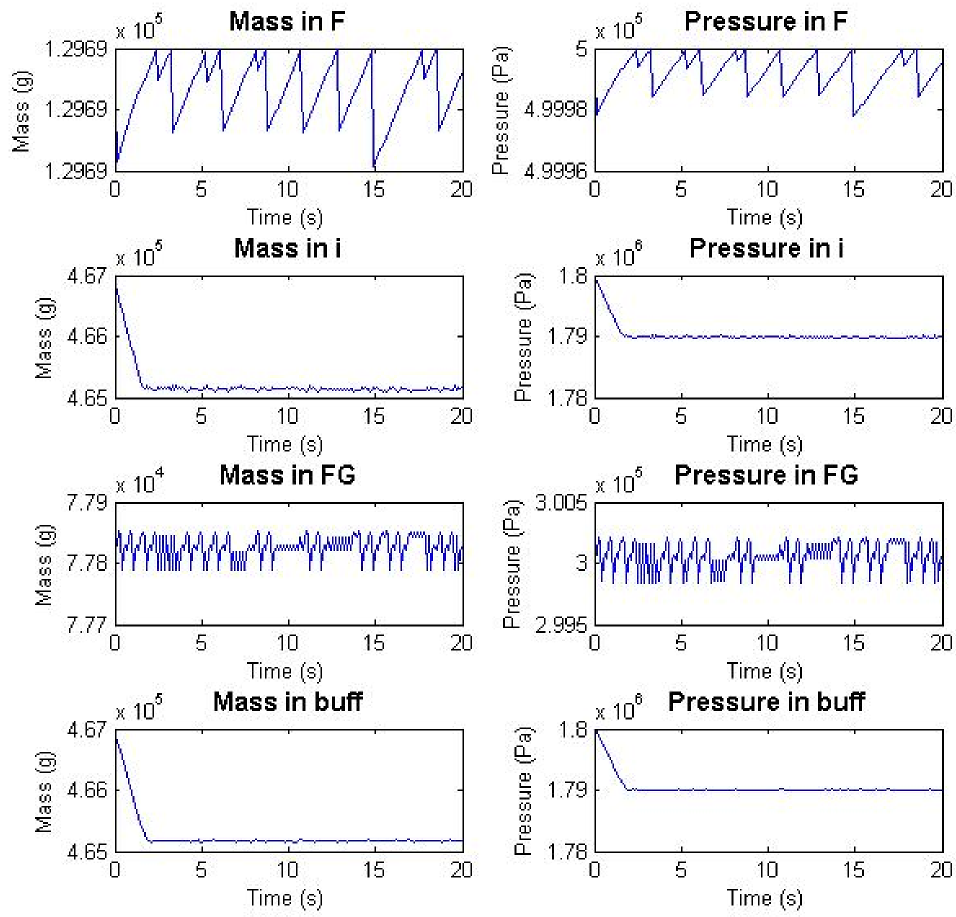

Figure 4-6 : Vessel pressures and mass accumulation variation – Analysis 2

4.3.6. Excess flows from vessels

Excess flows generated will be calculated based on the pressure increases over the set values in vessels. Here no excess flows were detected and all gases were consumed for either to be used in process heaters or to power generation. It is obvious that there is no excess gas, since all the gas required are made up in this case.

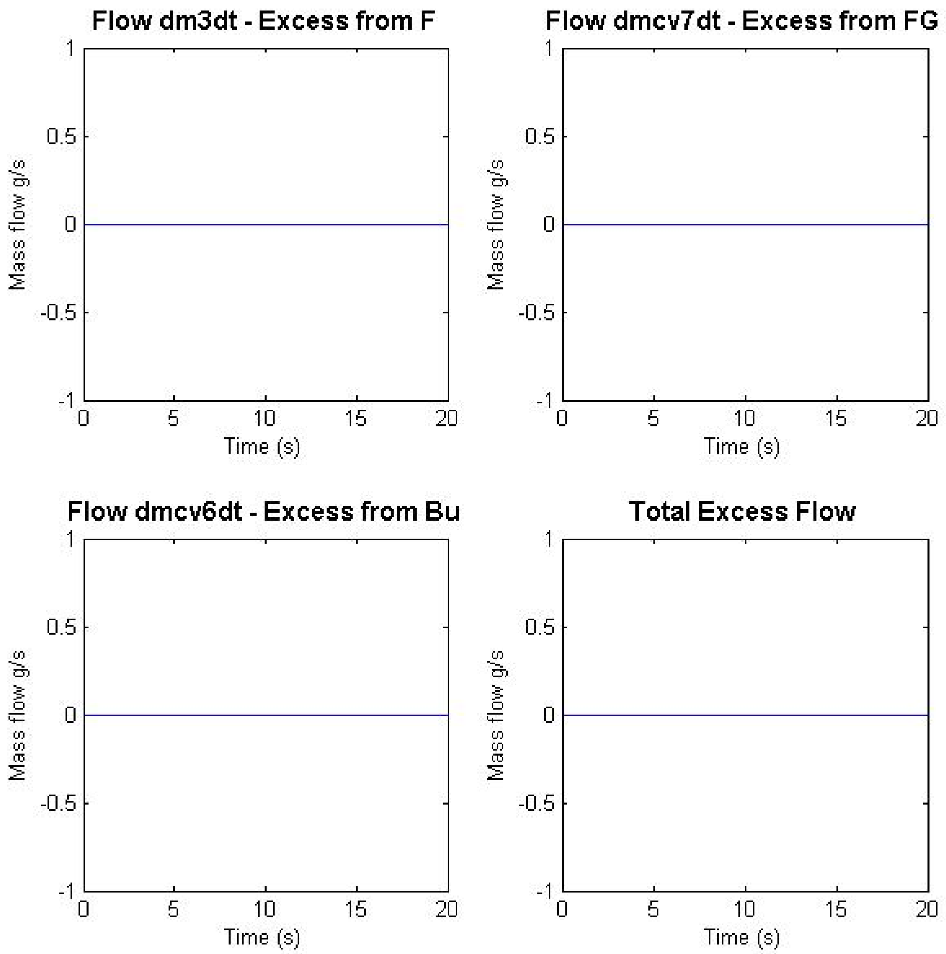

Figure 4-7 : Excess flow generation – Analysis 2

4.3.7. The two main flows to be maintained

Here also, the flows are regulated based on pressure differences and the flow rates can be adjusted to the desired values with the changes in pipe diameters. Here also the variations are negligible. The desired gas flows can be achieved by adjusting the pipe diameter or the valve positions of the out let gas streams. A flow of 1574 g/s can be taken out to process heaters and a flow of 422 g/s can be taken out of F vessel for power generation.

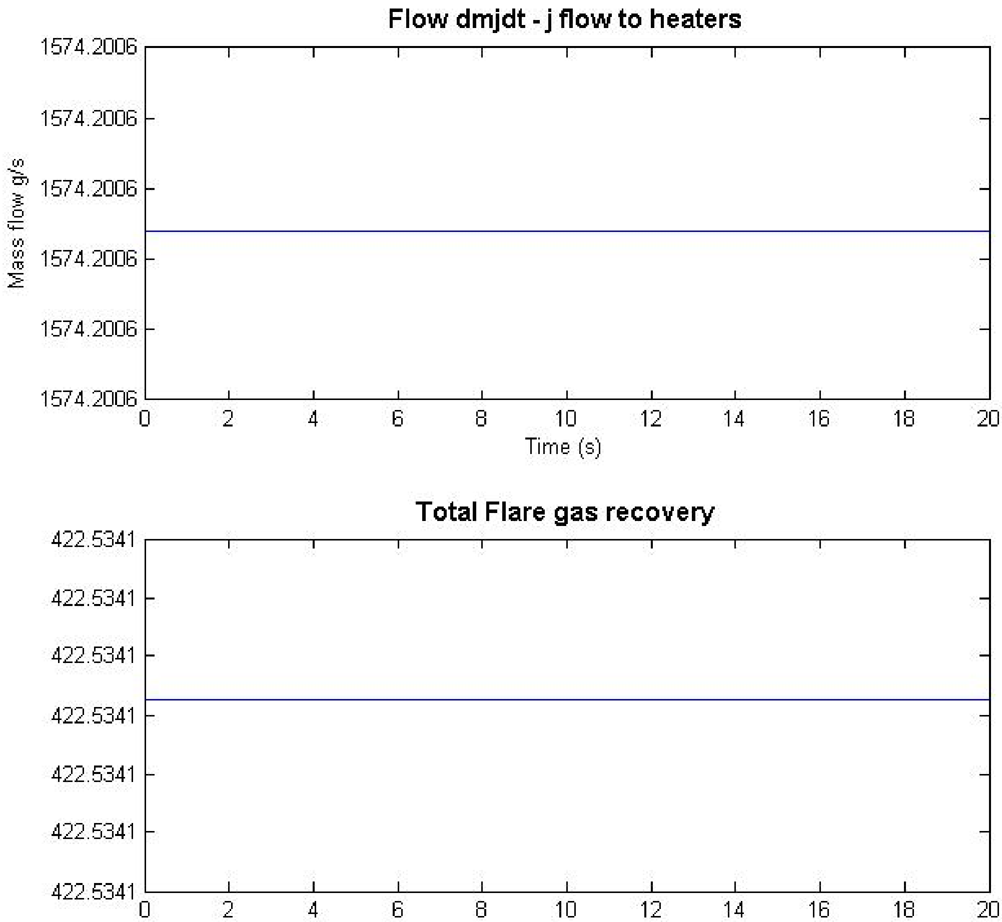

Figure 4-8 : The regulated flows - Analysis 2

4.4. Flow 1 is zero and i3 flow as a sin wave

Here the gas flow to the vessel F, Flare header, was set to zero and the gases from the plant to vessel I or vessel buff is assumed as fluctuating in between 500 g/s and 1500 g/s, in a sinusoidal pattern. The natural gas or LPG consumption is observed in vessel i and vessel buff and no gas makeup gases are detected in vessel F and vessel FG showing perfect regulation of pressure. The objective is introducing a less fluctuating flow than in case 4.1.

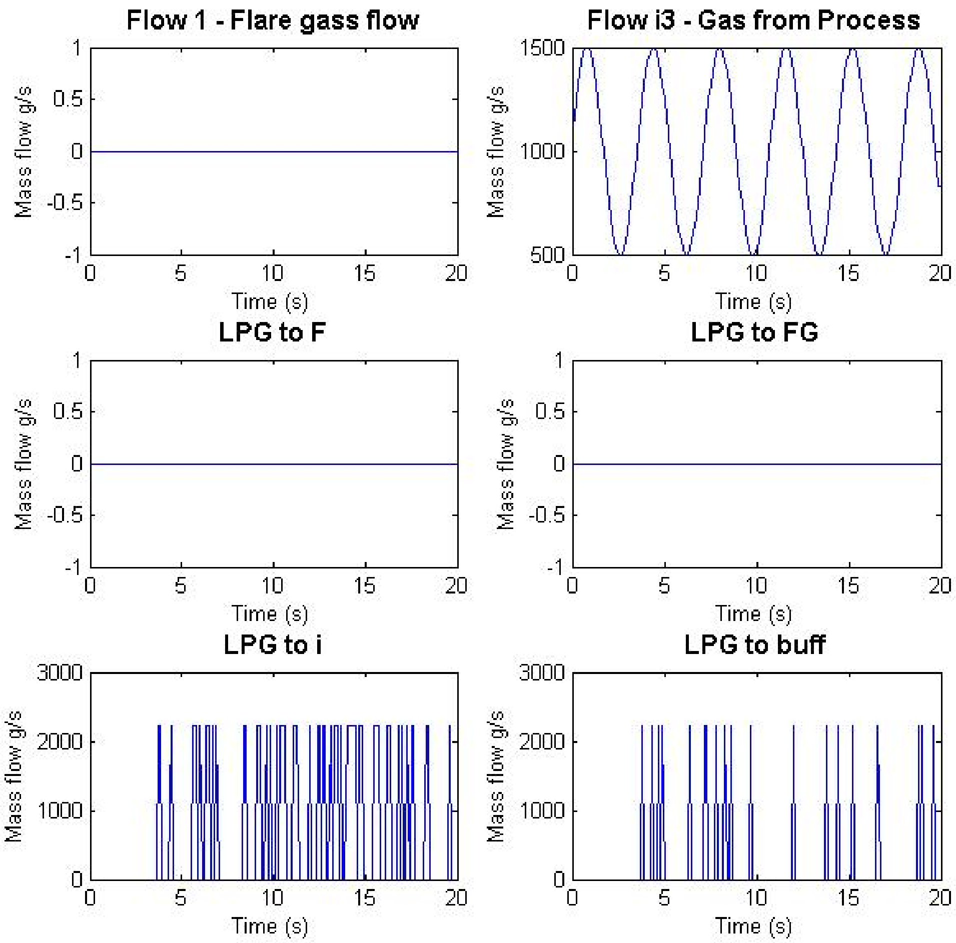

Figure 4-9 : Vessel input parameter variation – Analysis 3

4.4.1. Process parameter variations

Here also the pressure fluctuations of vessel F and vessel FG are in acceptable range where P_F lies between 4.9995 bar and 0005 bar, P_{FG} lies between 2.995 bar and 3.005 bar. Here also vessel i pressure and vessel buff pressure are dropped to 17.9 bar which is also acceptable.

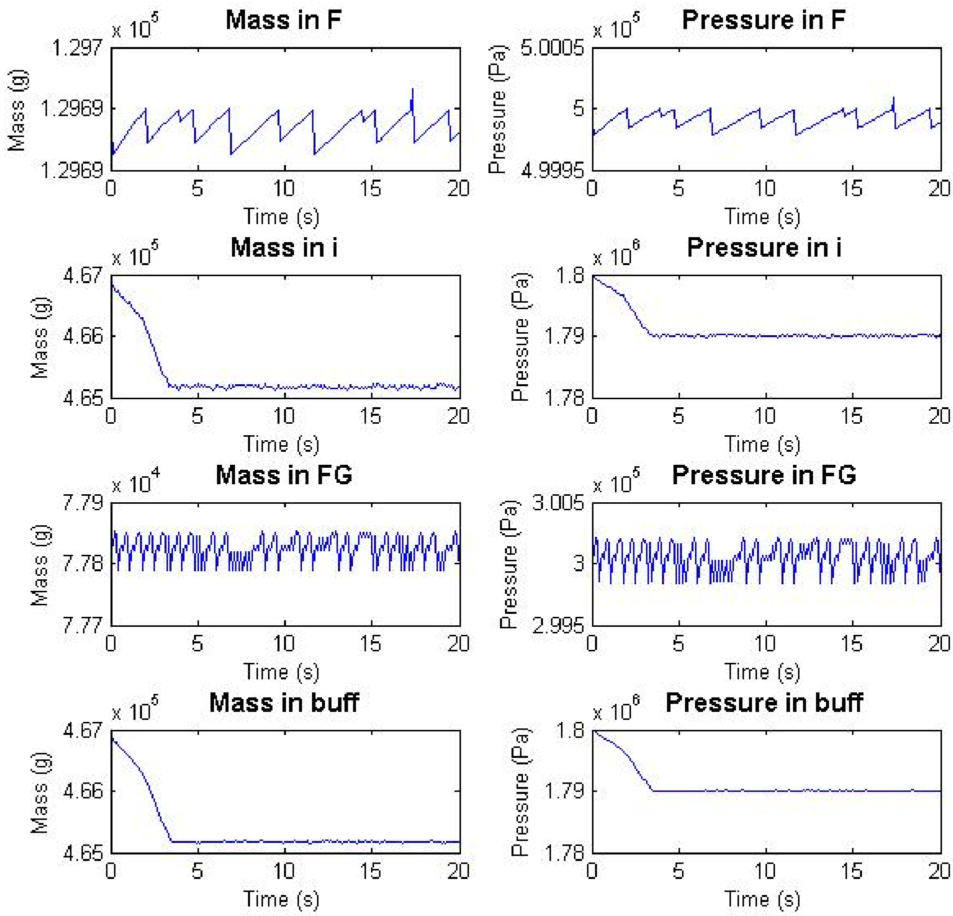

Figure 4-10 : Vessel pressures and mass accumulation variation – Analysis 3

4.4.2. Excess flows from vessels

Here also no excess flows were detected and all gases were consumed for either to be used in process heaters or to power generation. Excess flows generated will be calculated based on the pressure increases over the set values in vessels.

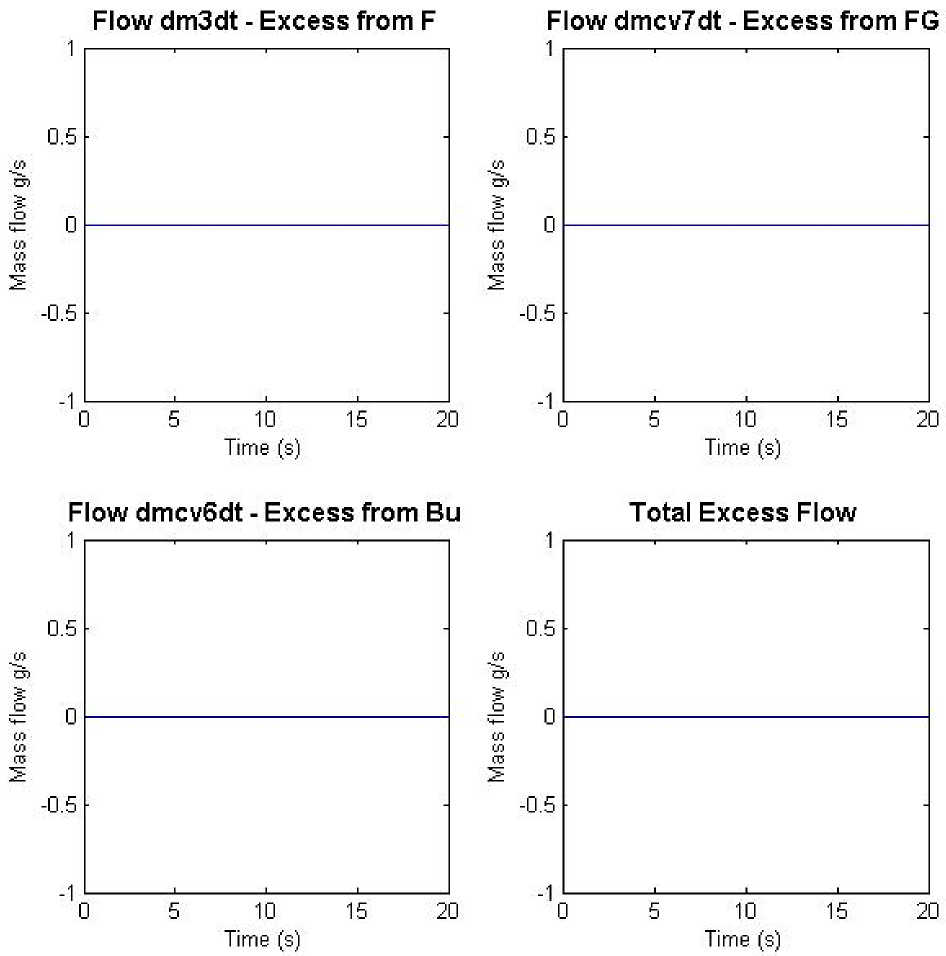

Figure 4-11 : Excess flow generation – Analysis 3

4.4.3. The two main flows to be maintained

Here also, the flows are regulated based on pressure differences and the flow rates can be adjusted to the desired values with the changes in pipe diameters. Here the variations are negligible. The desired gas flows can be achieved by adjusting the pipe diameter or the valve positions of the out let gas streams.

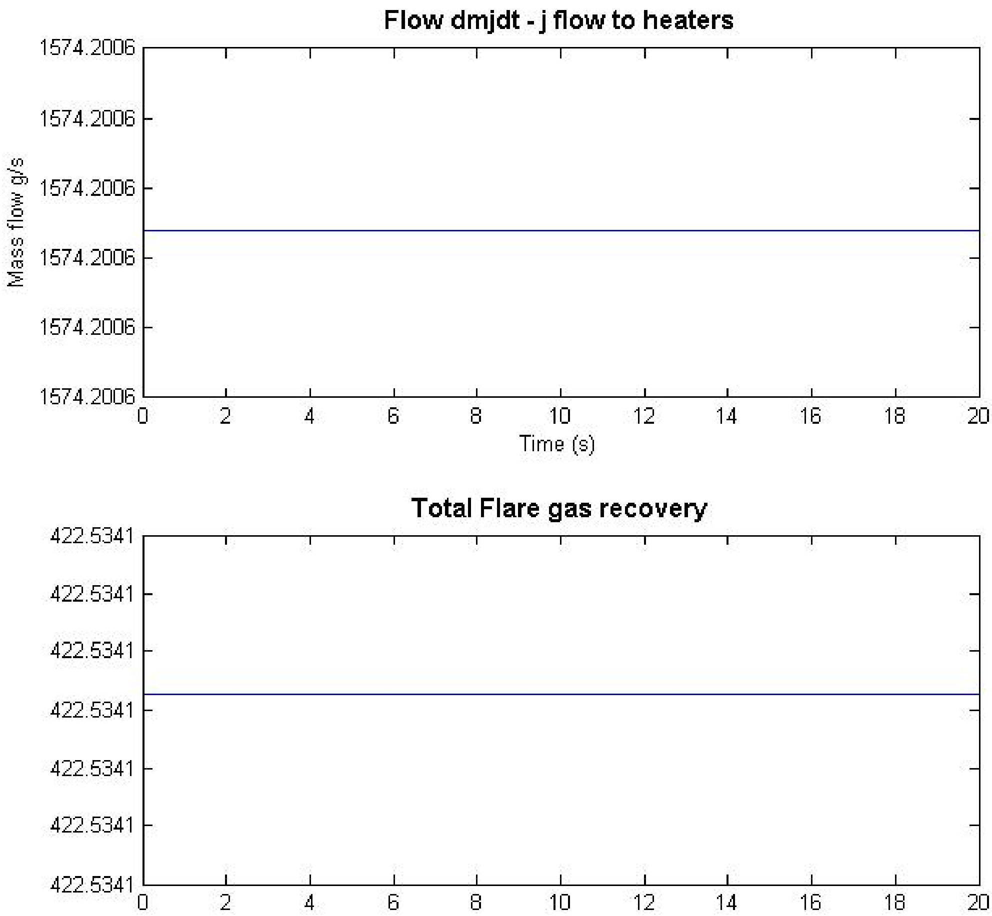

Figure 4-12 : The regulated flows – Analysis 3

4.5. Flow 1 as a sin wave and flow i3 is zero

Here the input flow i3 was set to zero and flow 1 was set to have varying between 200 g/s and 400 g/s over 2.5 seconds which is also a very high fluctuation. In this condition also the LPG flows do not occur in to vessel F and vessel FG but vessel i and vessel Buff has makeup flows to compensate the gas loss due to change in input flows.

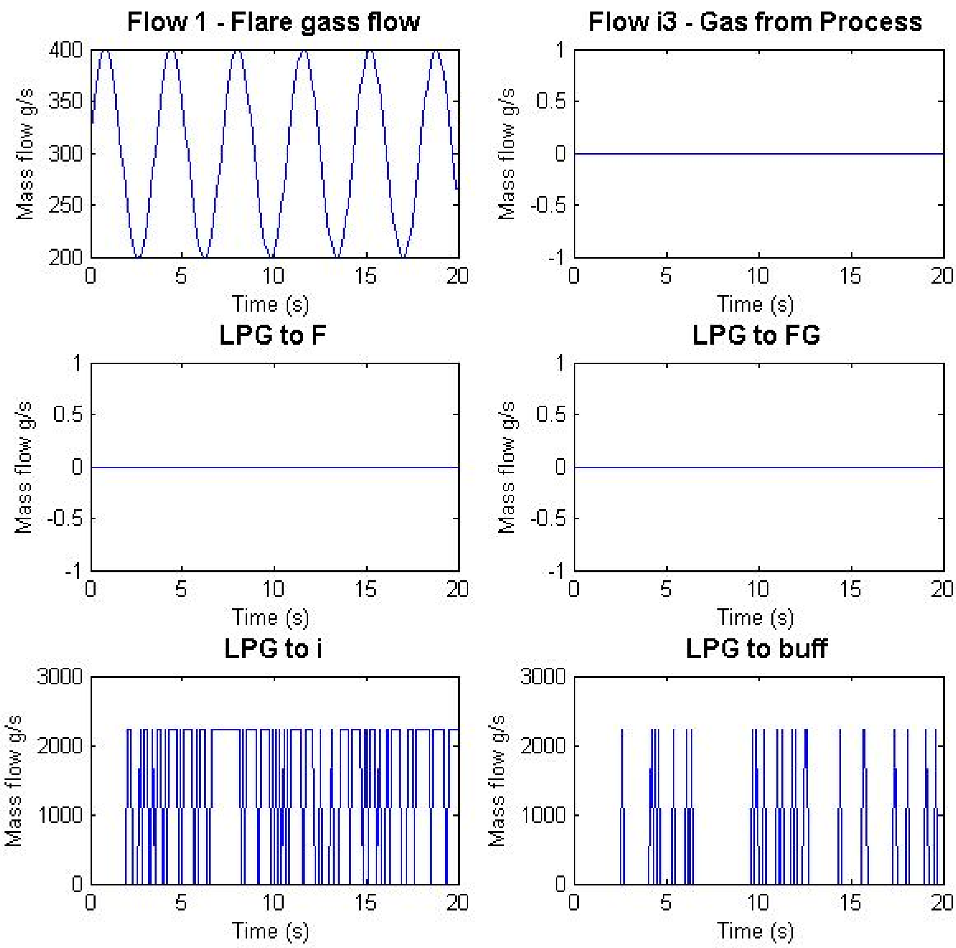

Figure 4-13 : Vessel input parameter variation – Analysis 4

4.5.1. Process parameter variations

Here the pressure variation of vessel F is very low. But it has continuous fluctuating pattern. This may due to the availability of gas flow 1. On the other hand, the fluctuation occurs may be due to making up the gas from vessel i which is also contributing to vessel FG. Vessel FG is having a big gas demand to process heaters.

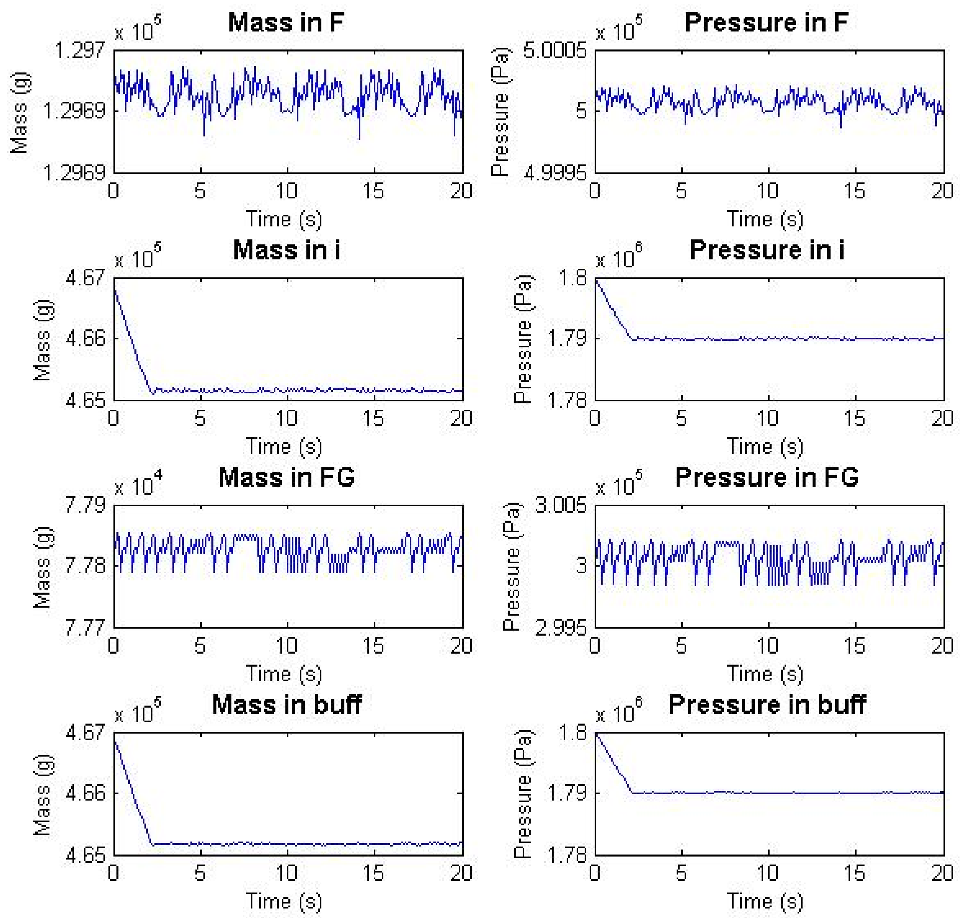

Figure 4-14 : Vessel pressures and mass accumulation variation – Analysis 4

4.5.2. Excess flows from vessels

Here also no excess flows were detected and all gases were consumed for either to be used in process heaters or to power generation. Excess flows generated will be calculated based on the pressure increases over the set values in vessels.

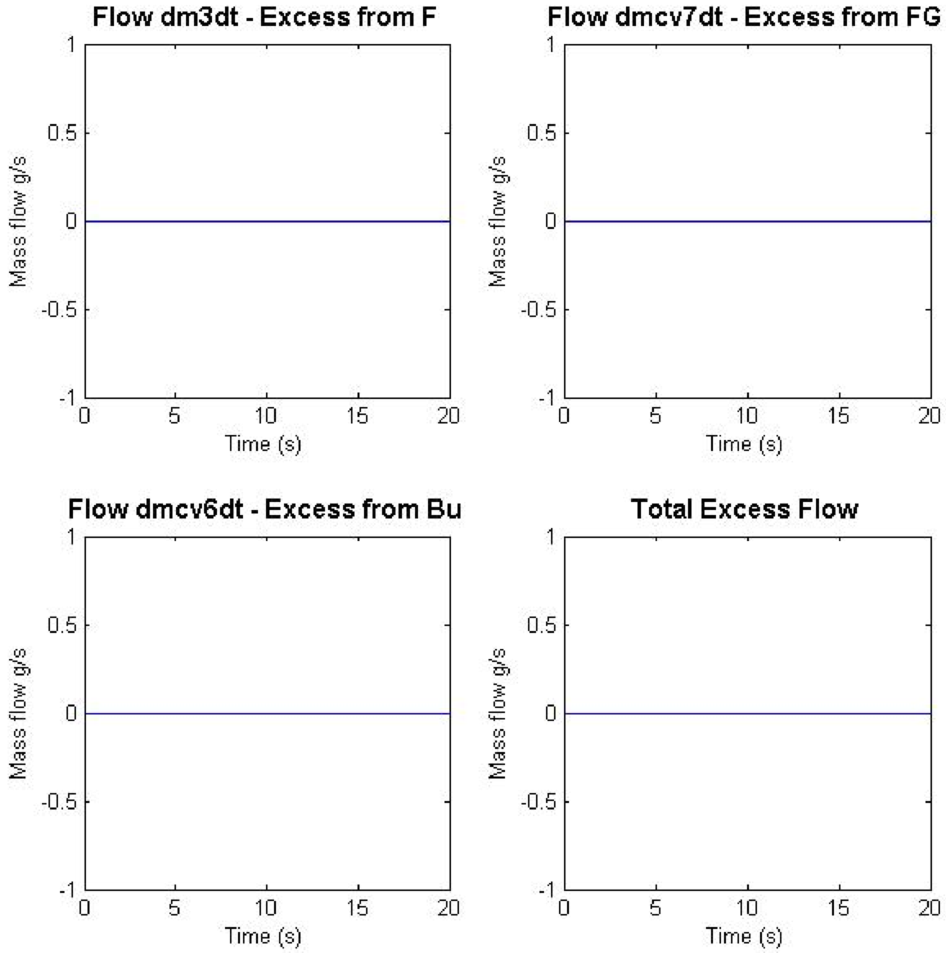

Figure 4-15 : Excess flow generation – Analysis 4

4.5.3. The two main flows to be maintained

Here also, the flows are regulated based on pressure differences and the flow rates can be adjusted to the desired values with the changes in pipe diameters. Here the variations are negligible. The desired gas flows can be achieved by adjusting the pipe diameter or the valve positions of the out let gas streams.

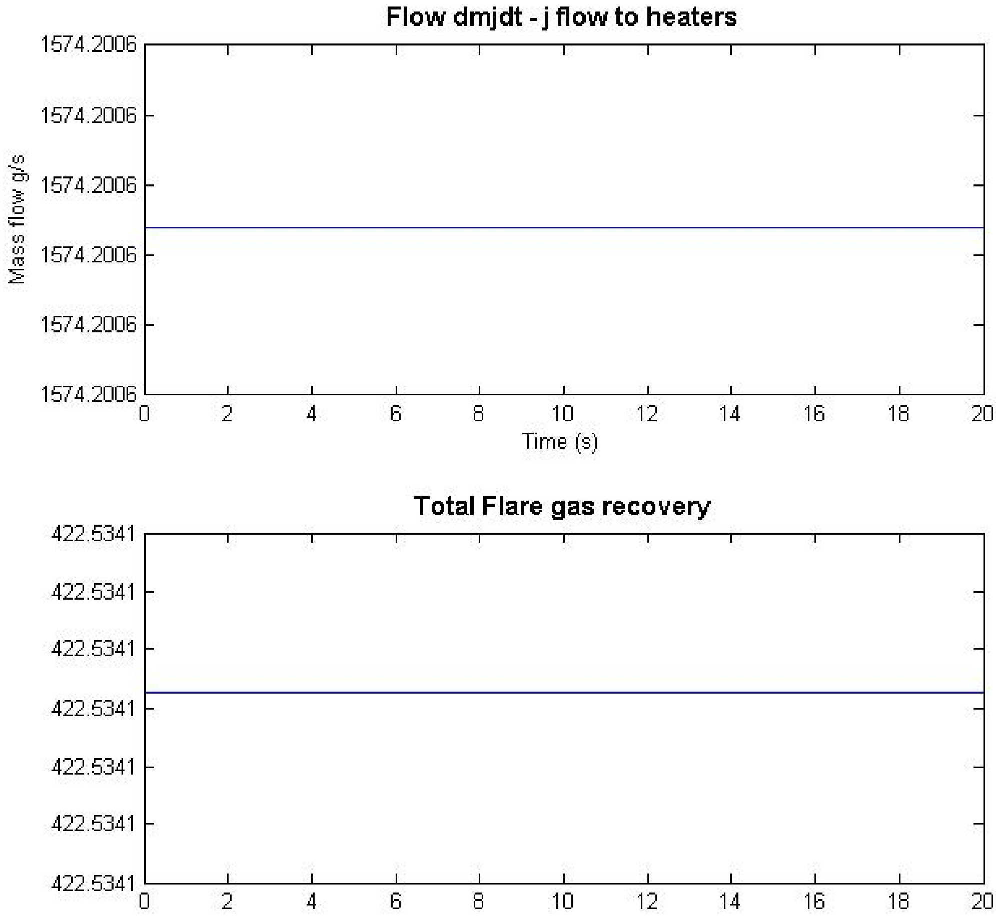

Figure 4-16 : The regulated flows – Analysis 4

4.6. Flow 1 and flow i3 as coinciding sin waves

Here the input flow 1 vary between 200 g/s and 400 g/s over 2.5 seconds which is a very high fluctuation and flow i3 was set to have vary between 500 g/s and 1500 g/s over 2.5 seconds which is also a very high fluctuation. In this condition also the LPG or natural gas flows does not occur in to vessel F and vessel FG but vessel i and vessel Buff has flows to compensate the gas loss due to change in input flows. In this case the makeup gas consumption seems considerably low compared to previous cases.

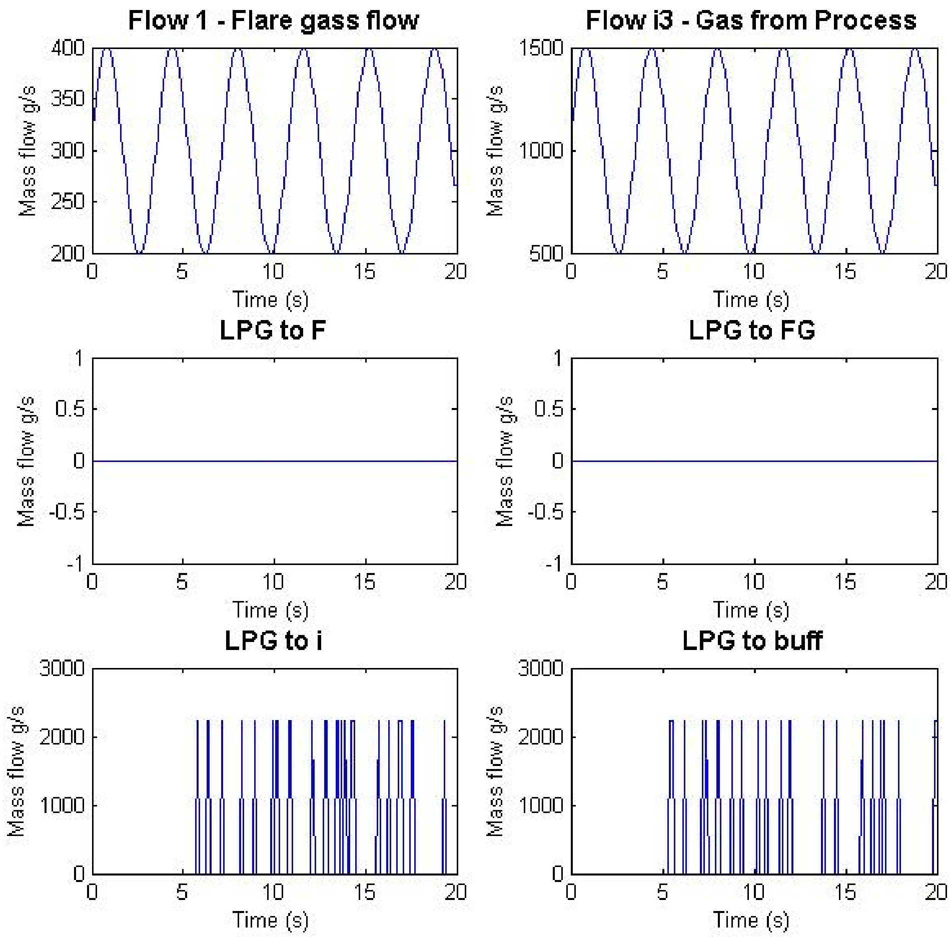

Figure 4-17 : Vessel input parameter variation – Analysis 5

4.6.1. Process parameter variation

Here the pressure variation of vessel F is very low. But it has continuous fluctuating pattern. This may due to the availability of gas flow 1. On the other hand, the fluctuation in vessel FG pressure is also high, but it lies in a very small range.

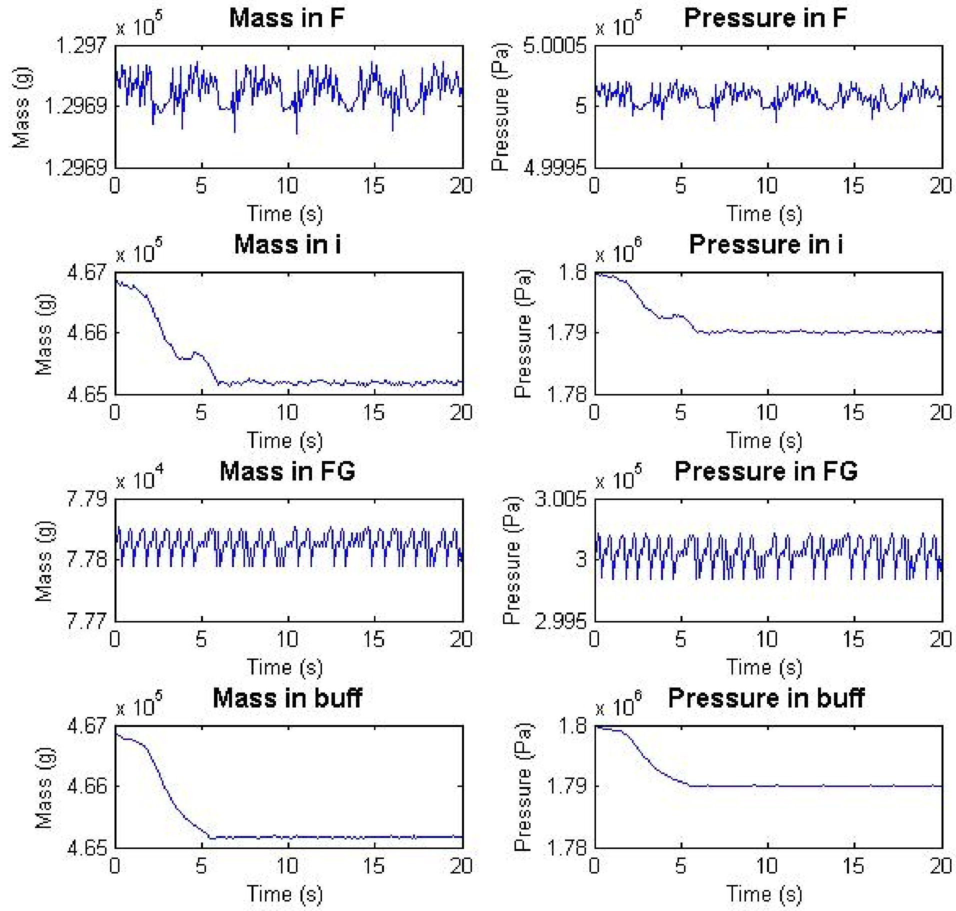

Figure 4-18 : Vessel pressures and mass accumulation variation – Analysis 5

4.6.2. Excess flows from vessels

No excess gas flows are detected. Even though the fluctuation is high and with low makeup gas flows, this may be due to the total gas flow available from the process and from flare system comparing the situation when both flow 1 and flow i3 are zero.

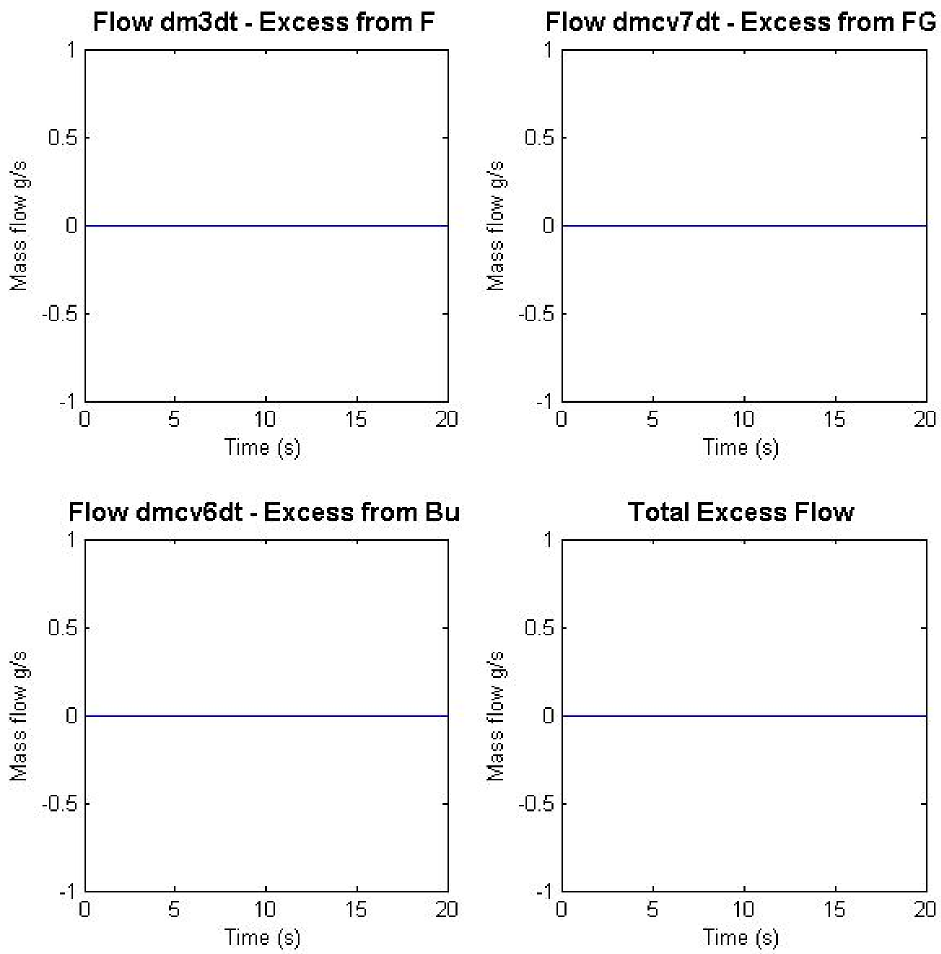

Figure 4-19 : Excess flow generation – Analysis 5

4.6.3. The two main flows to be maintained

Here also, the flows are regulated based on pressure differences and the flow rates can be adjusted to the desired values with the changes in pipe diameters. Here also the variations are negligible. The desired gas flows can be achieved by adjusting the pipe diameter or the valve positions of the out let gas streams.

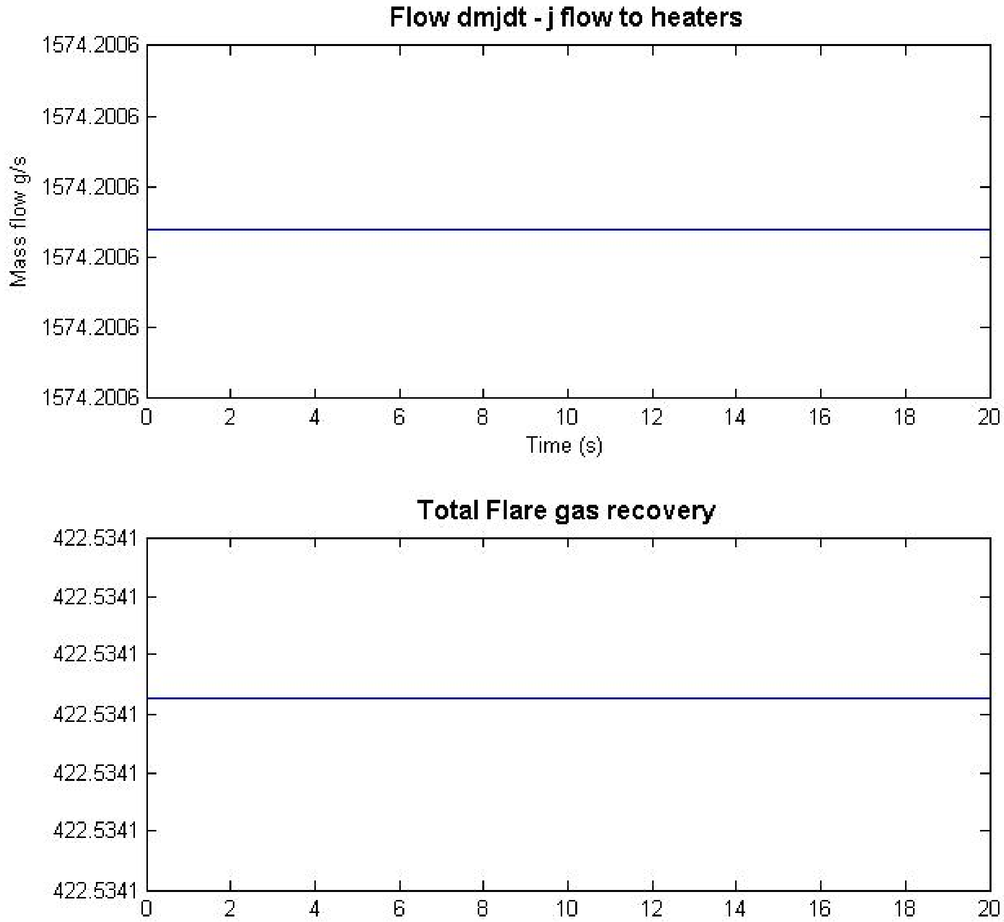

Figure 4-20 : The regulated flows – Analysis 5

4.7. Flow 1 in a sin wave and flow i3 in a cosine wave coinciding

Here the input flow 1 vary between 200 g/s and 400 g/s over 2.5 seconds which is a very high fluctuation and flow i3 was set to have vary between 500 g/s and 1500 g/s over 2.5 seconds which is also a very high fluctuation. In here the flows fluctuate in opposite directions. In this condition also the makeup gas flows do not occur in to vessel F and vessel FG but vessel i and vessel Buff has makeup gas flows to compensate the gas loss due to change in input flows.

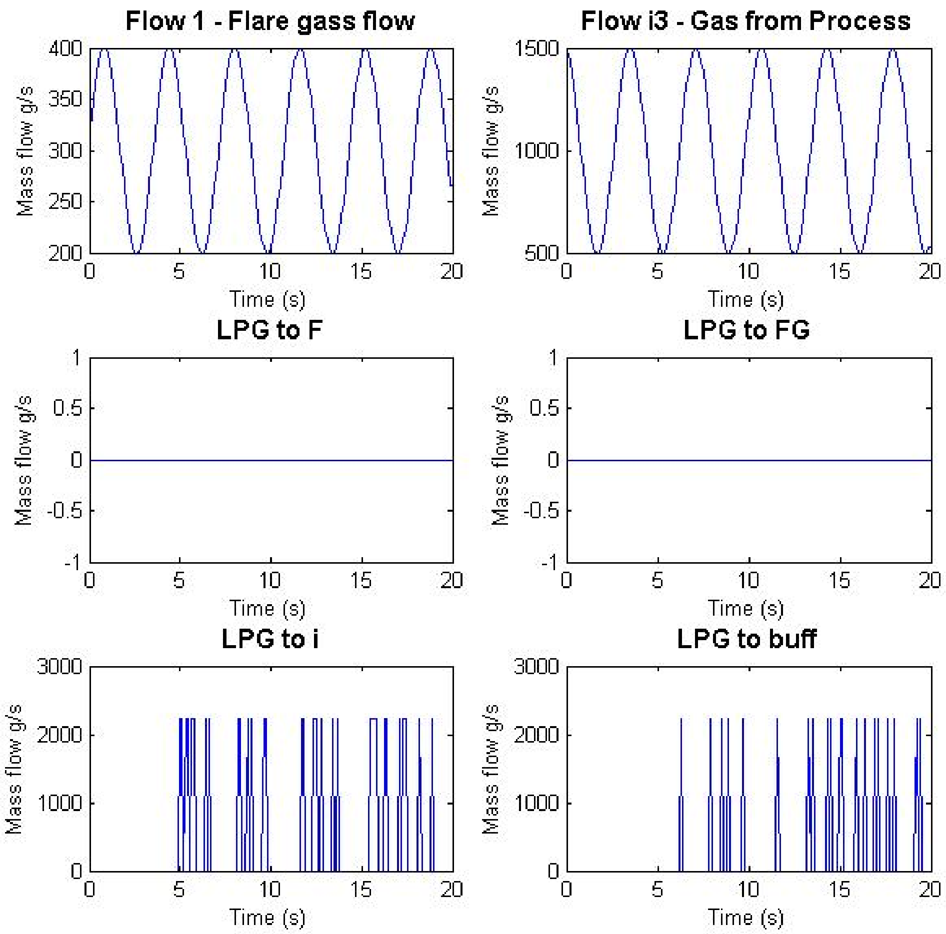

Figure 4-21 : Vessel input parameter variation – Analysis 6

4.7.1. Process parameter variation

Here the pressure variation of vessel F and vessel FG are very low. But both have continuous fluctuating pattern. Even though the gas flows vary in opposite directions, they contribute a total gas flow in to the system. On the other hand the maximum quantity of gas from each flow also differs.

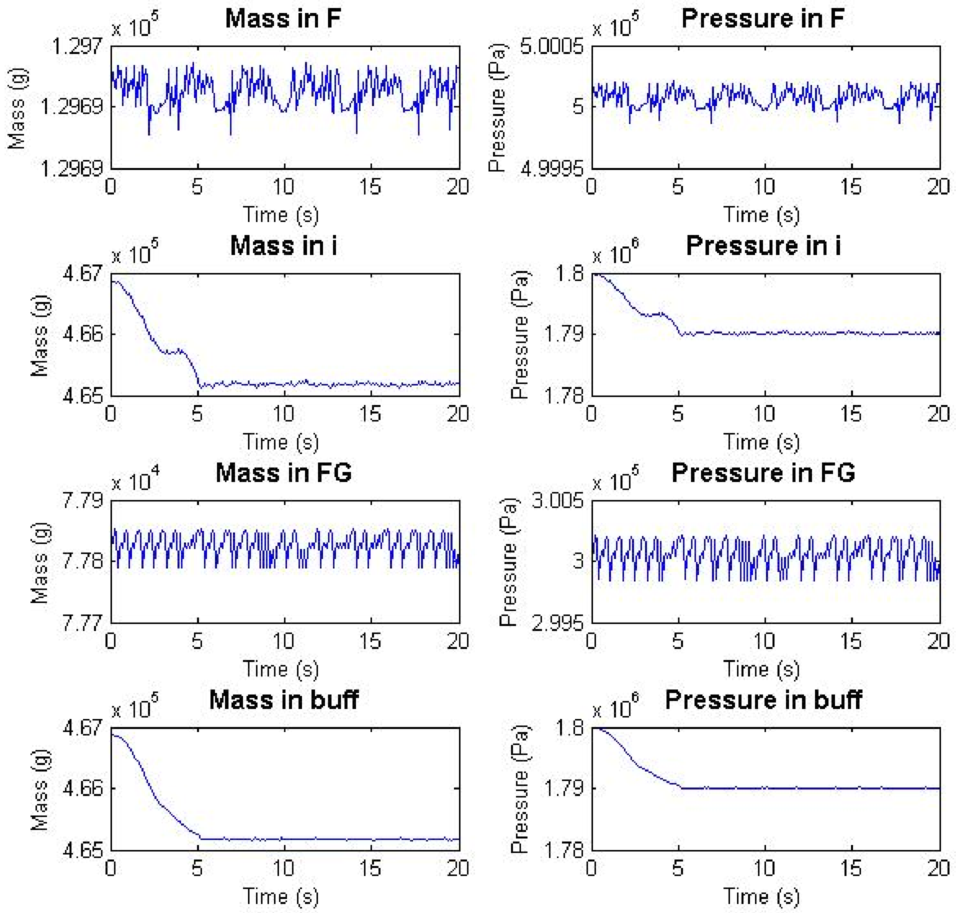

Figure 4-22 : Vessel pressures and mass accumulation variation – Analysis 6

4.7.2. Excess flows from vessels

Here also no excess flow is detected showing a perfect regulating action.

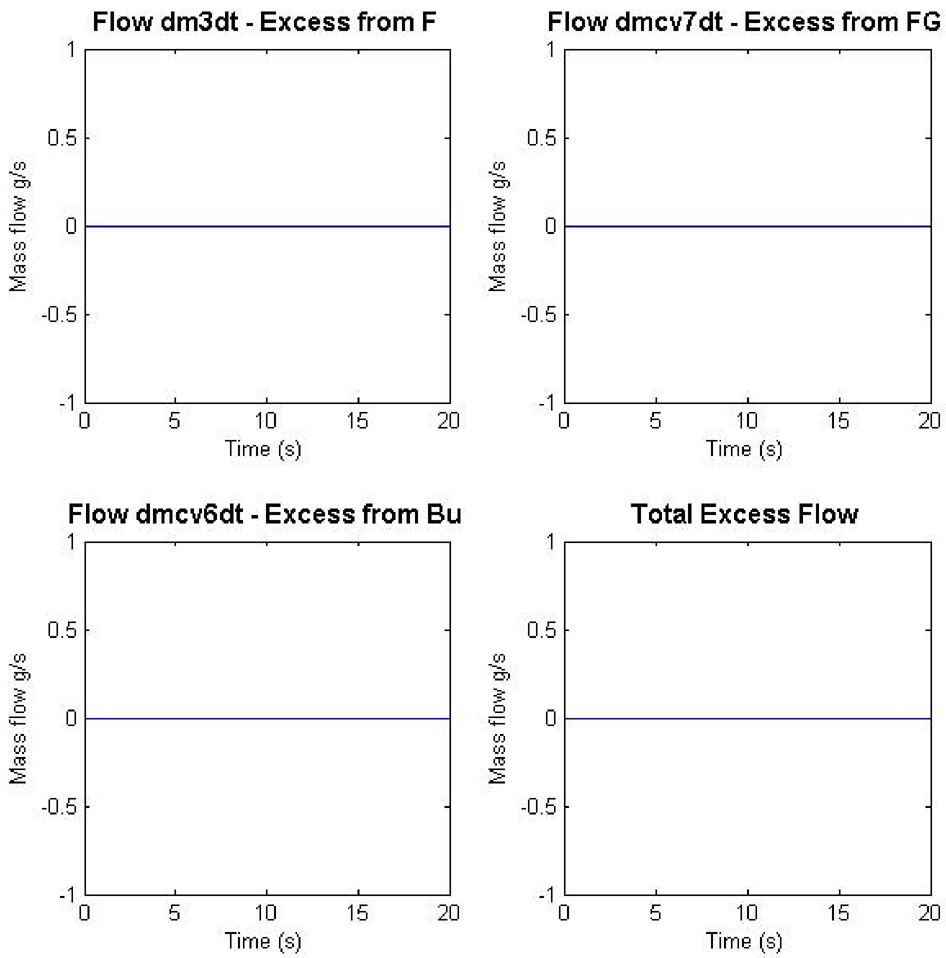

Figure 4-23 : Excess flow generation – Analysis 6

4.7.3. The two main flows to be maintained

Here also, the flows are regulated based on pressure differences and the flow rates can be adjusted to the desired values with the changes in pipe diameters. Here also the variations are negligible. The desired gas flows can be achieved by adjusting the pipe diameter or the valve positions of the out let gas streams. A flow of 1574 g/s can be taken out to process heaters and a flow of 422 g/s can be taken out of the F vessel for power generation.

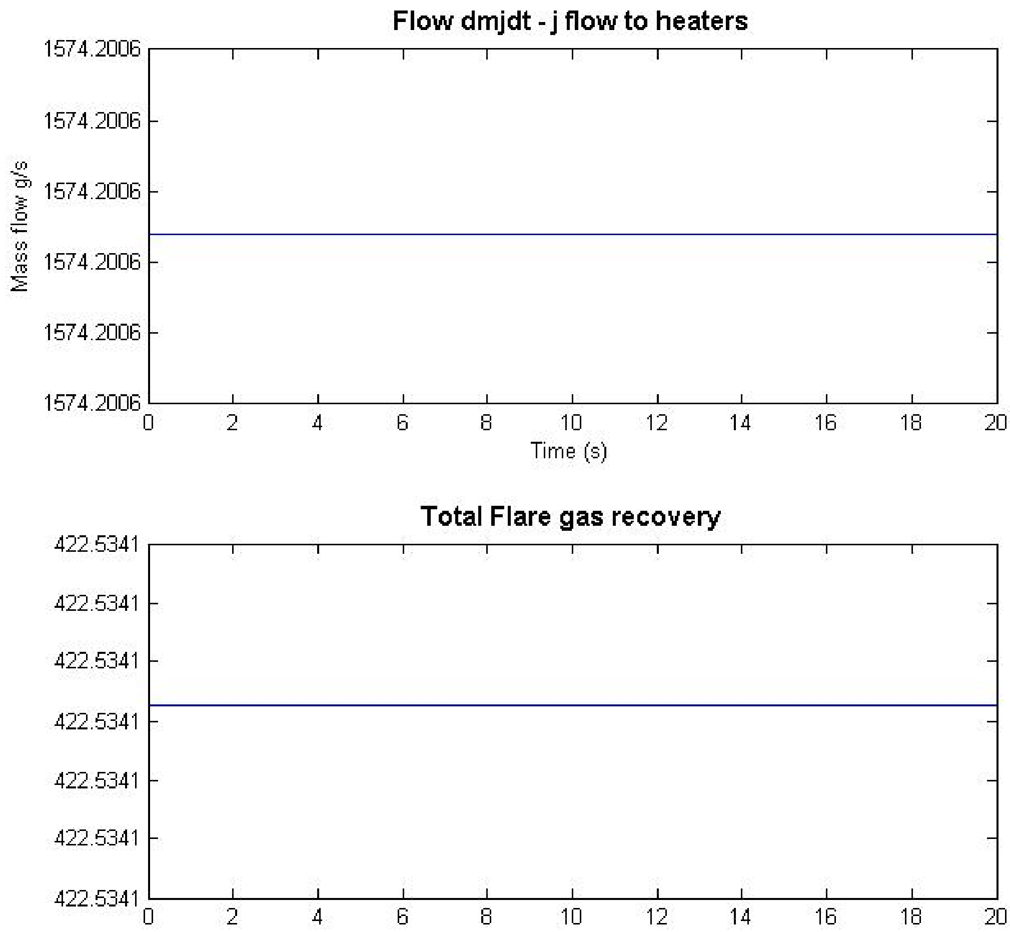

Figure 4-24 : The regulated flows – Analysis 6

4.8. Flow 1 in a cosine wave and flow i3 as a sin wave coinciding

Here the input flow 1 vary between 200 g/s and 400 g/s over 2.5 seconds which is a very high fluctuation and flow i3 was set to have vary between 500 g/s and 1500 g/s over 2.5 seconds which is also a very high fluctuation. In here also the flows fluctuate in opposite directions. In this condition also the makeup gas flows do not occur in to vessel F and vessel FG but vessel i and vessel Buff has makeup flows to compensate the gas loss due to change in input flows.

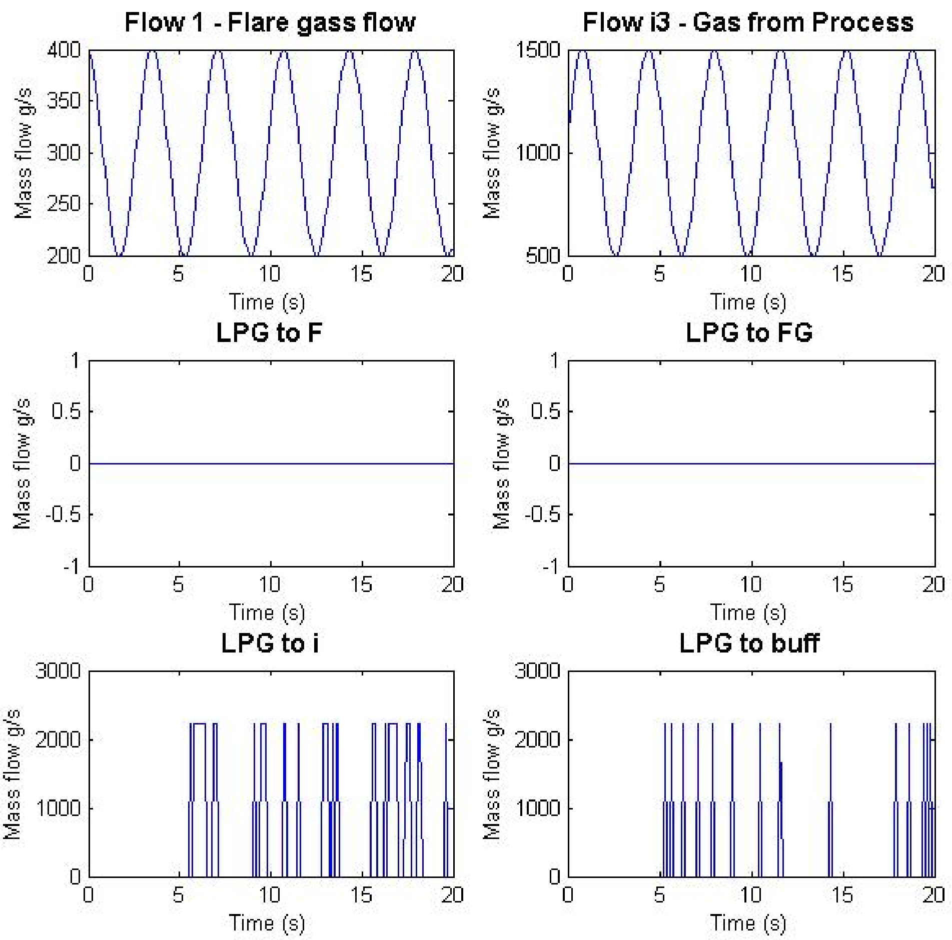

Figure 4-25 : Vessel input parameter variation – Analysis 7

4.8.1. Process parameter variation

Here the pressure variation of vessel F and vessel FG are very low. But both have continuous fluctuating pattern. Even though the gas flows vary in opposite directions, they contribute a total gas flow in to the system. On the other hand the maximum quantity of gas taken from flow 1 and flow i3 also differs.

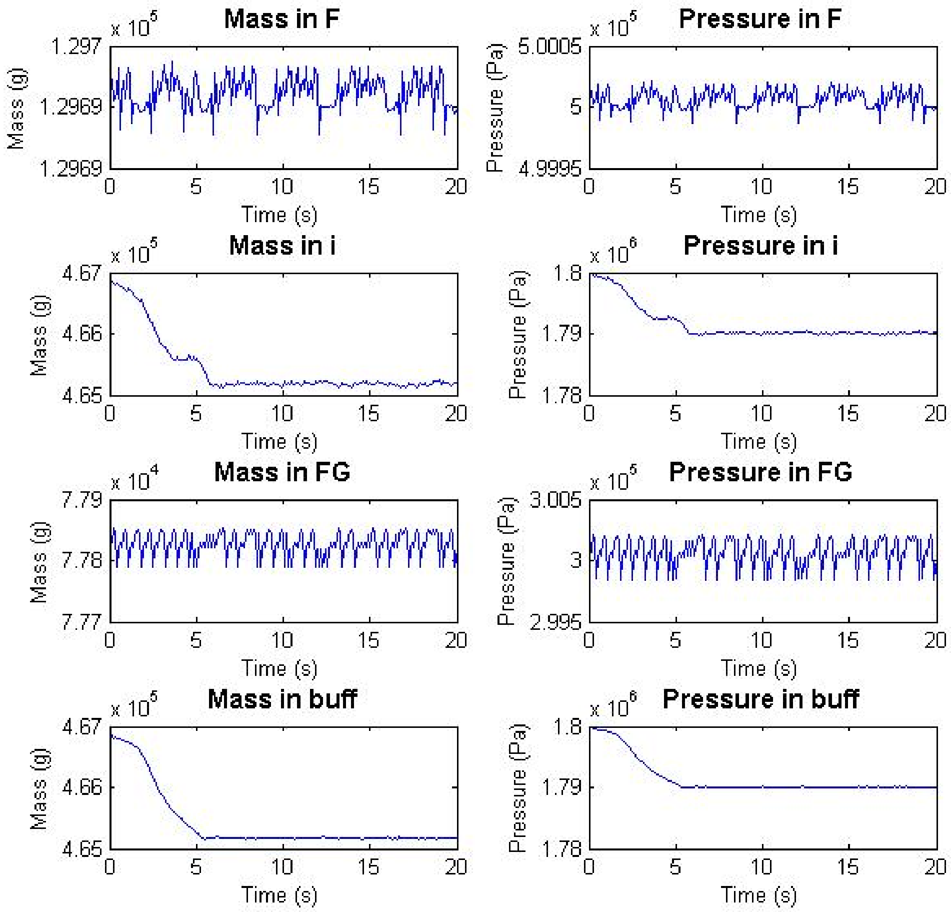

Figure 4-26 : Vessel pressures and mass accumulation variation – Analysis 7

4.8.2. Excess flows from vessels

Here also no excess flow is detected showing a perfect regulating action.

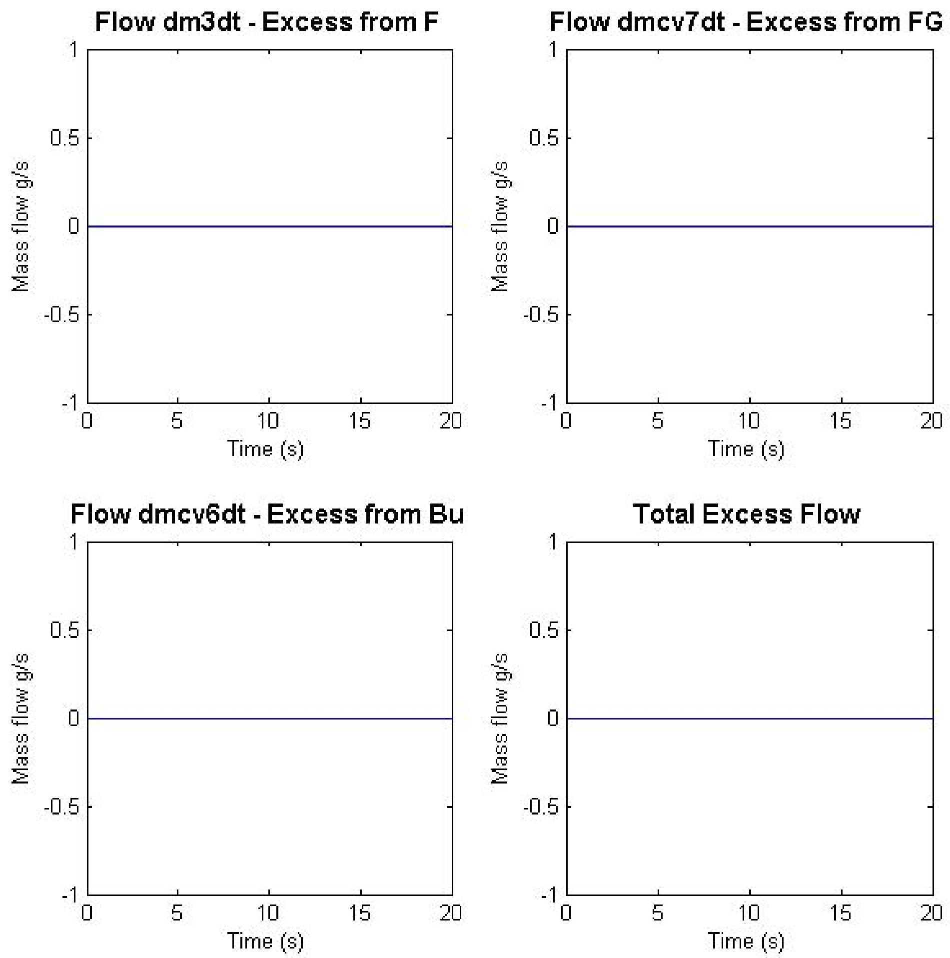

Figure 4-27 : Excess flow generation – Analysis 7

4.8.3. The two main flows to be maintained

Here also, the flows are regulated based on pressure differences and the flow rates can be adjusted to the desired values with the changes in pipe diameters. Here also the variations are negligible. The desired gas flows can be achieved by adjusting the pipe diameter or the valve positions of the out let gas streams.

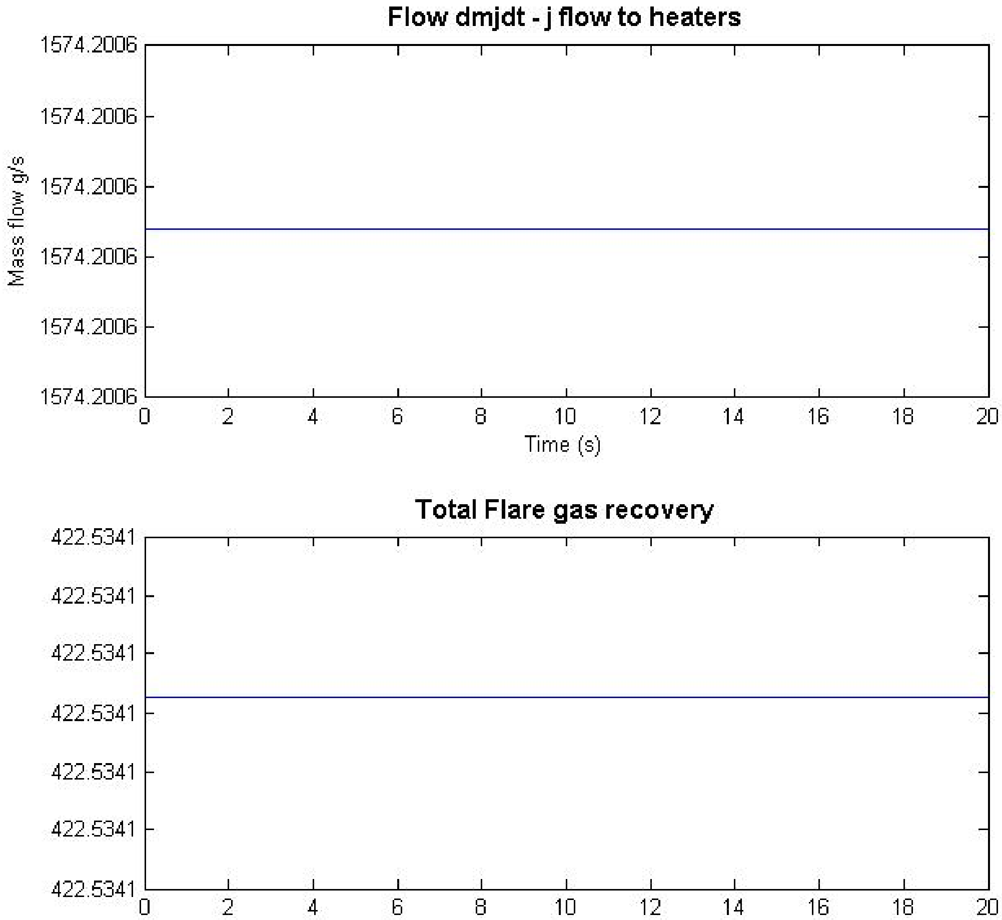

Figure 4-28 : The regulated flows – Analysis 7

4.9. Discussion

According to the cases analyzed from chapter 4.3 to chapter 4.8, there is no variation observed in the gas flow j, the flow to process heaters, and in the flow 1, gas flow to power generation. Flow j was adjusted to 1574 g/s and flow 1 is adjusted to 422 g/s. Those flows can be readjusted for the requirement using valve positions in the pipes. Other than that, the fluctuations were given to the gas flow i3 from 0.00 to 1500 g/s. Gas flow 1 was varied from 200 g/s to 400 g/s. The input variations are affecting the pressure of the vessel F and vessel FG since these is a slight variation appears in pressures of those vessels according to the input gas fluctuations. This can be further reduced by increasing the vessel volumes. But by using the makeup flow the overall effect of the gas reduction will be eliminated.

CHAPTER 5 : CASE STUDY

5.1. Background

The proposed model is applied to a live refinery process as a case study. The refinery gas generation depends on the process conditions and the generated gas flows are also in different pressures. Moreover those gas generation quantities also vary with time. Data for the case study were collected from the Sapugaskanda oil refinery in Sri Lanka. According to the data gathered 7 gas sources were identified and total 17 gas streams were identified. Table shows the respective gas stream under relevant gas generating source.

Table 5-1 : Gas stream Data **[7]**

Stream notation	**Pressure of the gas source - bar**	**Max MT/day**	**Min MT/day**	**Average MT/day**
Gas source S1				
Stream S1-1	0.84	12.12	0.00	1.76
Stream S1-2	15.30	19.38	0.00	3.62
Stream S1-3		46.64	0.00	1.78
Gas source S2				
Stream S2-1	44.00	13.13	0.00	1.42
Stream S2-2	12.06	5.89	0.00	3.22
Stream S2-3	8.14	36.97	0.00	18.13
Stream S2-4	44	1.89	0.00	0.17
Gas source S3				
Stream S3-1	24.00	21.88	0.00	7.37
Stream S3-1	18	43.86	0.00	22.62
Gas source S4				
Stream S4-1	44.00	1.35	0.00	0.09
Stream S4-2	6.91	1.80	0.00	0.48

Stream notation	Pressure of the gas source - bar	Max MT/day	Min MT/day	Average MT/day
Stream S4-3	3.25	5.56	0.00	3.22
Gas source S5				
Stream S5-1	1.40	1.15	0.00	0.13
Stream S5-2	4.10	22.24	0.00	4.90
Gas source S6				
Stream S6-1	44.00	1.68	0.00	0.90
Stream S6-2	4.50	37.20	0.00	24.97
Gas source S7				
Stream S7-1	13.79	74.87	0.00	13.03

5.2. Flare gas recovery

Since the gases generated within the process have different pressures, the proposed flare gas recovery system was studies in 3 cases. The gas collection were done in 3 pressure stages where the set pressure levels for vessel i is defined considering the average gas accumulation in different pressures.

According to the above table, the best options are 18 bar, 12bar and 7 bar. According to the current case, the refinery in Sri Lanka does not have natural gas. So LPG is selected to makeup the required gas. So that the vessels FG and F were only fed with LPG in order to reduce heat energy require to obtain relevant vapor pressure of LPG. The gases that cannot be collected in those vessels due to having pressures below 7 bar and above 3 bar, were directly fed to the fuel gas vessel FG. Else it will be directed to flare system directly. The set pressures for vessel F is considered as 5 bar and the set pressure for vessel FG is considered as 3 bar.

In the first case the flare gas collector is fed only with 18 bar fuel gas drum and in the second case the flare gas collector is fed with 2 fuel gas drums having pressures of 18 bar and 12 bar. In the third case the flare gas collector is fed with fuel gas drums having pressures of 18 bar, 12 bar and 7 bar respectively.

5.3. Data collection

Data for gas generation in all pressures in the process, gas utilization patterns and the total gases used for process heaters, the required LPG makeup flows, gases vented to flare system, total gases supplied to the FGN and the flow patterns of gas generation and flare gas generation were collected over a two years period from the Sapugaskanda oil refinery. Data collection period is from 2014 August to 2016 September. The collected data are attached in Appendix C.

5.4. Current situation

At present there is a tendency to release excess gases to the flare system via fuel gas system that cannot be utilized for process heaters. The gas amount has varied from 0.00 to a maximum of 30.48 MT/day with in the period of considered. There is a high amount of gases go to flare when some units are in shutdown, when startups and shutdowns occur frequently and with some malfunctioning of unit operations. The daily average flow pattern of gas from fuel gas network to flare is listed in Figure 5-1.

5.4.1. Gas from fuel gas network to flare

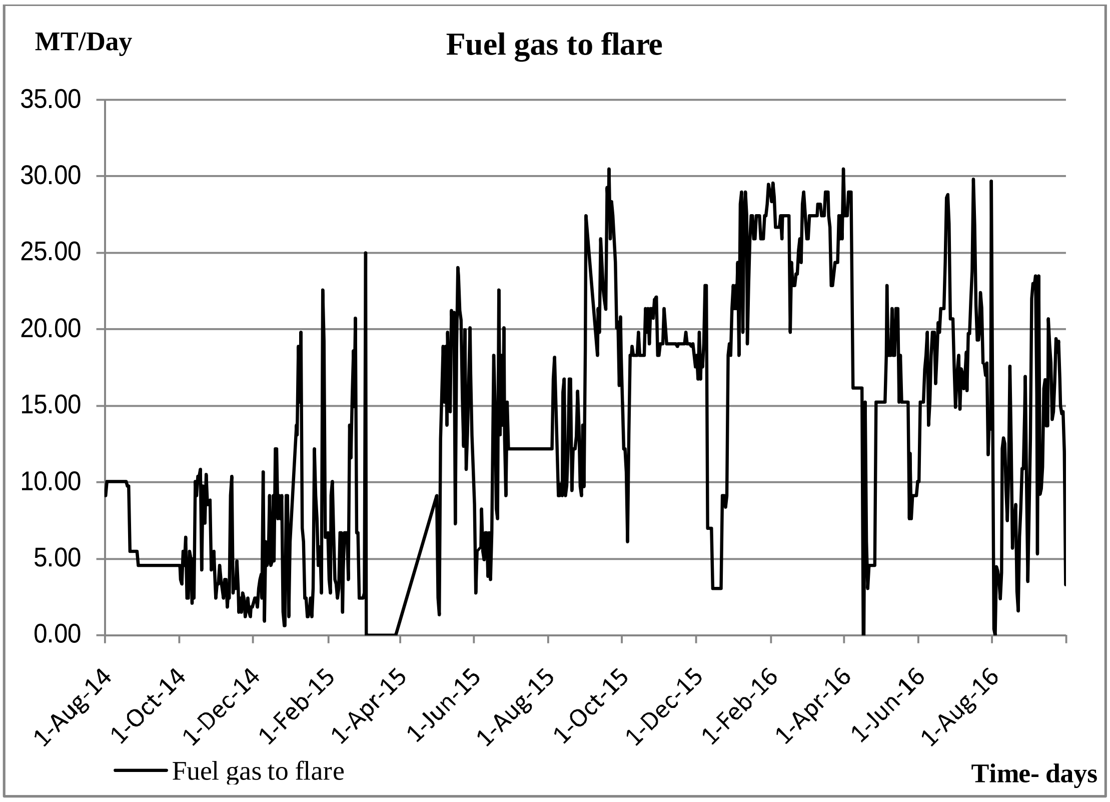

Figure 5-1 : Fuel gas to flare**[7]**

5.4.2. Gases goes directly to flare system

The gases generated below the set pressure of fuel gas system, currently 2.77 bar, is directly directed to the flare system. These gas flows also varies from 0.00 to 12 MT/day. The malfunction of gas generating units causes this. Other than that the gases generated via relief valve pop ups also goes to the flare system directly even though they are having a considerable high pressure depending on the situation. The flow pattern of daily average is listed in figure 5-2

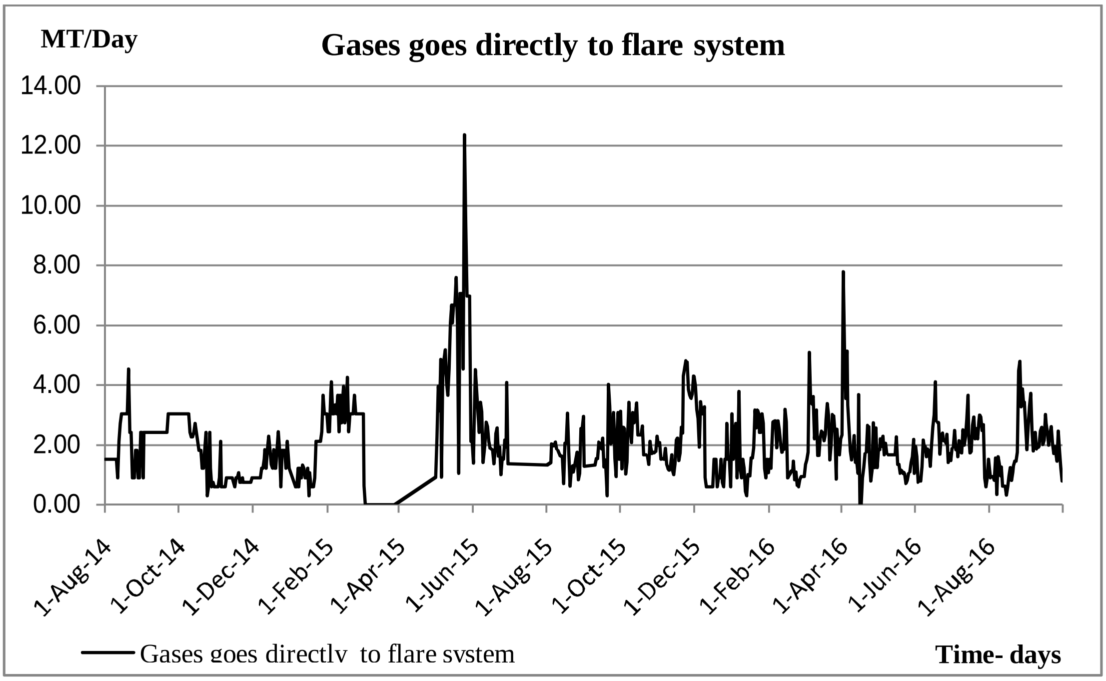

Figure 5-2 : Gases goes directly to flare system **[7]**

5.4.3. Total gas to flare

Total gases to flare consist of the gases having low pressure than the fuel gas system and excess gases from the fuel gas system.

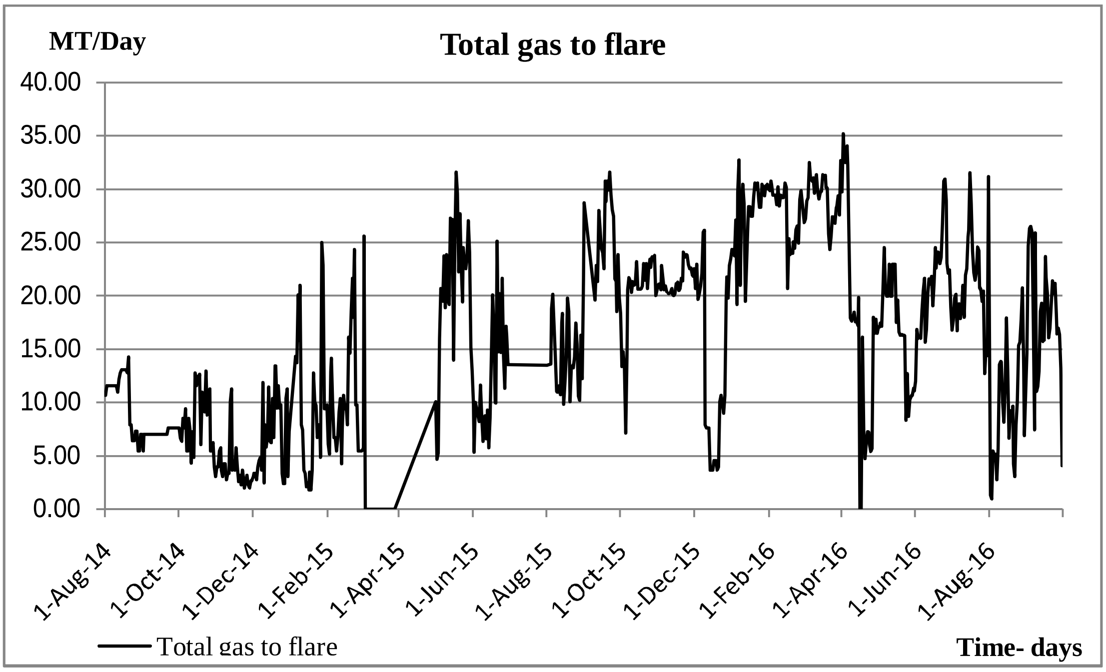

Figure 5-3 : Total gas to flare **[7]**

5.4.4. Current LPG make up flow

LPG makeup to balance the pressure of FGN main header as specified in figure 5-4. This consumption varies with time heavily. Even though there is an excess flow out of the FGN, there exists a makeup flow due to the heavy fluctuations of the pressure around the set pressure of FGN. The makeup flow varies from 0.00 to 46.64 MT/Day.

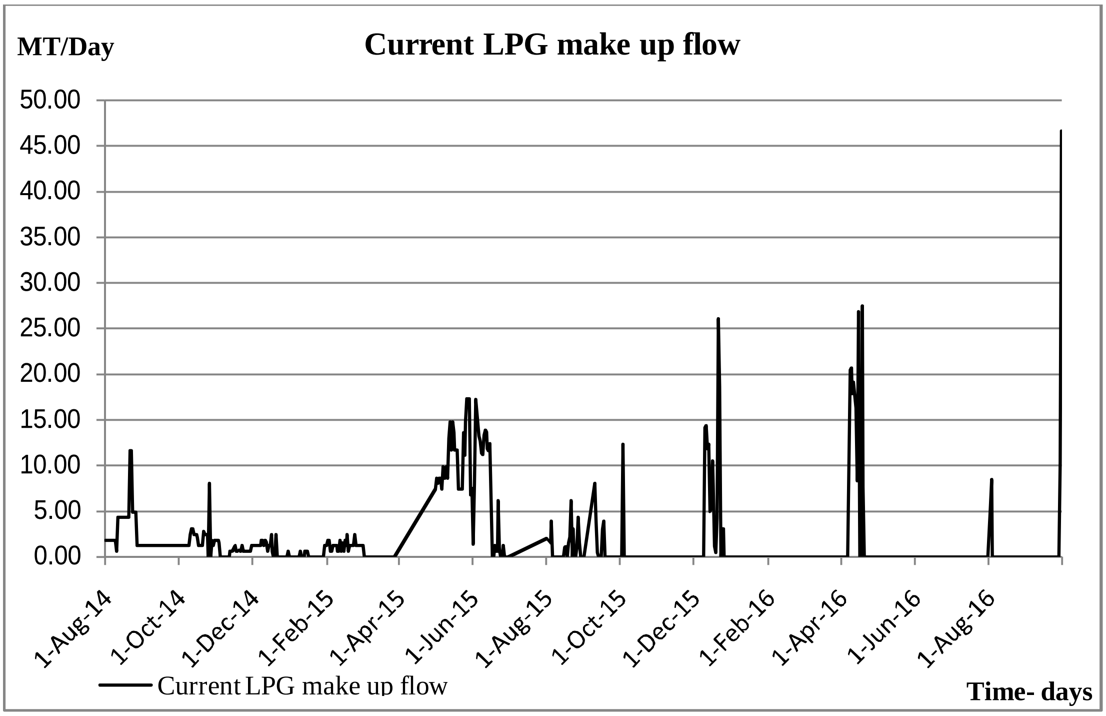

Figure 5-4 : Current LPG make up flow **[7]**

5.4.5. Total Fuel gas to Units

According to the gas utilizing pattern of the process heaters, the fuel gas to unit value varies. The reasons behind these values are the number of units in operation, the throughput variations of the units and process heater conditions such as oil to gas ratios to be maintained, fuel gas limitations due to maximum possible skin temperatures of pipes…etc. The sudden reduction of the values is due to plant shutdowns or the usage of fuel oil instead of gases. The variation is from 0.00 to 140.836 Mt/Day. Figure 5-5 shows the variation of values over the period of consideration.

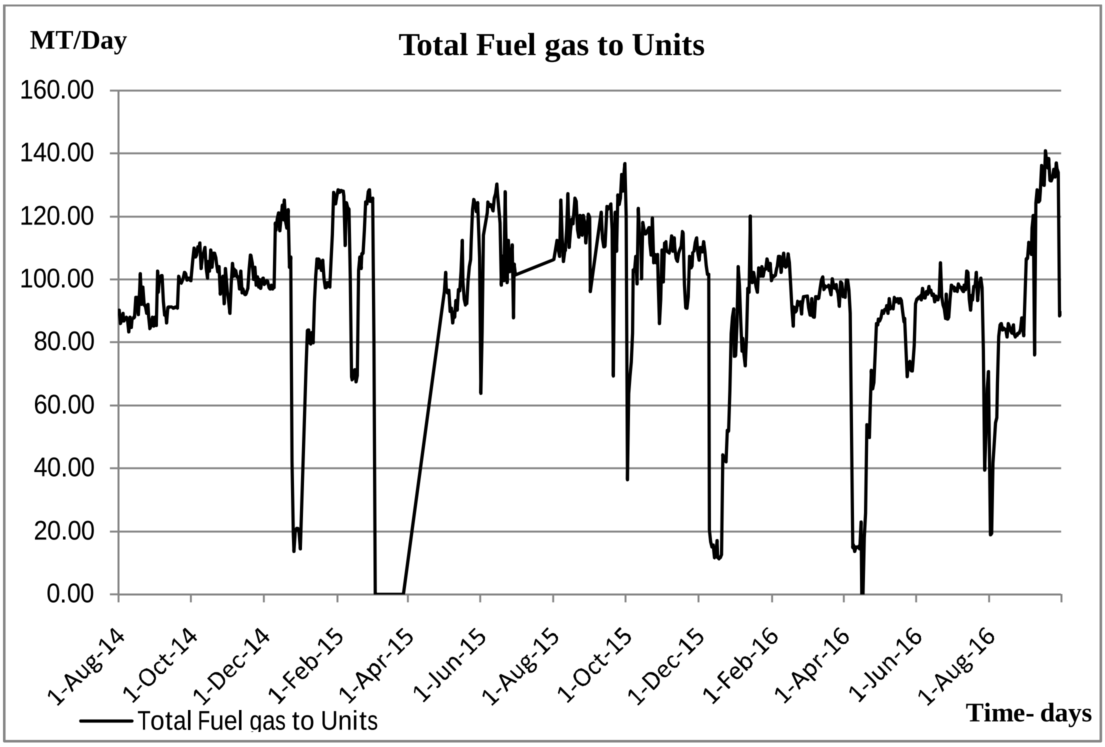

Figure 5-5 : Total Fuel gas to Units **[7]**

5.5. Case 1

5.5.1. Flow description

In this case the vessel i is fed with fuel gas at the pressure of 18 bar collected from the process plant. Flow fluctuates with time since the gas generation varies with the process conditions of the plant and process abnormalities. Pressure of vessel i is subjected to the control valves named CV2, CV 8, CV 1, CV5 and the gas intake is directly from the process plant, named flow i3. CV 2 is used to compensate the pressure using excess gas collected in the buffer vessel. CV 8 is used to feed the gas in to FG vessel with FG vessel pressure variations (Set to 3 bar). CV 1 is to feed gas to F vessel according to the pressure variations in F vessel (Set to 5 bar). CV 5 is to make up the vessel i to maintain 18 bar pressure if it does not getting any gas supply from the buffer vessel or directly from the process plant. It can be either natural gas or LPG pressure, raised above the set pressure of vessel i.

Vessel buff is also set to 18 bar to collect excess gases that cannot hold in vessel i. Pressure of vessel buff is also subjected to the control valves named CV 6, CV 2, CV 4, CV9 and gas intake directly from the process plant named flow i3. CV 6 is to regulate pressure in vessel buff in case it exceeds the vessel set pressure of 18 bar. CV 4 is to set the intake gas line i3 either to vessel buff or to vessel i depending on reaching vessel i pressure to 18 bar or reducing it below 18 bar. CV 9 is controlling the vessel pressure by making up using LPG or natural gas to maintain a smooth flow distribution within the FGN proposed.

Vessel F has the main objective of producing a constant gas flow out of the excess flare gases collected, fuel gas and LPG (or natural gas). The vessel is mainly fed with an excess gas flow from the process (flare gas flow). It is to be compressed into a specified pressure in order to use it for a gas turbine for power generation. Maintaining 5 bar pressure in vessel F is assumed in this situation. The makeup gas flow to the suction of the compressor can be used to avoid surging problems that can occur in the compressor operation. Other than that a gas flow form vessel i through control valve CV1 is fed to Vessel F, monitoring vessel F set pressure. (Set to 5 bar) An LPG flow via CV 11 is fed to vessel F in order to maintain a constant pressure, if the gas flows from both flow 1 and from vessel i do not able to maintain the pressure needed in vessel F. CV 3 is for to Avoid excess pressure building up beyond 5 bar in vessel F.

Vessel FG is to maintain a constant flow to process heaters. The vessel gets it gases from vessel i via CV 8 to regulate its set pressure at 3 bar. LPG supply is set to vessel FG via CV 10 to maintain the set pressure if it is not achieved through vessel i. Other than that CV 7 regulates vessel FG pressure by not allowing the pressure in FG exceeds over 3 bar. Flow j is the gas flow to process heaters. In this case flow 2 was taken as 36 MT/Day. Figure 5-6 shows the vessel arrangement and control system for the case with only 1 vessel at 18 bar.

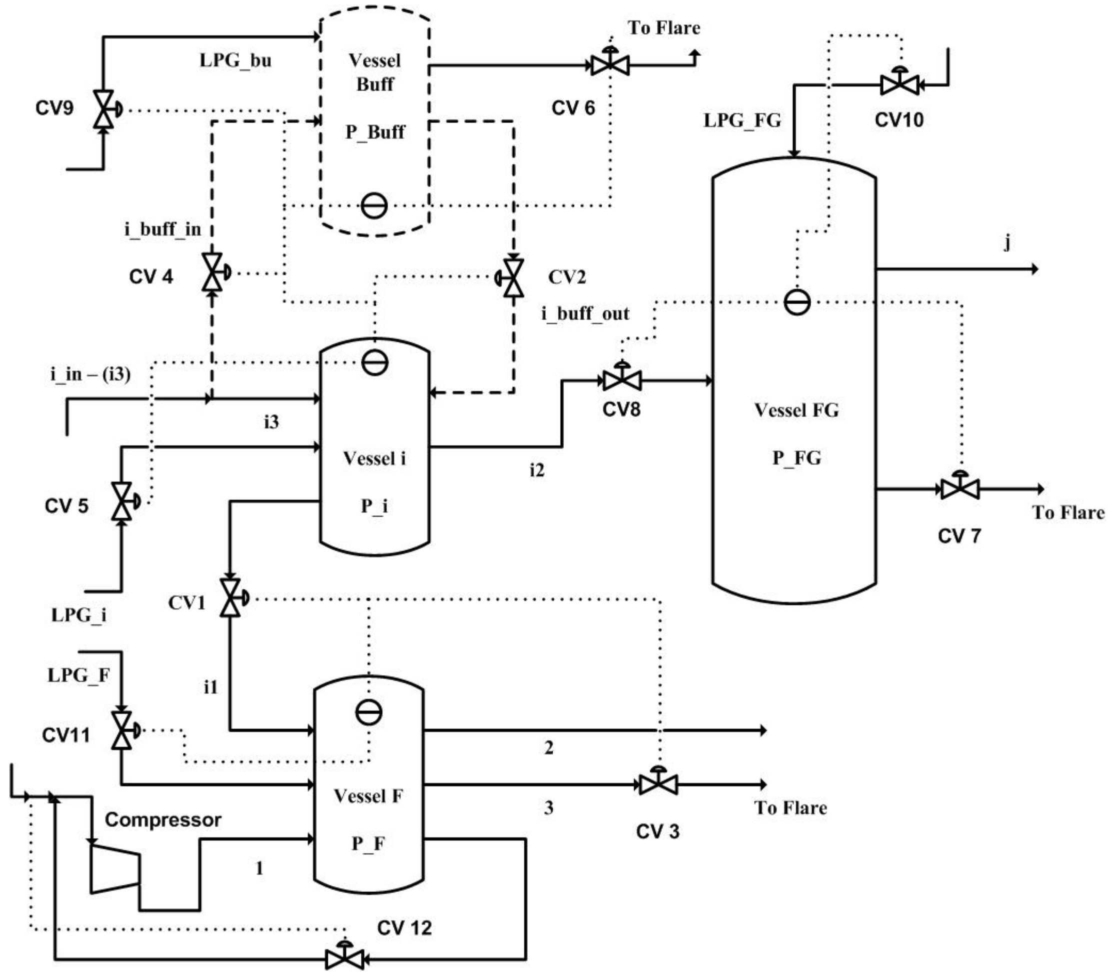

Figure 5-6 : Case 1 with only 18 bar vessel

5.5.2. Total Gases generated in 18 bar

The variation of gases generated having the pressure above 18 bar is listed in figure 5-7. The process unit shutdowns that generates the gases having the required pressure and throughput variation of those units cases to vary the gas generation. Figure 5-7 shows the gas generation throughout the period. The gases vary from 0.00 to 61.73 MT/Day.

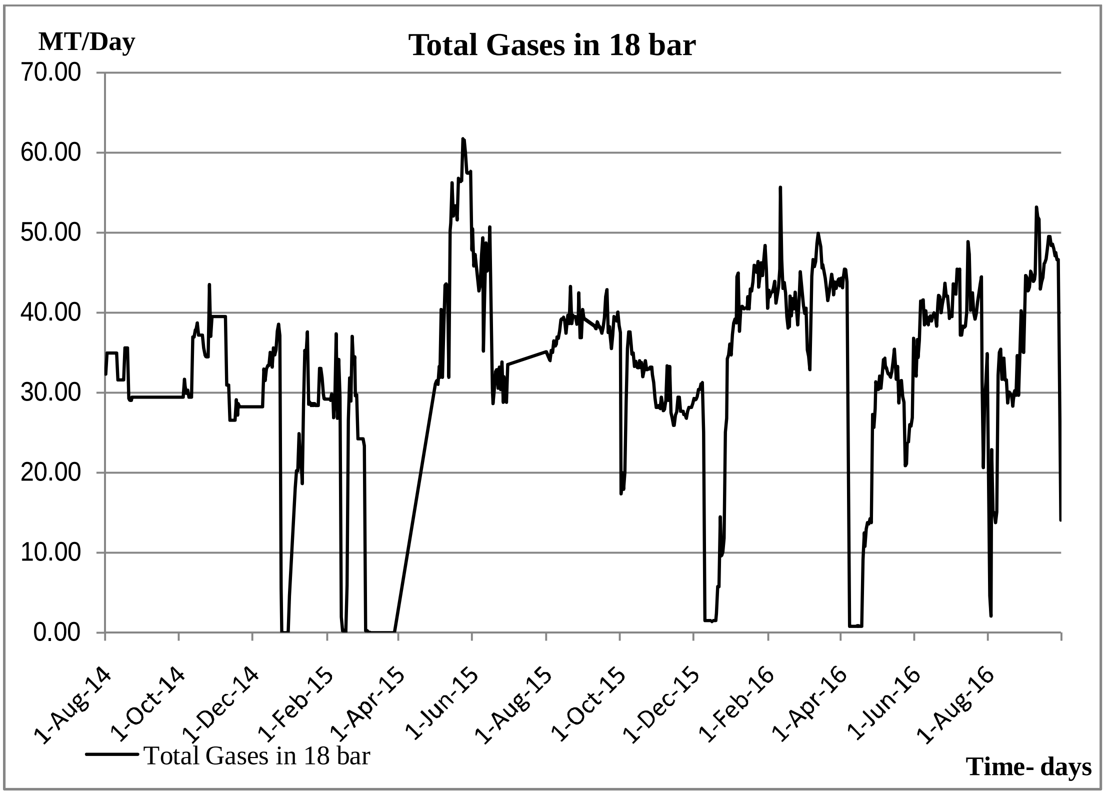

Figure 5-7 : Total Gases in 18 bar

5.5.3. Gases having pressure below 18 bar

According to the case selected the gases having pressure below 18 bar which also has a considerable potential of regulating pressure is listed in figure 5-8. This varies from 0.00 to 116.54 MT/Day.

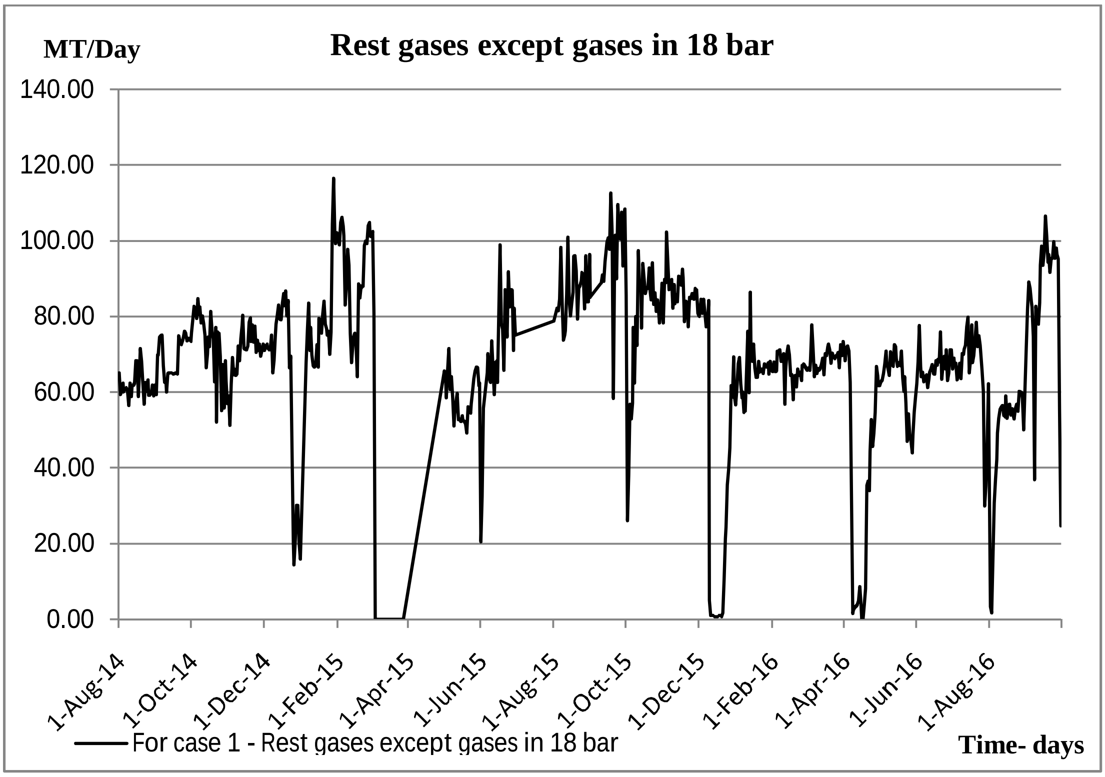

Figure 5-8 : Gases having pressure below 18 bar

5.6. Case 2

5.6.1. Flow description

Flare gas collector is fed with 2 fuel gas drums having pressures of 18 bar and 12 bar. Here the FGN consists with two i vessels and two buffer vessels. The arrangement is same as the case 1. The gases having pressures above 18 bar come to the vessel 1 and buffer vessel_buff_1. The gases having pressures above 12 bar and below 18 bar come to the vessel 2 and buffer vessel_buff_2. Control valves CV 1_9, CV1_4, CV1_6 and CV1_2 are controlling the gas content and pressure in the vessel_buff_1. They control the LPG or natural gas makeup flow, the gases having pressure above 18 bar when vessel 1 is reached to a pressure of 18 bar, excess gases when vessel_buff_1 is having pressure of 18 bar and gas makeup to vessel 1 to maintain a pressure of 18 bar respectively. The governing parameter for CV1_9 and CV1_6 are P_Buff_1, and for CV 1_4 and CV 1_2 are P_1.

Vessel 1 pressure is maintained using CV 1_5, CV 1_8, CV 1_1 and Flow 1_3 which controls the LPG or natural gas makeup to the vessel 1, the gas flow to vessel FG, the gas flow to vessel F and the gas in take from the process having a pressures above 18 bar respectively.

The set pressure of Vessel_Buff_2 is 12 bar and it is controlled via control valves CV 2_9, CV 2_6, CV 2_4, and CV 2_2 which controls the makeup flow, excess flow, gas flow in when the vessel 2 pressure exceeds or become 12 bar, and the gas flow to vessel 2, respectively. Other than CV 2_4 and CV 2_2 vessel 2 pressure is maintained at 12 bar by control valves CV 2_5, CV 2_8, CV 2_1, and flow 2_3. They control the makeup flow, gas flow to vessel FG, Gas flow to vessel F and the gases from the process having a pressure above 12 bar and below 18 bar. Gas feeding to the vessel F and vessel FG are from both vessel 1 and vessel 2. Other arrangements are same as in case 1. Figure 5-9 shows the schematic of the case 2 and the control valve arrangements.

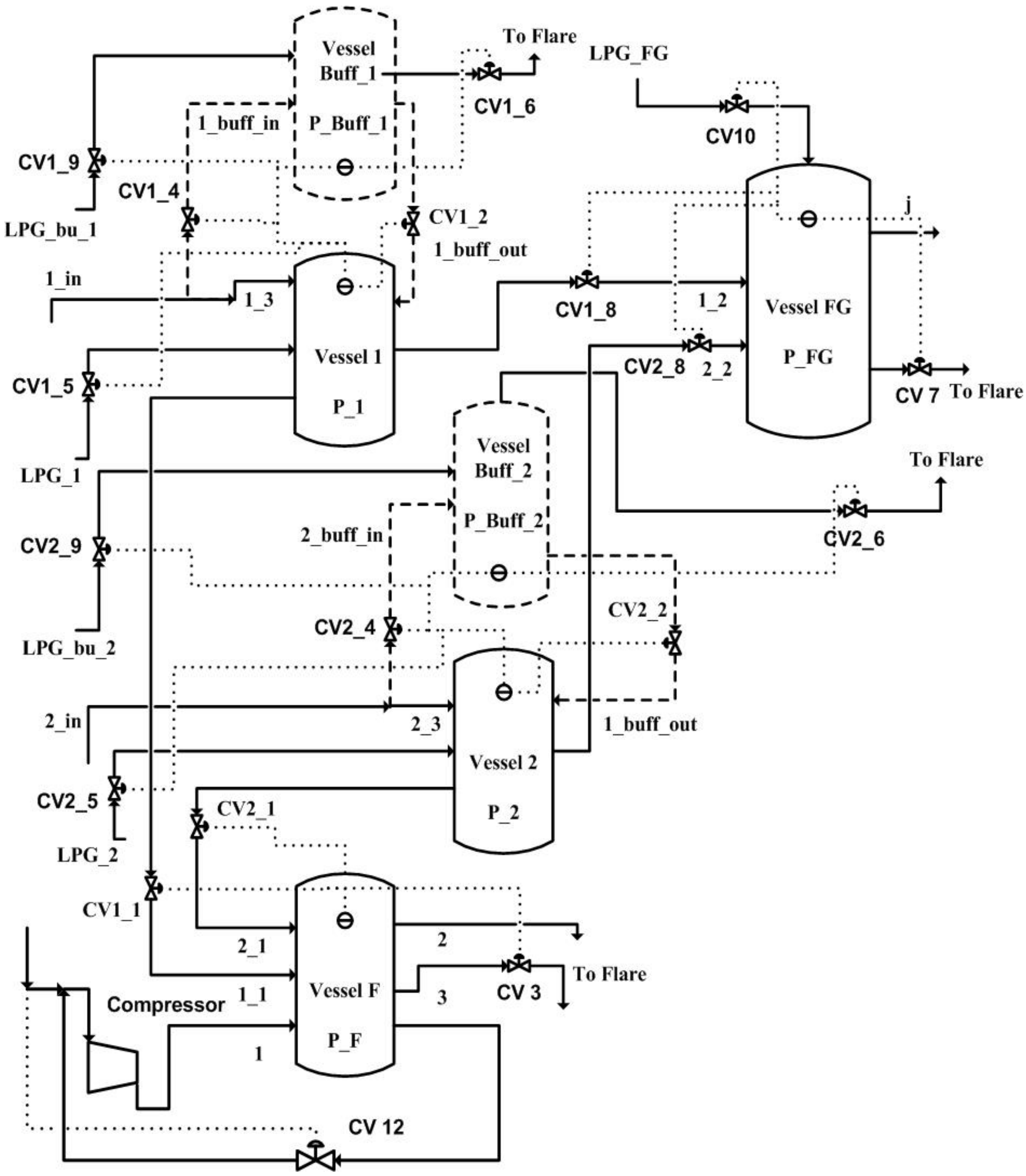

Figure 5-9 : Case 2

5.6.2. Total Gases in 12 bar

Total gases generated in pressure in between 12 bar 18 bar is listed in figure 5-10. This varies from 0.00 to 75.67 MT/Day.

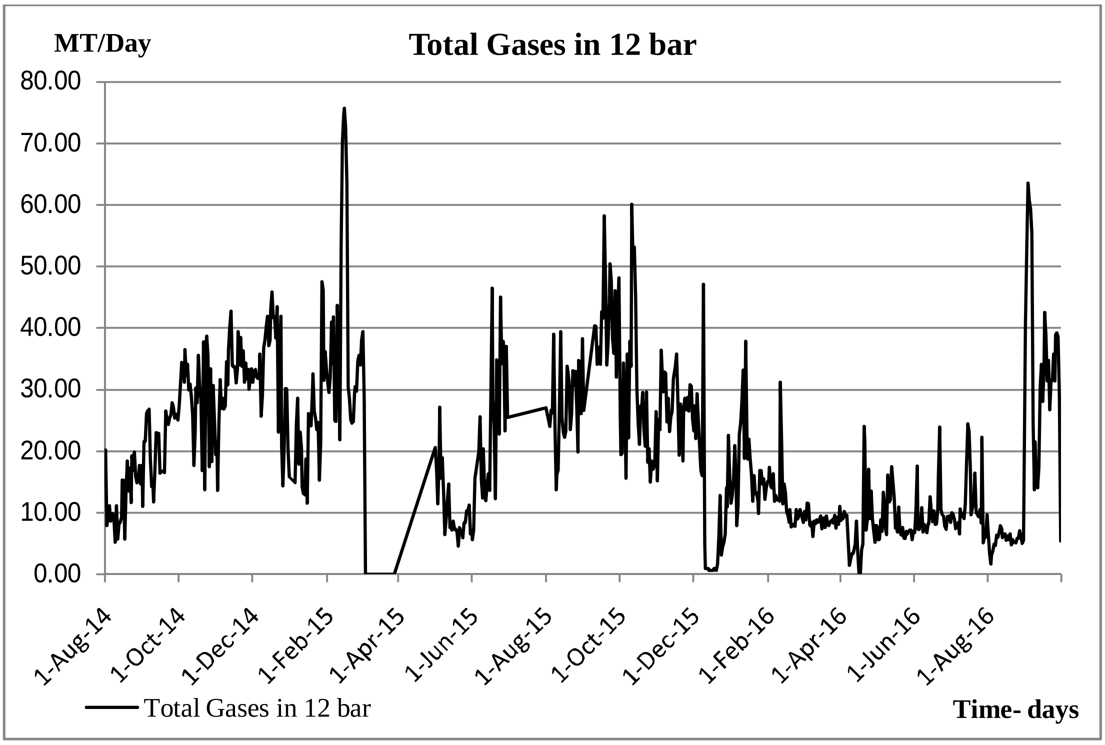

Figure 5-10 : Total Gases in 12 bar

5.6.3. Gases in pressures below 18 bar and 12 bar

The gases generate below 12 bar having potential to regulate pressure varies from 0.00 to 72.74 MT/Day. Rest gases except gases having 18 bar and 12 bar is listed in figure 5-11.

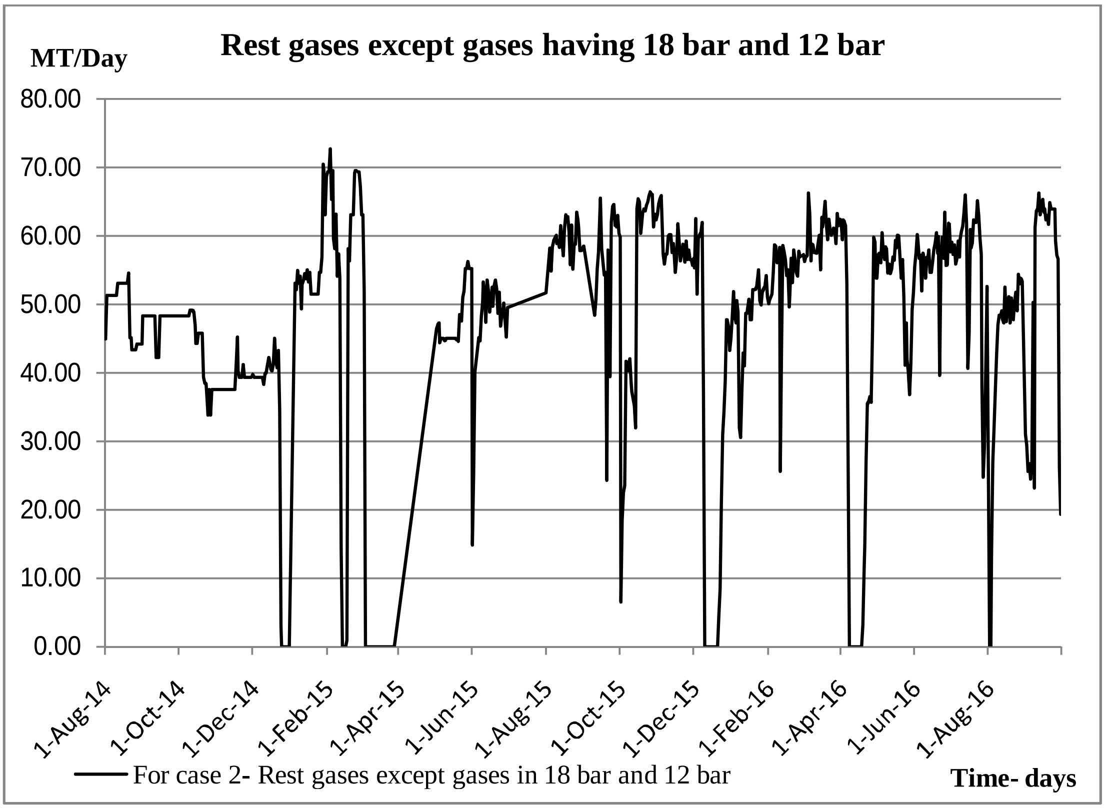

Figure 5-11 : Rest gases except gases having 18 bar and 12 bar

5.7. Case 3

5.7.1. Flow description

Flare gas collector is fed with gas vessels having pressures of 18 bar, 12 bar and 7 bar respectively. Here also the arrangement is same as in case 1. But the flare gas collector and FG vessel is fed with 3 pressure stages. The gases with pressure above 18 bar is fed to vessel 1 and vessel_buff_1, The gases having pressure below 18 bar and above 12 bar is fed to vessel 2 and vessel _buff_2 and the gases having pressure above 7 bar and below 12 bar is fed to the vessel 3 and vessel _buff_3.

Vessel _buff_1 pressure is maintained by control valves CV 1_9, CV 1_6, CV 1_4 and CV 1_2 which controls the makeup gas flow, excess gas flow, gas from the process and gas to vessel 1. In vessel 1, except CV1_4 and CV 1_2, its set pressure of 18 bar is controlled by CV 1_8, CV 1_1, CV 1_5 and flow 1_3 which controls the gas flow to vessel FG, gas flow to vessel F, makeup gas flow and the gases from the process.

Vessel _buff_2 pressure, set to 12 bar, is maintained by control valves CV 2_9, CV 2_6, CV 2_4 and CV 2_2 which controls the makeup gas flow, excess gas flow, gas from the process and gas to vessel 2. In vessel 2, except CV2_4 and CV 2_2, its set pressure of 12 bar is controlled by CV 2_8, CV 2_1, CV 2_5 and flow 2_3. They control the gas flow to vessel FG, gas flow to vessel F, makeup gas flow and the gases from the process.

Vessel _buff_3 pressure, set to 7 bar, is maintained by control valves CV 3_9, CV 3_6, CV 3_4 and CV 3_2 which controls the makeup gas flow, excess gas flow, gas from the process and gas to vessel 3. In vessel 3, except CV3_4 and CV 3_2, its set pressure of 7 bar is controlled by CV 3_8, CV 3_1, CV 3_5 and flow 3_3. They control the gas flow to vessel FG, gas flow to vessel F, makeup gas flow and the gases from the process. Gas feeding to the vessel F and vessel FG are from vessel 1, vessel 2 and vessel 3. Other arrangements are same as in case 1.

5.7.2. Total Gases in 7 bar

The gases generated in between 7 bar and 12 bar varies from 0.00 to 37.79 MT/Day. Total gases in 7 bar is listed in figure 5-12.

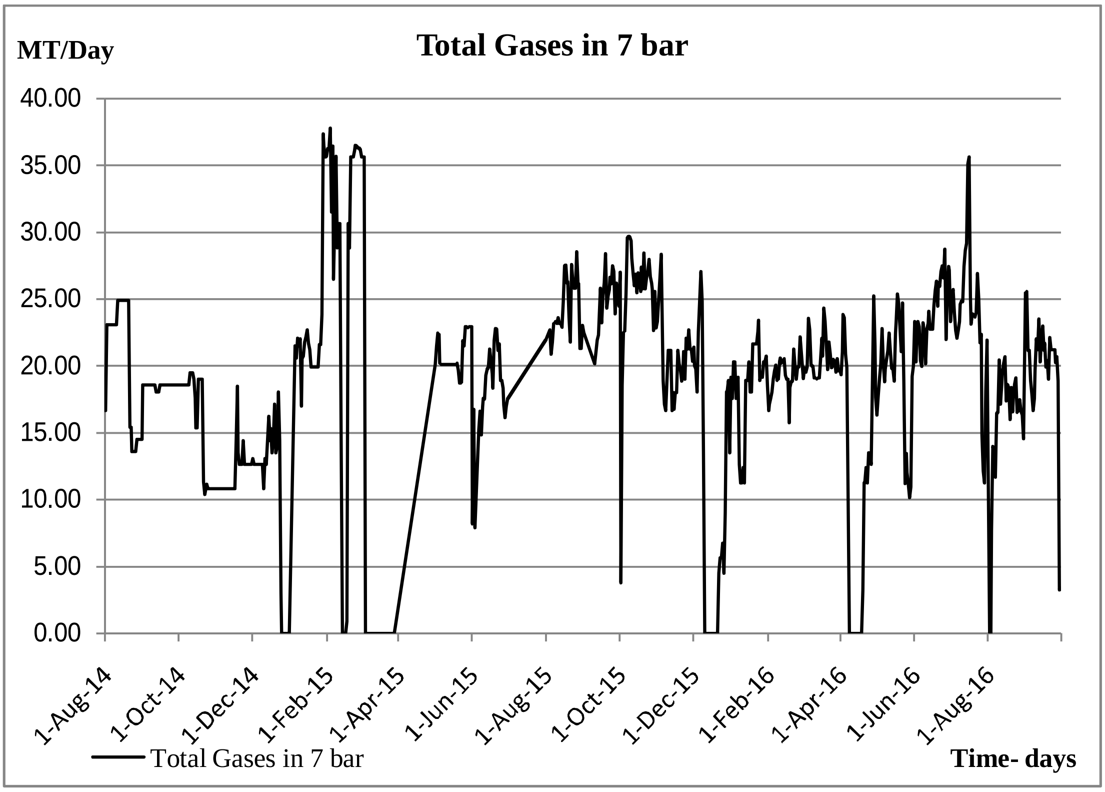

Figure 5-12 : Total Gases in 7 bar

5.7.3. Total Gases in above 3 bar and below 7 bar

The gases having no potential for producing a pressure regulating action according to the cases developed includes gasses generated in pressures below 7 bar and above 3 bar which varies from 0.00 to 42.76 MT/Day. The values are listed in figure 5-13.

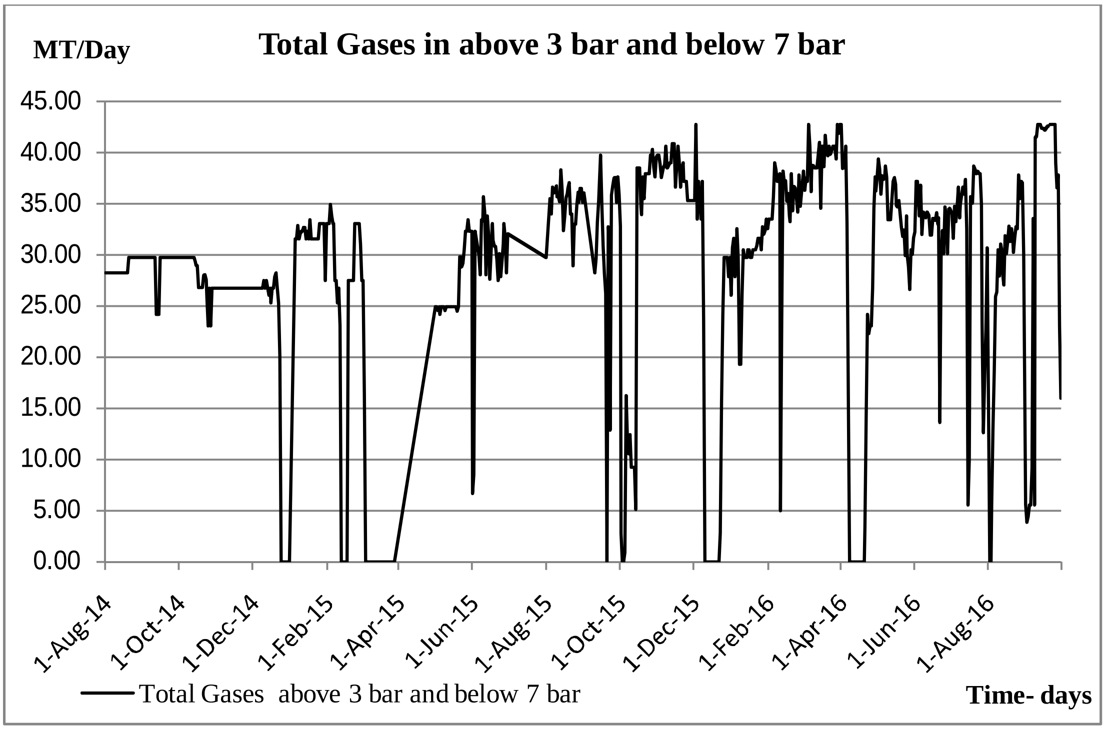

Figure 5-13 : Total Gases in above 3 bar and below 7 bar

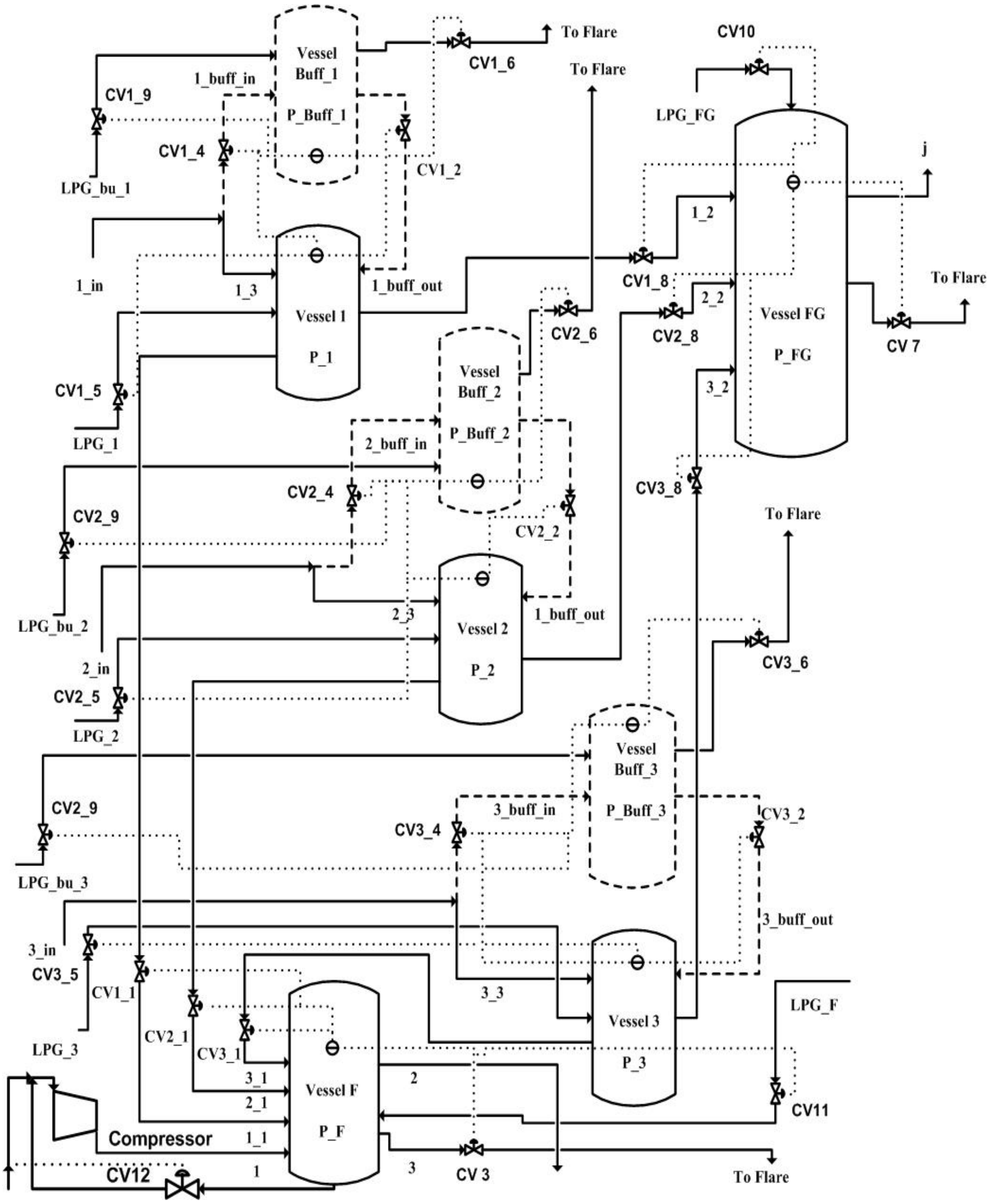

Figure 5-14 : Case 3

5.8. Discussion

In case 1 the gases used for to regulate the proposed FGN has an average value of 62 MT/Day. For case 2 the total gases having pressure above 12 bar has an average value of 53 MT/Day. In case 3 the total gases having pressure above 7 bar has an average value of 71 MT/Day. So increasing more pressure stages, we can achieve more gasses for regulating action. The total makeup gas flow variation is from 4 MT/Day to 86 MT/Day. The average value is 28 MT/Day. The high Make up gas flow indicates lack of gases produced in the plant. Figure 5-15 shows the total LPG requirement for the proposed study having flare gas recovery of 36 MT/Day.

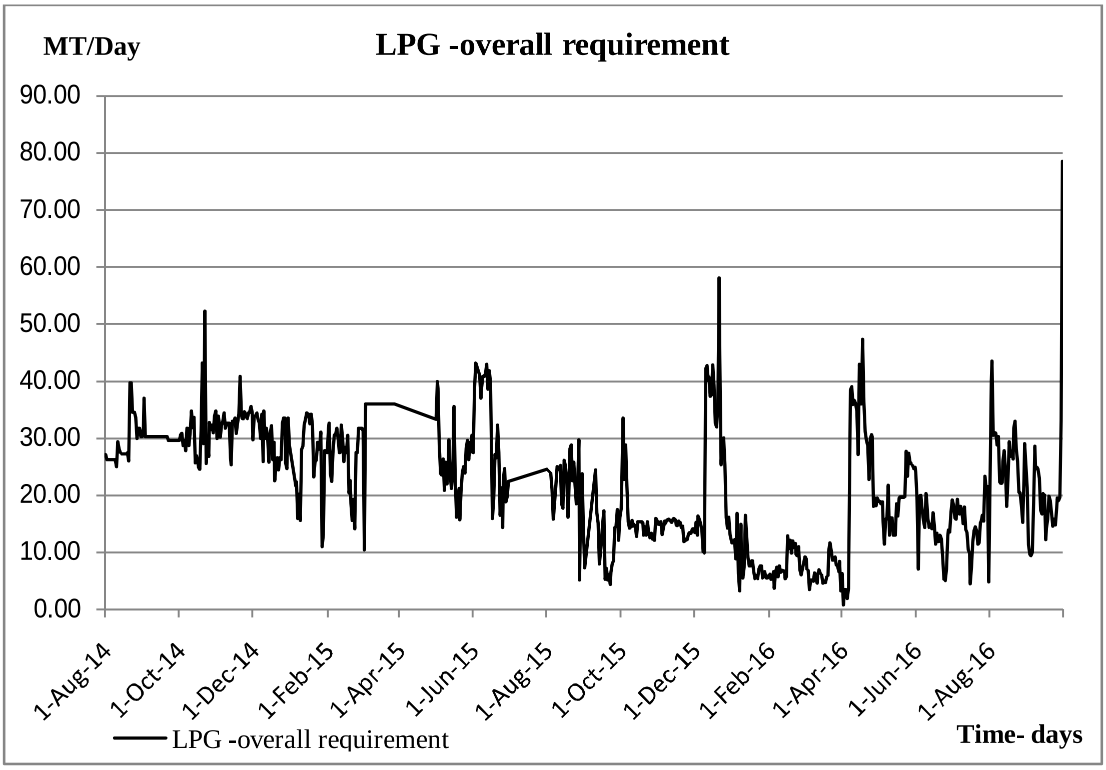

Figure 5-15 : Total LPG or makeup gas requirement

CHAPTER 6 : ENERGY SAVINGS

6.1. Introduction

The main utilization of waste gas from the flare system is considered to be used to generate electricity. Since the refinery currently expends huge amount of money to purchase extra electricity that cannot be generated inside the premises, this option was considered. Industrial electricity purchasing prices varies with the time of the day. It costs 23.5 LKR per kwh in peak hours, 10.25 LKR per kwh in day time and 5.9 LKR per kwh in off peak hours. Per day it has 4 peak hours, 13 day hours and 7 off peak hours defined. Table 6-1 shows the electricity demand for the refinery, month wise, and the relevant cost for to purchase electricity. For the analysis the power generation from a gas turbine in a combined cycle with overall efficiency of 55% is considered.

Table 6-1 : Purchased electricity cost **[7]**

Year	Month	Total Electricity demand from CEB- kWh per month	Current Total Cost for electricity- LKR/ month
2014	August	441,583	6,615,077
	September	538,093	7,726,027
	October	513,231	7,354,724
	November	501,738	7,158,703
	December	438,580	6,182,341
2015	January	380,324	5,368,495
	February	393,756	5,725,622
	March	263,435	3,986,241
	May	368,134	5,640,631
	June	504,549	7,300,438
	August	508,022	7,193,847
	September	472,916	6,706,756

Year	Month	Total Electricity demand from CEB- kWh per month	Current Total Cost for electricity- LKR/ month
2015	October	427,404	6,160,349
	November	528,779	7,526,357
	December	514,907	7,234,581
2016	January	463,969	6,521,806
	February	481,487	6,713,947
	March	432,370	6,263,650
	April	474,842	6,750,300
	May	441,701	6,368,683
	June	468,057	6,572,823
	July	499,070	7,055,095
	August	484,149	6,798,686
	September	492,508	6,910,385

For this study it is assumed generating an average power demand for the selected period. The average power demand is 459,734 kWh for the selected period. In order to full fill this requirement, three options were considered using recovered flare gas.

- Generating all the required power using the flare gas recovery flow.
- Generating only the peak and day loads using flare gas recovery and purchase the electricity for off peak loads.
- Generating only the peak loads using flare gas recovery and purchase the electricity for the rest requirements.

6.1.1. Situation 1

Here it is considered generating all the required power using the flare gas recovery system. The calculated values for net benefits from the current situation which is the process power requirement, and the proposed new system which considers the situation that all the power required from outside is generating with flare gas recovery system, are listed in Table 6-2. The months in 2014 August to December the net benefit from the proposed system becomes negative due to the high LPG price in the market. In 2015 February to march the total gas generation is stopped due to total plant shutdown hence the system is not profitable only with LPG. The rest months with net benefit with negative values are also due to the unit shutdowns that cause to reduce the gases from the process.

Table 6-2 : Generating power using the flare gas recovery system

Year - Month		Total LPG cost - LKR / month	Current Total Cost for electricity-LKR/ month	Total Electricity demand from CEB-kWh per month	For Current situation, Net benefit - LKR/ month	Net benefit from the new proposal-LKR/ month
2014	Aug	13,063,357	6,615,077	441,583	6,448,280	(6,418,087)
	Sep	15,861,730	7,726,027	538,093	8,135,703	(9,216,460)
	Oct	18,831,359	7,354,724	513,231	11,476,635	(12,186,089)
	Nov	20,059,606	7,158,703	501,738	12,900,903	(13,414,336)
	Dec	24,065,235	6,182,341	438,580	17,882,894	(17,419,965)
2015	Jan	6,577,854	5,368,495	380,324	1,209,359	67,416
	Feb	6,839,414	5,725,622	393,756	1,113,792	(194,144)
	Mar	16,771,263	3,986,241	263,435	12,785,023	(10,125,994)
	May	5,831,102	5,640,631	368,134	190,472	814,168
	Jun	21,200,141	7,300,438	504,549	13,899,704	(14,554,871)
	Aug	4,137,729	7,193,847	508,022	(3,056,118)	2,507,541
	Sep	408,838	6,706,756	472,916	(6,297,918)	6,236,432
	Oct	3,650,834	6,160,349	427,404	(2,509,515)	2,994,436
	Nov	4,550,111	7,526,357	528,779	(2,976,246)	2,095,159
	Dec	33,507,776	7,234,581	514,907	26,273,195	(26,862,506)
2016	Jan	1,471,502	6,521,806	463,969	(5,050,305)	5,173,768
	Feb	1,013,766	6,713,947	481,487	(5,700,181)	5,631,504

Year - Month		Total LPG cost - LKR / month	Current Total Cost for electricity- LKR/ month	Total Electricity demand from CEB- kWh per month	For Current situation, Net benefit - LKR/ month	Net benefit from the new proposal- LKR/ month
2016	Mar	-	6,263,650	432,370	(6,263,650)	6,645,270
	Apr	20,270,503	6,750,300	474,842	13,520,203	(13,625,233)
	May	7,202,847	6,368,683	441,701	834,164	(557,577)
	Jun	1,535,426	6,572,823	468,057	(5,037,397)	5,109,844
	Jul	-	7,055,095	499,070	(7,055,095)	6,645,270
	Aug	12,205,152	6,798,686	484,149	5,406,466	(5,559,882)
	Sep	6,144,343	6,910,385	492,508	(766,042)	500,927

6.1.2. Situation 2

Here it is considered generating only the peak and day loads using flare gas recovery and purchase the electricity for off peak loads. Cost for kVa is taken by CEB. The situation is same as 6.2.3. But the net gain is more in profitable months.

Table 6-3 : Generating only the peak and day loads using flare gas recovery

Year/ month		Total LPG requireme nt - kg / month	Current Total Cost for electricity - LKR/ month	Total Electricit y demand from CEB- per month	Current situation, Net benefit - LKR	Net benefit from the new proposal- LKR
2014	Aug	4,859,949	6,615,077	441,583	246,027	(1,085,764)
	Sep	4,525,014	7,726,027	538,093	(1,337,772)	(750,829)
	Oct	7,942,140	7,354,724	513,231	3,857,709	(4,167,956)

Year/ month		Total LPG requirement - kg / month	Current Total Cost for electricity - LKR/ month	Total Electricity demand from CEB- per month	Current situation, Net benefit - LKR	Net benefit from the new proposal- LKR
2015	Nov	9,092,547	7,158,703	501,738	5,677,834	(5,318,362)
	Dec	12,178,078	6,182,341	438,580	11,010,239	(8,403,893)
	Jan	2,270,609	5,368,495	380,324	(2,162,929)	1,503,576
	Feb	2,100,976	5,725,622	393,756	(2,759,538)	1,673,208
	Mar	8,572,589	3,986,241	263,435	8,116,238	(4,798,404)
	May	2,417,932	5,640,631	368,134	(2,227,080)	1,356,253
	Jun	12,563,925	7,300,438	504,549	10,436,868	(8,789,740)
	Aug	1,085,456	7,193,847	508,022	(5,661,438)	2,688,728
	Sep	59,350	6,706,756	472,916	(6,622,968)	3,714,835
	Oct	1,339,047	6,160,349	427,404	(4,269,930)	2,435,138
	Nov	603,180	7,526,357	528,779	(6,674,808)	3,171,004
	Dec	19,484,628	7,234,581	514,907	20,273,128	(15,710,443)
2016	Jan	297,590	6,521,806	463,969	(6,101,679)	3,476,594
	Feb	60,356	6,713,947	481,487	(6,628,739)	3,713,828
	Mar	-	6,263,650	432,370	(6,263,650)	3,774,185
	Apr	11,576,745	6,750,300	474,842	9,593,340	(7,802,560)
	May	2,469,169	6,368,683	441,701	(2,882,798)	1,305,016
	Jun	252,082	6,572,823	468,057	(6,216,942)	3,522,102
	Jul	-	7,055,095	499,070	(7,055,095)	3,774,185
	Aug	5,958,594	6,798,686	484,149	1,613,446	(2,184,409)
	Sep	3,305,565	6,910,385	492,508	(979,169)	468,619

6.1.3. Situation 3

In this situation it is considered generating only the peak and day loads using flare gas recovery and purchase the electricity for off peak loads. Cost for kVa is bared by refinery. Here the situation is same as 6.2.5. But the profitability is more since the cost for kVa is bared by the power generation using the flare gas recovery.

Table 6-4 : Generating only the peak and day loads

Year/month		Total LPG requirement - kg / month	Current Total Cost for electricity - LKR/ month	Total Electricity demand from CEB- per month	Current situation, Net benefit - LKR	Net benefit from the new proposal- LKR
2014	Aug	4,859,949	6,615,077	441,583	246,027	414,236
	Sep	4,525,014	7,726,027	538,093	(1,337,772)	749,171
	Oct	7,942,140	7,354,724	513,231	3,857,709	(2,667,956)
	Nov	9,092,547	7,158,703	501,738	5,677,834	(3,818,362)
	Dec	12,178,078	6,182,341	438,580	11,010,239	(6,903,893)
2015	Jan	2,270,609	5,368,495	380,324	(2,162,929)	3,003,576
	Feb	2,100,976	5,725,622	393,756	(2,759,538)	3,173,208
	Mar	8,572,589	3,986,241	263,435	8,116,238	(3,298,404)
	May	2,417,932	5,640,631	368,134	(2,227,080)	2,856,253
	Jun	12,563,925	7,300,438	504,549	10,436,868	(7,289,740)
	Aug	1,085,456	7,193,847	508,022	(5,661,438)	4,188,728
	Sep	59,350	6,706,756	472,916	(6,622,968)	5,214,835
	Oct	1,339,047	6,160,349	427,404	(4,269,930)	3,935,138
	Nov	603,180	7,526,357	528,779	(6,674,808)	4,671,004
	Dec	19,484,628	7,234,581	514,907	20,273,128	(14,210,443)
2016	Jan	297,590	6,521,806	463,969	(6,101,679)	4,976,594

Year/month		Total LPG requirement - kg / month	Current Total Cost for electricity - LKR/ month	Total Electricity demand from CEB- per month	Current situation, Net benefit - LKR	Net benefit from the new proposal- LKR
2016	Feb	60,356	6,713,947	481,487	(6,628,739)	5,213,828
	Mar	-	6,263,650	432,370	(6,263,650)	5,274,185
	Apr	11,576,745	6,750,300	474,842	9,593,340	(6,302,560)
	May	2,469,169	6,368,683	441,701	(2,882,798)	2,805,016
	Jun	252,082	6,572,823	468,057	(6,216,942)	5,022,102
	Jul	-	7,055,095	499,070	(7,055,095)	5,274,185
	Aug	5,958,594	6,798,686	484,149	1,613,446	(684,409)
	Sep	3,305,565	6,910,385	492,508	(2,243,705)	1,968,619

6.1.4. Situation 4

Generating only the peak loads using flare gas recovery and purchase the electricity for the rest requirement and kVa from CEB is not viable since in every month the total profit becomes negative. In that case the current power generation and sell the LPG that would have been used in the process is profitable.

6.1.5. Situation 5

In this situation it is considered generating electricity only for the peak loads using flare gas recovery and purchasing the electricity for the rest requirement. kVa is from the refinery. The highest profitable situation arises in here. By purchasing electricity and sell LPG is having negative profit values in many months and in the proposed situation except for months in unit shutdowns the net benefit becomes positive.

Table 6-5 : Generating electricity only for the peak loads

Year/month		Total LPG requirement - LKR / month	Current Total Cost for electricity - LKR/ month	Total Electricity demand from CEB- per month	Current situation, Net benefit - LKR	Net benefit from the new proposal- LKR
2014	Aug	223,949	6,615,077	441,583	(5,271,385)	485,728
	Sep	51,155	7,726,027	538,093	(7,419,100)	658,522
	Oct	520,671	7,354,724	513,231	(4,230,700)	189,006
	Nov	132,250	7,158,703	501,738	(6,365,206)	577,427
	Dec	791,715	6,182,341	438,580	(1,432,049)	(82,038)
2015	Jan	1,409	5,368,495	380,324	(5,360,041)	708,268
	Feb	-	5,725,622	393,756	(5,725,622)	709,677
	Mar	413,981	3,986,241	263,435	(1,502,354)	295,696
	May	173,619	5,640,631	368,134	(4,598,915)	536,058
	Jun	1,826,691	7,300,438	504,549	3,659,708	(1,117,014)
	Aug	-	7,193,847	508,022	(7,193,847)	709,677
	Sep	-	6,706,756	472,916	(6,706,756)	709,677
	Oct	74,501	6,160,349	427,404	(5,713,344)	635,176
	Nov	-	7,526,357	528,779	(7,526,357)	709,677
	Dec	3,061,329	7,234,581	514,907	11,133,392	(2,351,652)
2016	Jan	-	6,521,806	463,969	(6,521,806)	709,677
	Feb	-	6,713,947	481,487	(6,713,947)	709,677
	Mar	-	6,263,650	432,370	(6,263,650)	709,677
	Apr	1,528,522	6,750,300	474,842	2,420,834	(818,845)
	May	72,349	6,368,683	441,701	(5,934,587)	637,327
	Jun	-	6,572,823	468,057	(6,572,823)	709,677
	Jul	-	7,055,095	499,070	(7,055,095)	709,677
	Aug	459,735	6,798,686	484,149	(4,040,274)	249,942

Year/month		Total LPG requirement - LKR / month	Current Total Cost for electricity - LKR/ month	Total Electricity demand from CEB- per month	Current situation, Net benefit - LKR	Net benefit from the new proposal- LKR
2016	Sep	558,427	6,910,385	492,508	(3,559,823)	151,250

6.2. Discussion

The profitability of using the flare gas recovered depends on the excess gases generated within the refinery, total gasses used in the process furnaces, total electricity demand and the makeup gas price. Considering LPG as a makeup gas and with the low LPG prices, there is a significant profit achieved in above situations from situation 1 to situation 5 except in situation 4. Even though the LPG price becomes low, if the gas generation within the refinery reduces the profitability becomes negative. In most cases if the plant is running in steady conditions, using the proposed model is profitable.

CHAPTER 7 : CONCLUSION AND FUTURE WORK

The study was carried out based on the idea of recovering the excess gas flow daily emits from the flare system of Sapugaskanda oil refinery. The existing process generates gases from 0.00 to 159.83 MT/Day within the time period considered (August 2014 to September 2016). Other than that, out of those gases generated, an average amount of 92.96 MT/Day which has a minimum of 0.00 and a maximum of 140.83 MT/Day was used for process heaters. Total amount that is burned without taking any usage varies from 0 to 35.21 MT/Day. Considering the average gas compositions of the flare gas it carries 9763 KJ/Kg of energy which is a very high value that can easily be used to generate electricity which is purchased from outside at present. But the main problem is the high fluctuating gas flow comes to the flare system that makes it very hard to feed for a gas generating facility. Some countries use this to compress and re inject to the fuel gas system, but here there is always an excess gas amount exists in the FGN.

To develop the gas recovery system a pressure vessel arrangement was proposed having multiple pressure stages which are maintained using the pressures generated within the processes. 7 Gas sources and 17 gas streams having different pressures were identified in the oil refinery considered. The model was proposed for a single pressure stage and it was tested for 7 different gas flow variations from the plant. Those conditions were taken based on the patterns of gas fluctuation observed in the day to day operation. Other than that, the variations that can occur for the gas flow to process heaters, if a side stream is taken out from the FGN, is also considered. The model was developed and simulated in MATLAB to assess the results. The results gave a smooth out put out of the FGN to the existing process heaters and a gas stream to power generation.

Plant data was analyzed based on the model proposed in steady state cases. Here the gas collection was proposed to have 3 pressure stages namely 18 bar, 12 bar and 7 bar. Those pressures were considered due to the high amount of gas availability considering the collected data. The overall LPG or makeup gas consumption was calculated to generate a 36 MT/Day constant gas flow output for power generation. With the high usage of process gases having multiple pressures, the regulating action becomes easy (With more pressure stages).

Finally the cost calculation was done to assess whether the proposed facility is viable to produce electricity or purchasing electricity is viable. There also 3 cases were considered. It includes that generating power only for the peak loads, only for peak and day time loads and generating power for all peak ,day and off peak periods. There the total profit for using the recovered flare gas becomes positive in all the cases in many months. The months that total profit becomes negative mostly contain a major shutdown of the plant, a unit shut down or an abnormal price increase of LPG. In profitable situations the plant is having more gases and all the units running.

As future works some recommendations can be suggested further improve the system. The system can get rid of excess toxic gases mainly from H_2S by adding a gas cleaning unit. Other than that, the pressure stages for the system should be considered with the future plan of the refinery that evaluates future gas generation patterns according to the catalytic unit activities. The changes in process units and catalysts used in the process, change the amount of gases generate heavily. So in order to have profits from the proposed system those things should be considered. LPG consumption as specified for the oil refinery in Sri Lanka should be considered with the cost of LPG that can be used to sell LPG as a fuel to outside market. If the cost is high, a plan should be there to use the system in optimum time periods. Other than that, if natural gas can be used to making up the gases required the system is profitable in all the time since it costs very low compared to the LPG price.

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APPENDIX A

A.1. Energy potential of the flare gas

Average gas compositions of flare gas

Table A-0-1 : Average flare gas composition

Component	Vol %	Mol. wt	wt %
H2S	5.000	66	15.127
H2	43.023	2	3.944
C1	16.088	16	11.800
C2	14.050	30	19.321
C3	13.070	44	26.362
iC4	3.271	58	8.696
nC4	5.294	58	14.076
iC5	0.204	72	0.674
nC5	0.000	72	0.000
Total	**100.000**	**418.000**	**100.000**

A.1.1 Element wise weight fraction

Table A-0-2 : Element wise weight fraction

%	**C1**	**C2**	**C3**	**iC4**	**nC4**	**iC5**	**nC5**	**H2S**	**H2**	**Total**
C	8.85	15.46	21.57	7.20	11.65	0.56	0.00	0.00	0.00	65.28
H	2.95	3.86	4.79	1.50	2.43	0.11	0.00	0.47	3.94	20.06
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.65	0.00	14.65

A.1.2. Estimating energy potential

$$\mathrm{HHV} = 14500 \times \mathrm{C} + 62000 \times \left(\mathrm{H}_2 - \frac{\mathrm{O}_2}{8}\right) + 4000 \times \mathrm{S}$$

Equation A-1 **[23] [29]**

$$HHV = 14500 \times 0.653 + 62000 \times \left(0.201 - \frac{0}{8}\right) + 4000 \times 0.147$$

$$HHV = 22518.5 \text{ Btu/lb}$$

$$LHV = HHV - 9720 \times H_2 - 1110W$$

Equation A-2 **[23] [29]**

$$LHV = 22518.5 - 9720 \times 0.201 - 0$$

$$LHV = 20564.78 \text{ Btu/lb}$$

APPENDIX B

The data gathered from the Sapugaskanda oil refinery from 2014 August to 2016 September. LPG overall requirement is based on 36 MT/Day flare gas recovery.

Date	**Total Gases in 18 bar**	**Total Gases in 12 bar**	**Total Gases in 7 bar**	**Total Gases above 3 bar and below 7 bar**	**For case 1 - Rest gases except gases in 18 bar**	**For case 2- Rest gases except gases in 18 bar and 12 bar**	**Exist LPG make up flow**	**Total gas to FG system**	**Fuel gas to flare**	**Total gas to flare**	**Total Fuel gas to Units**	**To Fuel**	**LPG - overall require ment**
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
1-Aug-14	32.29	20.19	16.69	28.25	65.13	44.95	1.85	99.27	9.14	10.66	90.13	90.13	27.19
2-Aug-14	34.91	7.95	23.09	28.25	59.29	51.34	1.85	96.05	10.06	11.57	86.00	86.00	26.28
3-Aug-14	34.91	9.25	23.09	28.25	60.59	51.34	1.85	97.35	10.06	11.57	87.30	87.30	26.28
4-Aug-14	34.91	11.15	23.09	28.25	62.49	51.34	1.85	99.25	10.06	11.57	89.19	89.19	26.28
5-Aug-14	34.91	8.65	23.09	28.25	59.99	51.34	1.85	96.75	10.06	11.57	86.70	86.70	26.28
6-Aug-14	34.91	9.48	23.09	28.25	60.82	51.34	1.85	97.58	10.06	11.57	87.53	87.53	26.28
7-Aug-14	34.91	9.85	23.09	28.25	61.19	51.34	1.85	97.95	10.06	11.57	87.90	87.90	26.28
8-Aug-14	34.91	9.06	23.09	28.25	60.40	51.34	1.85	97.16	10.06	11.57	87.11	87.11	26.28
9-Aug-14	34.91	5.24	23.09	28.25	56.58	51.34	1.85	93.34	10.06	11.57	83.28	83.28	26.28
10-Aug-14	34.91	11.09	23.09	28.25	62.43	51.34	0.62	97.95	10.06	11.57	87.90	87.90	25.04
11-Aug-14	31.59	5.70	24.89	28.25	58.85	53.14	4.32	94.75	10.06	10.97	84.70	84.70	29.36
12-Aug-14	31.59	8.19	24.89	28.25	61.33	53.14	4.32	97.24	10.06	12.18	87.18	87.18	28.15
13-Aug-14	31.59	8.52	24.89	28.25	61.66	53.14	4.32	97.57	10.06	12.79	87.51	87.51	27.54

A	B	C	D	E	F	G	H	I	J	K	L	M	N
14-Aug-14	31.59	9.24	24.89	28.25	62.38	53.14	4.32	98.29	10.06	13.09	88.23	88.23	27.24
15-Aug-14	31.59	15.24	24.89	28.25	68.39	53.14	4.32	104.30	10.06	13.09	94.24	94.24	27.24
16-Aug-14	31.59	15.25	24.89	28.25	68.39	53.14	4.32	104.30	10.06	13.09	94.24	94.24	27.24
17-Aug-14	35.61	5.75	24.89	28.25	58.89	53.14	4.32	98.83	10.06	13.09	88.77	88.77	27.24
18-Aug-14	35.61	13.62	24.89	28.25	66.76	53.14	4.32	106.70	10.06	13.09	96.64	96.64	27.24
19-Aug-14	35.61	18.44	24.89	28.25	71.58	53.14	4.32	111.52	9.75	12.78	101.76	101.76	27.54
20-Aug-14	29.35	13.49	24.89	29.74	68.12	54.63	4.32	101.80	9.75	14.30	92.05	92.05	26.03
21-Aug-14	29.00	17.23	15.42	29.74	62.39	45.16	11.68	103.07	5.49	7.91	97.58	97.58	39.77
22-Aug-14	29.00	11.68	15.42	29.74	56.84	45.16	11.68	97.52	5.49	7.91	92.03	92.03	39.77
23-Aug-14	29.45	19.23	13.62	29.74	62.59	43.36	4.94	96.98	5.49	6.40	91.49	91.49	34.55
24-Aug-14	29.45	16.85	13.62	29.74	60.21	43.36	4.94	94.60	5.49	6.40	89.11	89.11	34.55
25-Aug-14	29.45	19.82	13.62	29.74	63.18	43.36	4.94	97.57	5.49	6.40	92.08	92.08	34.55
26-Aug-14	29.45	15.87	13.62	29.74	59.22	43.36	4.94	93.62	5.49	7.30	88.13	88.13	33.64
27-Aug-14	29.45	14.86	14.52	29.74	59.12	44.26	1.24	89.80	5.49	7.30	84.32	84.32	29.93
28-Aug-14	29.45	15.25	14.52	29.74	59.51	44.26	1.24	90.19	4.57	5.48	85.62	85.62	31.75
29-Aug-14	29.45	17.65	14.52	29.74	61.91	44.26	1.24	92.60	4.57	5.48	88.02	88.02	31.75
30-Aug-14	29.45	14.70	14.52	29.74	58.96	44.26	1.24	89.64	4.57	7.00	85.07	85.07	30.24
31-Aug-14	29.45	17.67	14.52	29.74	61.93	44.26	1.24	92.61	4.57	7.00	88.04	88.04	30.24
1-Sep-14	29.45	10.98	18.58	29.74	59.30	48.32	1.24	89.98	4.57	5.48	85.41	85.41	31.75
2-Sep-14	29.45	21.47	18.58	29.74	69.79	48.32	1.24	100.48	4.57	7.00	102.69	102.69	37.02
3-Sep-14	29.45	21.59	18.58	29.74	69.90	48.32	1.24	100.59	4.57	7.00	96.02	96.02	30.24
4-Sep-14	29.45	26.04	18.58	29.74	74.36	48.32	1.24	105.05	4.57	7.00	100.48	100.48	30.24
5-Sep-14	29.45	26.59	18.58	29.74	74.91	48.32	1.24	105.59	4.57	7.00	101.02	101.02	30.24
6-Sep-14	29.45	26.82	18.58	29.74	75.14	48.32	1.24	105.82	4.57	7.00	101.25	101.25	30.24
7-Sep-14	29.45	18.63	18.58	29.74	66.95	48.32	1.24	97.64	4.57	7.00	93.06	93.06	30.24
8-Sep-14	29.45	14.19	18.58	29.74	62.51	48.32	1.24	93.19	4.57	7.00	88.62	88.62	30.24
9-Sep-14	29.45	14.54	18.58	29.74	62.86	48.32	1.24	93.55	4.57	7.00	88.97	88.97	30.24
10-Sep-14	29.45	11.77	18.58	29.74	60.09	48.32	1.24	90.77	4.57	7.00	86.20	86.20	30.24
11-Sep-14	29.45	16.69	18.58	29.74	65.01	48.32	1.24	95.70	4.57	7.00	91.12	91.12	30.24

A	B	C	D	E	F	G	H	I	J	K	L	M	N
12-Sep-14	29.45	22.93	18.04	24.18	65.15	42.22	1.24	95.84	4.57	7.00	91.26	91.26	30.24
13-Sep-14	29.45	22.89	18.04	24.18	65.10	42.22	1.24	95.79	4.57	7.00	91.22	91.22	30.24
14-Sep-14	29.45	22.82	18.04	24.18	65.04	42.22	1.24	95.72	4.57	7.00	91.15	91.15	30.24
15-Sep-14	29.45	16.46	18.58	29.74	64.78	48.32	1.24	95.46	4.57	7.00	90.89	90.89	30.24
16-Sep-14	29.45	16.69	18.58	29.74	65.01	48.32	1.24	95.70	4.57	7.00	91.12	91.12	30.24
17-Sep-14	29.45	16.70	18.58	29.74	65.02	48.32	1.24	95.71	4.57	7.00	91.13	91.13	30.24
18-Sep-14	29.45	16.73	18.58	29.74	65.04	48.32	1.24	95.73	4.57	7.00	91.16	91.16	30.24
19-Sep-14	29.45	16.49	18.58	29.74	64.81	48.32	1.24	95.50	4.57	7.00	90.93	90.93	30.24
20-Sep-14	29.45	26.54	18.58	29.74	74.86	48.32	1.24	105.54	4.57	7.00	100.97	100.97	30.24
21-Sep-14	29.45	25.11	18.58	29.74	73.43	48.32	1.24	104.12	4.57	7.00	99.54	99.54	30.24
22-Sep-14	29.45	24.28	18.58	29.74	72.60	48.32	1.24	103.28	4.57	7.60	98.71	98.71	29.63
23-Sep-14	29.45	25.33	18.58	29.74	73.64	48.32	1.24	104.33	4.57	7.60	99.76	99.76	29.63
24-Sep-14	29.45	25.86	18.58	29.74	74.18	48.32	1.24	104.87	4.57	7.60	100.30	100.30	29.63
25-Sep-14	29.45	27.87	18.58	29.74	76.19	48.32	1.24	106.87	4.57	7.60	102.30	102.30	29.63
26-Sep-14	29.45	27.12	18.58	29.74	75.44	48.32	1.24	106.12	4.57	7.60	101.55	101.55	29.63
27-Sep-14	29.45	25.34	18.58	29.74	73.66	48.32	1.24	104.34	4.57	7.60	99.77	99.77	29.63
28-Sep-14	29.45	25.98	18.58	29.74	74.30	48.32	1.24	104.99	4.57	7.60	100.42	100.42	29.63
29-Sep-14	29.45	25.90	18.58	29.74	74.22	48.32	1.24	104.91	4.57	7.60	100.34	100.34	29.63
30-Sep-14	29.45	25.09	18.58	29.74	73.41	48.32	1.24	104.10	4.57	7.60	99.53	99.53	29.63
1-Oct-14	29.45	27.38	18.58	29.74	75.70	48.32	1.24	106.38	4.57	7.60	101.81	101.81	29.63
2-Oct-14	29.45	30.90	18.58	29.74	79.22	48.32	1.24	109.90	3.66	6.69	106.25	106.25	30.55
3-Oct-14	29.45	34.38	18.58	29.74	82.69	48.32	1.24	113.38	3.35	6.38	110.03	110.03	30.85
4-Oct-14	29.45	33.57	18.58	29.74	81.89	48.32	1.24	112.58	5.49	8.52	107.09	107.09	28.72
5-Oct-14	31.69	31.22	18.58	29.74	79.54	48.32	1.24	112.47	4.57	7.60	107.90	107.90	29.63
6-Oct-14	30.79	36.48	18.58	29.74	84.80	48.32	1.24	116.83	6.40	9.43	110.43	110.43	27.80
7-Oct-14	29.90	32.22	18.58	29.74	80.53	48.32	1.24	111.67	2.44	5.47	109.23	109.23	31.77
8-Oct-14	30.35	34.14	18.58	29.74	82.46	48.32	1.24	114.04	2.44	5.47	111.61	111.61	31.77
9-Oct-14	29.45	29.96	18.58	29.74	78.28	48.32	1.24	108.97	5.49	8.52	103.48	103.48	28.72
10-Oct-14	29.45	30.89	19.48	29.74	80.11	49.22	2.47	112.03	5.03	7.45	107.00	107.00	31.02

A	B	C	D	E	F	G	H	I	J	K	L	M	N
11-Oct-14	29.45	28.88	19.48	29.74	78.10	49.22	3.09	110.64	2.07	4.35	108.57	108.57	34.74
12-Oct-14	36.92	25.85	19.48	29.74	75.07	49.22	3.09	115.07	5.00	7.27	110.08	110.08	31.82
13-Oct-14	36.92	17.63	19.03	29.74	66.40	48.77	2.47	105.79	2.44	4.86	103.35	103.35	33.61
14-Oct-14	37.84	23.17	17.63	29.33	70.14	46.97	2.47	110.45	10.06	12.79	100.39	100.39	25.69
15-Oct-14	37.80	30.26	15.36	29.01	74.63	44.37	2.47	114.90	9.14	11.57	105.75	105.75	26.90
16-Oct-14	38.69	27.82	15.36	28.95	72.12	44.31	2.16	112.98	10.36	12.48	102.61	102.61	25.68
17-Oct-14	37.16	35.50	19.01	26.80	81.31	45.81	1.24	119.71	10.36	12.18	109.35	109.35	25.05
18-Oct-14	37.16	30.44	19.01	26.80	76.25	45.81	1.24	114.65	10.85	12.67	103.80	103.80	24.57
19-Oct-14	37.16	28.30	19.01	26.80	74.11	45.81	1.24	112.51	4.27	6.09	108.24	108.24	31.15
20-Oct-14	37.16	16.86	19.01	26.80	62.68	45.81	1.24	101.08	9.75	10.97	108.29	108.29	43.24
21-Oct-14	35.55	37.75	11.32	28.01	77.08	39.34	2.78	115.42	8.53	9.75	106.88	106.88	29.03
22-Oct-14	34.80	13.67	10.40	28.09	52.16	38.49	2.47	89.44	7.32	9.13	105.12	105.12	52.34
23-Oct-14	34.49	37.50	10.90	27.55	75.95	38.45	2.47	112.91	10.52	12.94	102.39	102.39	25.53
24-Oct-14	34.49	38.66	11.14	25.89	75.69	37.03	2.47	112.64	8.53	8.84	104.11	104.11	29.63
25-Oct-14	34.49	35.46	10.82	23.06	69.35	33.89	0.00	103.84	8.53	9.14	95.30	95.30	26.86
26-Oct-14	43.48	17.48	10.82	26.78	55.08	37.61	8.03	106.59	8.84	11.26	97.75	97.75	32.77
27-Oct-14	37.04	33.39	10.82	23.06	67.27	33.89	0.00	104.31	4.27	5.48	101.03	101.03	31.51
28-Oct-14	39.49	18.27	10.82	26.78	55.88	37.61	1.85	97.22	4.88	5.48	92.34	92.34	32.37
29-Oct-14	39.49	30.67	10.82	26.78	68.27	37.61	1.24	108.99	5.49	6.24	103.51	103.51	30.99
30-Oct-14	39.49	25.36	10.82	26.78	62.96	37.61	1.85	104.30	3.35	3.96	100.95	100.95	33.89
31-Oct-14	39.49	19.42	10.82	26.78	57.02	37.61	1.85	98.36	2.44	3.04	95.92	95.92	34.81
1-Nov-14	39.49	21.42	10.82	26.78	59.03	37.61	1.85	100.36	3.35	3.96	93.11	93.11	29.99
2-Nov-14	39.49	13.63	10.82	26.78	51.24	37.61	1.85	92.58	3.35	3.96	89.22	89.22	33.89
3-Nov-14	39.49	24.44	10.82	26.78	62.05	37.61	1.54	103.08	4.57	5.48	98.51	98.51	32.06
4-Nov-14	39.49	31.58	10.82	26.78	69.18	37.61	0.00	108.67	3.66	5.78	105.01	105.01	30.22
5-Nov-14	39.49	26.96	10.82	26.78	64.57	37.61	0.00	104.05	3.05	3.65	101.00	101.00	32.35
6-Nov-14	39.49	28.58	10.82	26.78	66.19	37.61	0.00	105.67	2.44	3.04	103.23	103.23	32.96
7-Nov-14	39.49	26.81	10.82	26.78	64.41	37.61	0.00	103.90	3.66	4.26	102.91	102.91	34.41
8-Nov-14	39.49	27.31	10.82	26.78	64.91	37.61	0.00	104.40	3.66	4.26	100.74	100.74	31.74

A	B	C	D	E	F	G	H	I	J	K	L	M	N
9-Nov-14	30.98	34.54	10.82	26.78	72.14	37.61	0.00	103.12	1.83	2.74	100.73	100.73	32.70
10-Nov-14	30.98	30.75	10.82	26.78	68.35	37.61	0.00	99.34	2.44	3.35	96.90	96.90	32.65
11-Nov-14	30.98	36.52	10.82	26.78	74.13	37.61	0.00	105.11	2.44	3.35	102.67	102.67	32.65
12-Nov-14	26.52	40.07	10.82	26.78	77.68	37.61	0.62	104.82	9.14	10.05	95.68	95.68	26.56
13-Nov-14	26.52	42.75	10.82	26.78	80.36	37.61	0.62	107.50	10.36	11.27	97.14	97.14	25.35
14-Nov-14	26.52	33.95	10.82	26.78	71.56	37.61	0.62	98.70	2.74	3.65	95.96	95.96	32.97
15-Nov-14	26.52	33.71	10.82	26.78	71.32	37.61	0.93	98.77	3.66	4.42	95.11	95.11	32.51
16-Nov-14	26.52	33.68	10.82	26.78	71.29	37.61	1.24	99.05	3.05	3.65	96.00	96.00	33.58
17-Nov-14	29.09	31.05	14.43	26.78	72.26	41.21	0.62	101.97	4.88	5.79	97.09	97.09	30.83
18-Nov-14	27.18	33.30	18.49	26.78	78.57	45.27	0.62	106.36	3.05	3.96	103.31	103.31	32.66
19-Nov-14	28.64	39.44	13.53	26.78	79.75	40.31	0.80	109.19	1.52	2.58	107.67	107.67	34.22
20-Nov-14	28.19	34.04	12.63	26.78	73.45	39.41	0.62	102.26	2.44	3.20	107.28	107.28	40.88
21-Nov-14	28.19	38.41	12.63	26.78	77.82	39.41	0.62	106.63	1.52	2.28	105.11	105.11	34.34
22-Nov-14	28.19	33.83	12.63	26.78	73.24	39.41	1.24	102.66	2.74	3.65	99.92	99.92	33.58
23-Nov-14	28.19	36.30	14.43	26.78	77.51	41.21	0.62	106.32	2.44	3.20	103.89	103.89	33.42
24-Nov-14	28.19	31.14	12.63	26.78	70.55	39.41	0.62	99.36	1.22	1.98	98.14	98.14	34.64
25-Nov-14	28.19	34.34	12.63	26.78	73.75	39.41	0.62	102.56	1.83	2.59	100.73	100.73	34.03
26-Nov-14	28.19	31.66	12.63	26.78	71.07	39.41	0.62	99.88	2.44	3.20	97.45	97.45	33.42
27-Nov-14	28.19	33.29	12.63	26.78	72.70	39.41	0.62	101.51	1.52	2.28	99.98	99.98	34.34
28-Nov-14	28.19	30.08	12.63	26.78	69.49	39.41	0.62	98.30	1.22	1.98	97.08	97.08	34.64
29-Nov-14	28.19	31.65	12.63	26.78	71.06	39.41	0.62	99.87	1.83	2.59	99.59	99.59	35.58
30-Nov-14	28.19	33.39	12.63	26.78	72.79	39.41	1.24	102.22	1.83	2.74	100.39	100.39	34.50
1-Dec-14	28.19	31.22	13.08	26.78	71.08	39.86	1.24	104.96	2.13	3.04	98.38	98.38	29.75
2-Dec-14	28.19	33.04	12.63	26.78	72.45	39.41	1.24	101.88	2.44	3.35	99.44	99.44	33.89
3-Dec-14	28.19	33.25	12.63	26.78	72.66	39.41	1.24	102.09	2.44	3.35	99.65	99.65	33.89
4-Dec-14	28.19	32.15	12.63	26.78	71.56	39.41	1.24	100.98	1.83	2.74	99.16	99.16	34.50
5-Dec-14	28.19	31.84	12.63	26.78	71.24	39.41	1.24	100.67	3.05	3.96	97.63	97.63	33.28
6-Dec-14	28.19	31.81	12.63	26.78	71.22	39.41	1.24	100.64	3.66	4.57	96.99	96.99	32.67
7-Dec-14	28.19	35.77	12.63	26.78	75.18	39.41	1.24	104.61	3.96	4.87	98.22	98.22	29.94

A	B	C	D	E	F	G	H	I	J	K	L	M	N
8-Dec-14	28.19	25.70	12.63	26.78	65.11	39.41	1.85	99.43	2.44	3.65	97.00	97.00	34.20
9-Dec-14	28.19	29.02	12.63	26.78	68.43	39.41	1.85	107.93	10.67	11.89	97.26	97.26	25.96
10-Dec-14	32.92	36.79	10.82	27.53	75.14	38.35	1.24	118.75	0.91	2.44	117.84	117.84	34.80
11-Dec-14	31.53	38.06	13.08	26.78	77.92	39.86	1.85	121.69	6.10	7.94	115.60	115.60	29.92
12-Dec-14	32.92	40.27	12.63	27.53	80.42	40.15	1.54	123.95	4.57	5.80	119.38	119.38	31.75
13-Dec-14	33.32	41.87	14.43	26.78	83.08	41.21	0.62	126.08	4.88	6.71	121.20	121.20	29.91
14-Dec-14	33.39	37.12	16.23	26.04	79.39	42.27	1.24	124.58	9.14	11.43	115.43	115.43	25.80
15-Dec-14	35.05	38.01	14.43	26.78	79.22	41.21	1.24	124.57	4.57	6.40	119.99	119.99	30.83
16-Dec-14	34.34	43.01	15.33	25.30	83.64	40.63	2.47	128.45	4.88	6.22	123.57	123.57	32.25
17-Dec-14	33.20	45.82	13.53	26.78	86.13	40.31	0.62	127.95	9.14	10.37	118.81	118.81	26.25
18-Dec-14	35.56	41.68	14.43	26.78	82.90	41.21	0.00	130.13	4.88	6.71	125.25	125.25	29.29
19-Dec-14	34.74	41.76	17.13	27.90	86.79	45.03	0.00	130.43	12.19	13.42	118.24	118.24	22.58
20-Dec-14	35.31	38.35	13.53	28.27	80.15	41.80	2.47	128.49	12.19	13.42	116.30	116.30	25.05
21-Dec-14	37.64	43.41	13.98	26.78	84.17	40.76	0.00	129.82	7.62	9.45	122.20	122.20	26.55
22-Dec-14	38.51	23.07	18.04	25.30	66.40	43.33	0.00	112.92	9.14	11.58	103.78	103.78	24.42
23-Dec-14	37.13	35.06	14.43	20.09	69.57	34.52	0.00	114.71	7.62	9.45	107.09	107.09	26.55
24-Dec-14	5.52	41.93	3.02	0.00	44.95	3.02	0.00	51.14	9.14	9.75	42.00	42.00	26.25
25-Dec-14	0.00	20.79	0.00	0.00	20.79	0.00	0.00	20.79	1.52	3.34	19.27	19.27	32.66
26-Dec-14	0.00	14.30	0.00	0.00	14.30	0.00	0.00	14.30	0.61	2.43	13.69	13.69	33.57
27-Dec-14	0.00	20.53	0.00	0.00	20.53	0.00	0.00	20.53	0.61	2.43	19.92	19.92	33.57
28-Dec-14	0.00	30.16	0.00	0.00	30.16	0.00	0.00	30.16	9.14	10.36	21.02	21.02	25.64
29-Dec-14	0.00	30.03	0.00	0.00	30.03	0.00	0.00	30.03	9.14	11.27	20.89	20.89	24.74
30-Dec-14	0.00	20.34	0.00	0.00	20.34	0.00	0.62	20.96	1.22	3.04	19.74	19.74	33.58
31-Dec-14	4.62	15.85	0.00	0.00	15.85	0.00	0.00	20.47	6.10	7.31	14.37	14.37	28.69
5-Jan-15	18.08	14.81	21.48	31.60	67.90	53.09	0.00	86.23	13.72	14.32	72.52	72.52	21.68
6-Jan-15	20.20	24.18	20.58	31.60	76.37	52.18	0.00	96.83	13.11	13.71	83.72	83.72	22.29
7-Jan-15	20.24	28.63	22.08	32.87	83.58	54.95	0.00	102.78	18.90	20.11	83.89	83.89	15.89
8-Jan-15	24.89	17.91	21.51	31.60	71.02	53.11	0.00	94.87	15.24	15.85	79.63	79.63	20.15
9-Jan-15	21.26	23.07	22.01	32.11	77.19	54.12	0.62	99.19	19.81	21.02	79.38	79.38	15.59

A	B	C	D	E	F	G	H	I	J	K	L	M	N
10-Jan-15	20.23	20.53	16.99	32.35	69.87	49.34	0.00	90.12	7.01	7.92	83.11	83.11	28.08
11-Jan-15	18.61	14.27	20.61	32.35	67.23	52.96	0.00	85.99	6.10	7.43	79.89	79.89	28.57
12-Jan-15	28.52	13.15	20.81	32.72	66.67	53.52	0.00	95.24	2.44	3.65	92.81	92.81	32.35
13-Jan-15	35.27	12.89	21.78	32.72	67.39	54.50	0.62	103.35	2.44	3.35	100.92	100.92	33.27
14-Jan-15	34.69	18.73	22.16	31.60	72.49	53.76	0.62	107.77	1.22	2.13	106.55	106.55	34.49
15-Jan-15	37.57	11.59	22.68	32.35	66.62	55.03	0.62	104.88	1.22	2.43	103.66	103.66	34.19
16-Jan-15	28.57	26.14	21.71	31.60	79.45	53.31	0.00	107.97	1.52	1.83	106.45	106.45	34.17
17-Jan-15	28.79	24.17	21.20	33.46	78.82	54.66	0.00	107.64	2.44	3.50	105.21	105.21	32.50
18-Jan-15	28.40	24.10	19.90	31.60	75.60	51.51	0.00	104.00	1.22	1.83	102.78	102.78	34.17
19-Jan-15	28.63	29.18	19.90	31.60	80.69	51.51	0.00	109.09	3.05	3.65	106.04	106.04	32.35
20-Jan-15	28.40	32.52	19.90	31.60	84.03	51.51	0.00	112.43	12.19	12.80	100.24	100.24	23.20
21-Jan-15	28.63	26.55	19.90	31.60	78.06	51.51	0.00	106.46	9.14	10.05	97.31	97.31	25.95
22-Jan-15	28.40	25.36	19.90	31.60	76.86	51.51	0.00	105.26	7.62	9.74	97.64	97.64	26.26
23-Jan-15	28.40	23.54	19.90	31.60	75.04	51.51	0.00	103.45	4.57	6.69	98.87	98.87	29.31
24-Jan-15	28.40	24.61	19.90	31.60	76.11	51.51	0.00	104.51	5.79	7.91	98.72	98.72	28.09
25-Jan-15	33.00	15.29	21.59	33.09	69.96	54.68	0.00	102.96	5.49	7.61	97.47	97.47	28.39
26-Jan-15	33.00	21.24	21.59	33.09	75.92	54.68	0.00	108.92	2.74	4.86	106.17	106.17	31.14
27-Jan-15	31.86	47.48	23.84	33.09	104.41	56.93	0.00	136.77	22.56	24.99	114.22	114.22	11.01
28-Jan-15	29.82	46.09	37.37	33.09	116.54	70.46	0.00	146.87	19.20	22.85	127.66	127.66	13.15
29-Jan-15	29.25	31.47	36.47	33.09	101.03	69.56	1.24	132.02	6.40	9.45	125.61	125.61	27.79
30-Jan-15	29.19	36.21	35.62	27.53	99.36	63.15	1.24	130.28	6.40	9.45	123.88	123.88	27.79
31-Jan-15	29.19	33.40	35.67	33.09	102.16	68.76	1.24	133.08	6.71	9.75	126.38	126.38	27.49
1-Feb-15	29.19	31.19	36.26	33.09	100.54	69.35	1.85	132.08	3.66	6.10	128.42	128.42	31.76
2-Feb-15	29.19	29.56	36.26	33.09	98.91	69.35	1.85	130.45	2.74	5.18	127.71	127.71	32.67
3-Feb-15	29.00	32.17	37.79	34.95	104.91	72.74	0.62	137.45	9.14	12.88	128.30	128.30	23.74
4-Feb-15	29.85	40.93	31.52	33.83	106.29	65.36	0.62	138.02	10.06	14.16	127.96	127.96	22.45
5-Feb-15	29.25	34.24	36.47	33.09	103.79	69.56	1.24	134.78	6.71	9.75	128.08	128.08	27.49
6-Feb-15	26.89	41.75	26.50	33.09	101.34	59.59	1.24	129.97	3.66	6.70	126.31	126.31	30.53
7-Feb-15	29.44	24.92	30.66	27.53	83.11	58.19	1.30	114.09	3.35	6.70	110.74	110.74	30.60

A	B	C	D	E	F	G	H	I	J	K	L	M	N
8-Feb-15	37.34	24.88	35.67	27.53	88.07	63.20	1.24	126.89	2.44	5.48	124.45	124.45	31.75
9-Feb-15	26.83	43.67	28.86	25.30	97.82	54.15	0.62	125.77	3.05	6.70	122.72	122.72	29.92
10-Feb-15	34.17	36.03	30.66	26.78	93.47	57.45	0.62	128.86	6.71	9.14	122.16	122.16	27.47
11-Feb-15	29.37	21.80	30.66	23.06	75.53	53.73	1.85	107.20	6.71	10.36	100.49	100.49	27.50
12-Feb-15	1.94	53.35	14.43	0.00	67.78	14.43	0.62	70.59	1.52	4.27	69.06	69.06	32.35
13-Feb-15	0.25	70.25	0.00	0.00	70.25	0.00	1.54	72.30	4.27	7.61	68.03	68.03	29.93
14-Feb-15	0.36	74.64	0.00	0.00	74.64	0.00	0.62	75.75	6.71	10.66	69.05	69.05	25.96
15-Feb-15	0.20	75.67	0.00	0.00	75.67	0.00	1.85	78.03	6.71	9.45	71.32	71.32	28.41
16-Feb-15	0.00	72.51	0.00	0.00	72.51	0.00	1.24	74.24	6.71	9.75	67.54	67.54	27.49
17-Feb-15	5.94	63.27	0.90	0.00	64.17	0.90	2.47	73.09	3.66	7.91	69.43	69.43	30.56
18-Feb-15	26.57	30.40	30.66	27.53	88.59	58.19	0.62	116.54	13.72	16.15	102.82	102.82	20.46
19-Feb-15	31.79	28.47	28.86	27.53	84.86	56.39	1.24	118.64	11.58	14.63	107.06	107.06	22.61
20-Feb-15	28.93	25.01	35.62	27.53	88.16	63.15	1.24	119.08	15.54	18.59	103.53	103.53	18.65
21-Feb-15	37.01	24.53	35.62	27.53	87.67	63.15	1.24	126.68	18.59	21.64	108.09	108.09	15.60
22-Feb-15	33.58	24.73	35.62	27.53	87.87	63.15	1.24	123.19	14.94	17.98	108.26	108.26	19.26
23-Feb-15	34.48	29.53	36.10	33.09	98.73	69.19	2.47	136.17	20.73	24.38	115.45	115.45	14.09
24-Feb-15	29.59	30.41	36.48	33.09	99.98	69.57	1.24	131.30	6.71	9.75	124.60	124.60	27.49
25-Feb-15	29.73	29.69	36.44	33.09	99.22	69.53	1.24	130.69	6.71	9.75	123.98	123.98	27.49
26-Feb-15	24.26	34.60	36.30	33.09	103.99	69.39	1.24	129.99	2.44	5.48	127.55	127.55	31.75
27-Feb-15	24.26	35.52	36.30	33.09	104.91	69.39	1.24	130.91	2.44	5.48	128.47	128.47	31.75
28-Feb-15	24.26	34.00	36.18	31.09	101.27	67.27	1.24	127.27	2.44	5.48	124.83	124.83	31.75
1-Mar-15	24.26	38.04	35.62	27.53	101.19	63.15	1.24	127.19	2.44	5.48	124.75	124.75	31.75
2-Mar-15	24.26	39.38	35.62	27.53	102.53	63.15	1.24	128.53	2.74	5.79	125.79	125.79	31.45
3-Mar-15	23.37	28.72	35.62	16.37	80.71	51.99	0.00	104.38	24.99	25.61	79.38	79.38	10.39
4-Mar-15	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
5-Mar-15	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
6-Mar-15	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
7-Mar-15	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
8-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00

A	B	C	D	E	F	G	H	I	J	K	L	M	N
9-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
10-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
11-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
12-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
13-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
14-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
21-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
22-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
23-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
24-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
25-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
26-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
27-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
28-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
28-Mar-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
1-May-15	31.12	20.61	20.12	24.97	65.70	45.09	7.41	105.22	9.14	10.07	96.07	96.07	33.34
2-May-15	31.47	17.11	21.47	24.97	63.55	46.44	8.65	104.66	2.44	4.68	102.22	102.22	39.97
3-May-15	31.00	11.43	22.47	24.58	58.48	47.05	8.03	98.50	1.34	5.30	97.15	97.15	38.73
4-May-15	33.30	18.21	22.37	24.97	65.56	47.35	8.65	108.49	12.80	15.95	95.69	95.69	28.70
5-May-15	31.89	27.15	20.20	24.18	71.53	44.38	8.65	112.34	15.85	20.72	96.49	96.49	23.93
6-May-15	40.39	15.60	20.12	24.97	60.69	45.09	7.41	108.72	18.90	19.82	89.82	89.82	23.59
7-May-15	31.89	18.97	20.12	24.97	64.06	45.09	9.88	106.05	15.24	19.50	90.81	90.81	26.39
8-May-15	37.70	13.46	20.12	24.97	58.55	45.09	8.65	105.13	18.90	23.76	86.23	86.23	20.89
9-May-15	43.33	6.41	20.12	24.59	51.11	44.71	8.65	103.26	13.72	18.88	89.55	89.55	25.76
10-May-15	43.56	9.01	20.12	24.97	54.10	45.09	9.88	107.76	19.81	23.89	87.95	87.95	22.00
11-May-15	43.20	12.01	20.12	24.97	57.10	45.09	8.65	109.17	15.97	19.62	93.20	93.20	25.03
12-May-15	31.89	14.70	20.12	24.97	59.79	45.09	12.97	104.87	14.63	19.19	90.24	90.24	29.78
13-May-15	50.22	7.60	20.12	24.97	52.69	45.09	14.83	117.96	21.23	27.31	96.73	96.73	23.52
14-May-15	51.17	7.93	20.12	24.97	53.02	45.09	11.74	116.16	19.83	26.52	96.32	96.32	21.22

A	B	C	D	E	F	G	H	I	J	K	L	M	N
15-May-15	56.22	7.16	20.12	24.97	52.25	45.09	14.83	123.52	21.09	27.17	102.43	102.43	23.66
16-May-15	52.07	8.62	20.12	24.97	53.72	45.09	13.59	119.60	7.28	13.97	112.31	112.31	35.62
17-May-15	53.35	7.36	20.12	24.97	52.45	45.09	11.74	117.77	18.69	25.38	99.07	99.07	22.36
18-May-15	53.35	7.29	20.12	24.97	52.38	45.09	11.74	117.69	24.02	31.61	93.67	93.67	16.13
19-May-15	51.56	7.01	20.23	24.53	51.78	44.77	11.74	115.40	23.49	29.57	91.91	91.91	18.17
20-May-15	56.74	4.53	19.67	24.97	49.17	44.64	7.41	113.54	21.21	22.26	92.33	92.33	21.15
21-May-15	56.38	7.57	18.75	29.81	56.12	48.56	7.41	120.14	20.62	27.69	99.53	99.53	15.73
22-May-15	56.38	6.95	18.75	29.81	55.50	48.56	7.41	119.52	15.55	22.62	103.97	103.97	20.79
23-May-15	56.49	6.95	18.78	28.80	54.52	47.58	7.41	118.59	12.35	19.42	106.25	106.25	24.00
24-May-15	61.73	5.91	21.91	29.19	57.01	51.09	13.59	132.33	19.98	24.53	112.35	112.35	25.07
25-May-15	61.56	8.30	21.49	30.51	60.30	52.00	11.12	133.03	10.84	23.21	122.19	122.19	23.91
26-May-15	59.90	8.37	22.93	32.35	63.65	55.28	14.83	138.63	13.17	22.56	125.46	125.46	28.27
27-May-15	57.47	10.31	22.93	32.35	65.59	55.28	17.30	140.56	16.68	23.65	123.88	123.88	29.65
28-May-15	57.42	10.31	22.86	33.46	66.62	56.32	17.30	141.60	20.08	27.05	121.51	121.51	26.25
29-May-15	57.47	11.22	22.93	32.35	66.50	55.28	17.30	141.48	17.07	24.03	124.41	124.41	29.26
30-May-15	57.67	6.51	22.93	32.35	61.79	55.28	6.80	126.26	13.04	15.16	113.22	113.22	27.63
31-May-15	47.83	7.16	22.93	32.35	62.44	55.28	7.54	117.81	10.86	12.97	106.95	106.95	30.56
1-Jun-15	50.47	5.59	8.18	6.66	20.42	14.84	1.42	72.31	8.53	9.93	63.77	63.77	27.49
2-Jun-15	45.81	7.16	16.77	8.56	32.49	25.33	8.03	85.98	2.74	5.37	83.23	83.23	38.67
3-Jun-15	47.28	15.56	7.89	32.35	55.79	40.24	17.24	119.56	5.49	10.00	114.07	114.07	43.24
6-Jun-15	42.67	19.89	15.25	29.93	65.07	45.18	13.28	126.96	5.79	8.21	121.17	121.17	41.08
7-Jun-15	43.41	25.58	16.63	28.07	70.28	44.70	12.73	132.87	8.23	11.65	124.64	124.64	37.08
8-Jun-15	47.07	15.40	14.83	33.46	63.69	48.29	11.43	128.54	5.49	8.59	123.05	123.05	38.84
9-Jun-15	49.36	12.34	16.97	33.31	62.62	50.29	11.24	128.63	4.94	6.35	123.69	123.69	40.89
10-Jun-15	35.22	20.36	17.56	35.69	73.62	53.26	13.34	129.73	6.71	8.53	123.03	123.03	40.82
11-Jun-15	42.50	14.27	17.52	34.20	65.99	51.72	13.90	128.46	6.71	8.75	121.75	121.75	41.15
12-Jun-15	48.70	11.95	19.33	28.05	59.33	47.38	13.59	129.56	3.84	6.61	125.72	125.72	42.98
13-Jun-15	45.18	14.46	19.74	33.81	68.01	53.55	11.92	133.88	6.71	9.31	127.18	127.18	38.62
14-Jun-15	45.34	16.33	19.91	32.16	68.40	52.07	11.61	133.82	3.66	5.78	130.16	130.16	41.83

A	B	C	D	E	F	G	H	I	J	K	L	M	N
15-Jun-15	50.68	13.60	21.28	27.62	62.51	48.91	12.42	133.83	6.71	8.58	127.13	127.13	39.83
17-Jun-15	30.58	46.50	19.44	33.10	99.03	52.54	0.00	136.19	18.29	20.10	117.91	117.91	15.90
18-Jun-15	28.67	28.37	18.34	31.44	78.15	49.78	0.00	113.39	15.24	16.60	98.15	98.15	19.40
19-Jun-15	30.38	23.93	21.90	30.87	76.70	52.77	1.24	115.48	8.23	10.08	107.25	107.25	27.16
20-Jun-15	32.51	12.23	22.81	30.79	65.83	53.60	0.62	107.29	7.62	9.99	99.67	99.67	26.63
21-Jun-15	32.86	34.82	22.74	29.57	87.13	52.31	0.62	129.55	22.56	25.11	127.78	127.78	32.28
22-Jun-15	30.56	34.33	21.19	27.53	83.05	48.72	6.18	128.16	13.11	14.74	115.05	115.05	27.44
23-Jun-15	33.15	22.76	21.64	30.13	74.54	51.78	0.74	117.35	18.29	20.21	99.06	99.06	16.53
24-Jun-15	30.42	44.99	18.94	27.90	91.82	46.84	0.00	126.04	13.72	14.73	112.32	112.32	21.27
25-Jun-15	33.80	34.21	18.94	29.39	82.54	48.33	0.00	122.46	20.12	21.69	102.34	102.34	14.31
26-Jun-15	28.76	37.81	18.34	31.05	87.19	49.39	1.24	118.86	12.80	14.32	106.06	106.06	22.92
27-Jun-15	31.96	36.71	17.10	33.09	86.91	50.20	0.00	120.04	9.14	11.31	110.89	110.89	24.69
28-Jun-15	30.87	23.30	16.14	31.68	71.12	47.82	0.00	103.11	15.24	17.16	87.87	87.87	18.84
29-Jun-15	28.81	36.95	16.98	28.23	82.17	45.21	0.00	117.04	12.19	16.28	104.85	104.85	19.72
30-Jun-15	33.53	25.45	17.51	32.08	75.04	49.59	0.00	113.65	12.19	13.55	101.45	101.45	22.45
1-Aug-15	35.07	27.07	21.99	29.76	78.83	51.75	2.06	118.51	12.19	13.51	106.31	106.31	24.55
4-Aug-15	34.02	24.01	22.71	35.51	82.23	58.22	1.54	124.47	12.19	13.60	112.28	112.28	23.94
5-Aug-15	35.23	26.56	20.89	34.02	81.48	54.91	3.90	126.32	16.76	18.79	109.55	109.55	21.11
6-Aug-15	35.05	26.22	21.81	36.63	84.66	58.44	0.00	125.40	18.16	20.14	107.24	107.24	15.86
7-Aug-15	36.43	38.96	23.19	36.07	98.21	59.25	0.00	140.50	15.24	17.21	125.26	125.26	18.79
8-Aug-15	35.82	24.08	23.29	36.35	83.71	59.63	0.00	125.55	12.19	14.29	113.36	113.36	21.71
9-Aug-15	36.18	13.71	23.35	36.74	73.79	60.08	0.00	114.80	9.14	11.02	105.65	105.65	24.98
10-Aug-15	36.96	16.26	23.21	35.68	75.14	58.88	0.00	118.17	9.14	10.97	109.02	109.02	25.04
11-Aug-15	36.80	16.93	23.64	35.68	76.24	59.31	0.00	119.06	9.86	11.56	109.19	109.19	24.44
12-Aug-15	37.67	27.20	23.17	35.19	85.55	58.36	0.00	125.07	9.14	10.76	115.92	115.92	25.24
13-Aug-15	39.01	39.39	23.25	38.30	100.94	61.54	0.00	142.97	15.85	17.48	127.12	127.12	18.52
14-Aug-15	39.23	25.49	22.92	36.24	84.65	59.16	0.00	126.86	16.76	18.33	110.10	110.10	17.67
15-Aug-15	39.42	23.07	24.80	32.36	80.23	57.16	0.00	124.47	9.14	9.85	115.33	115.33	26.15
16-Aug-15	38.95	22.26	27.51	33.75	83.53	61.27	1.03	128.89	9.81	11.86	119.08	119.08	25.17

A	B	C	D	E	F	G	H	I	J	K	L	M	N
17-Aug-15	37.43	23.32	27.53	35.55	86.41	63.09	1.13	129.76	12.19	14.25	117.57	117.57	22.88
18-Aug-15	39.03	33.77	26.20	35.98	95.95	62.18	0.00	137.30	16.76	19.82	120.54	120.54	16.18
19-Aug-15	39.63	33.20	26.30	36.54	96.04	62.84	1.54	142.59	16.76	18.52	125.83	125.83	19.03
20-Aug-15	38.64	31.28	23.60	37.09	91.97	60.69	2.19	134.21	9.45	10.08	124.76	124.76	28.11
21-Aug-15	43.24	23.51	21.78	34.01	79.30	55.79	6.18	128.05	12.19	13.37	115.86	115.86	28.80
22-Aug-15	38.60	26.08	27.59	34.01	87.69	61.61	0.00	125.62	12.19	13.50	113.43	113.43	22.50
23-Aug-15	39.66	33.06	26.24	28.95	88.25	55.19	3.09	132.56	12.19	13.28	120.37	120.37	25.81
24-Aug-15	39.54	30.66	25.82	33.01	89.49	58.83	0.00	127.69	13.00	14.27	114.69	114.69	21.73
25-Aug-15	39.54	32.92	25.82	33.01	91.75	58.83	0.00	129.95	15.96	17.48	113.99	113.99	18.52
26-Aug-15	38.53	27.22	28.54	34.96	90.71	63.49	1.08	133.98	13.72	15.48	120.26	120.26	21.60
27-Aug-15	38.70	19.81	26.14	36.11	82.05	62.25	4.38	127.74	9.75	10.59	117.99	117.99	29.78
28-Aug-15	42.50	34.72	26.14	35.15	96.00	61.29	1.54	142.82	9.14	10.19	111.53	111.53	5.20
29-Aug-15	36.87	26.10	21.30	36.54	83.93	57.84	0.00	130.33	13.74	16.29	116.59	116.59	19.71
30-Aug-15	36.87	26.10	21.30	36.54	83.93	57.84	0.00	130.33	9.70	12.25	120.64	120.64	23.75
31-Aug-15	40.38	38.30	23.05	35.14	96.49	58.19	0.00	138.41	18.61	21.57	119.79	119.79	14.43
1-Sep-15	39.29	26.59	22.51	36.05	85.16	58.56	0.00	123.58	27.43	28.72	96.15	96.15	7.28
10-Sep-15	38.34	40.37	20.15	28.26	88.79	48.41	8.03	139.61	18.29	19.62	121.32	121.32	24.41
11-Sep-15	38.01	40.25	21.03	29.66	90.94	50.69	3.86	134.39	21.34	22.87	113.05	113.05	16.99
12-Sep-15	38.86	34.11	21.93	33.19	89.23	55.12	0.51	130.23	19.81	21.35	110.41	110.41	15.17
13-Sep-15	38.36	36.94	22.34	35.24	94.51	57.58	0.00	136.54	25.91	28.00	110.63	110.63	8.00
15-Sep-15	37.96	34.08	25.83	39.73	99.65	65.56	0.00	145.76	22.55	24.40	123.21	123.21	11.60
16-Sep-15	37.42	42.59	23.23	34.93	100.74	58.15	3.04	144.29	21.85	24.08	122.43	122.43	14.96
17-Sep-15	38.12	41.56	25.30	30.90	97.77	56.20	3.91	143.99	21.31	22.58	122.68	122.68	17.33
18-Sep-15	39.37	58.24	26.19	28.18	112.61	54.37	0.00	153.19	29.26	30.77	123.93	123.93	5.23
19-Sep-15	42.01	47.78	28.41	26.27	102.45	54.67	0.00	143.40	27.65	28.86	115.74	115.74	7.14
20-Sep-15	42.90	34.00	24.35	0.00	58.35	24.35	0.00	99.87	30.48	30.79	69.39	69.39	5.21
21-Sep-15	37.51	37.64	25.25	32.74	95.63	57.99	0.00	138.00	25.91	29.94	112.10	112.10	6.06
22-Sep-15	38.24	44.23	25.70	31.62	101.56	57.32	0.00	149.63	28.35	31.63	121.28	121.28	4.37
23-Sep-15	37.09	50.42	26.62	12.87	89.91	39.49	0.00	136.35	27.43	29.46	108.92	108.92	6.54

A	B	C	D	E	F	G	H	I	J	K	L	M	N
24-Sep-15	35.53	47.70	26.14	35.85	109.69	61.99	0.00	152.64	25.91	28.08	126.73	126.73	7.92
25-Sep-15	37.20	38.23	27.49	36.74	102.46	64.23	0.00	148.12	24.38	27.47	123.74	123.74	8.54
26-Sep-15	39.53	35.87	27.06	37.54	100.48	64.60	0.00	145.97	20.12	21.68	125.85	125.85	14.32
27-Sep-15	39.10	46.02	23.91	37.60	107.52	61.50	0.00	153.71	20.48	21.43	133.23	133.23	14.57
28-Sep-15	38.97	31.97	26.20	35.15	93.31	61.35	0.00	144.31	16.31	18.51	128.00	128.00	17.49
29-Sep-15	40.09	42.74	25.34	37.65	105.73	62.99	0.00	155.57	20.82	23.90	134.75	134.75	12.10
30-Sep-15	38.42	48.10	24.46	35.91	108.46	60.36	0.00	154.99	18.29	19.80	136.70	136.70	16.20
1-Oct-15	37.51	25.73	27.02	32.82	85.57	59.84	0.00	135.61	15.24	18.36	120.37	120.37	17.64
2-Oct-15	17.31	19.46	3.79	2.75	26.00	6.54	0.00	48.62	12.19	13.40	36.43	36.43	22.60
3-Oct-15	20.01	19.74	18.53	0.00	38.27	18.53	12.36	75.93	12.19	14.78	63.74	63.74	33.58
4-Oct-15	17.91	34.34	22.50	0.00	56.84	22.50	0.00	80.05	10.67	13.20	69.39	69.39	22.80
5-Oct-15	20.06	29.34	22.61	0.93	52.88	23.54	0.00	79.91	6.10	7.12	73.82	73.82	28.88
6-Oct-15	28.89	15.57	25.40	16.26	57.23	41.66	0.00	95.92	13.08	14.51	82.83	82.83	21.49
7-Oct-15	35.54	35.76	29.54	11.89	77.19	41.43	0.00	121.40	18.29	20.58	103.11	103.11	15.42
8-Oct-15	37.61	22.15	29.70	10.59	62.44	40.28	0.00	120.92	18.29	21.70	102.63	102.63	14.30
9-Oct-15	37.61	37.85	29.66	12.45	79.96	42.10	0.00	126.20	18.90	21.43	107.31	107.31	14.57
10-Oct-15	35.85	33.79	29.36	9.28	72.42	38.64	0.00	116.91	18.29	20.36	98.62	98.62	15.64
11-Oct-15	34.75	60.06	28.05	9.28	97.40	37.34	0.00	140.78	18.29	21.38	122.49	122.49	14.63
12-Oct-15	34.91	50.67	26.99	9.28	86.94	36.27	0.00	131.04	18.29	21.02	112.75	112.75	14.98
13-Oct-15	33.27	53.13	26.01	9.28	88.42	35.29	0.00	130.88	18.29	21.25	112.59	112.59	14.75
14-Oct-15	33.87	44.98	26.85	5.11	76.94	31.96	0.00	120.00	19.81	23.22	100.19	100.19	12.78
15-Oct-15	33.16	30.01	25.50	38.49	93.99	63.99	0.00	136.32	18.29	20.62	118.03	118.03	15.38
16-Oct-15	33.11	24.57	26.95	38.49	90.00	65.44	0.00	134.00	18.29	20.62	115.71	115.71	15.38
17-Oct-15	34.01	21.12	26.50	38.49	86.11	64.99	0.00	132.66	18.29	20.62	114.37	114.37	15.38
18-Oct-15	33.13	27.32	25.60	34.77	87.68	60.37	0.00	133.36	18.29	20.62	115.07	115.07	15.38
19-Oct-15	33.73	26.17	27.40	33.93	87.50	61.33	0.00	133.83	18.29	20.92	115.54	115.54	15.08
20-Oct-15	31.95	29.51	25.76	37.65	92.92	63.41	0.00	137.84	21.34	23.01	116.51	116.51	12.99
21-Oct-15	32.81	23.53	28.46	35.51	87.51	63.98	0.00	131.45	19.81	21.48	111.64	111.64	14.52
22-Oct-15	34.00	20.80	25.76	37.93	84.49	63.69	0.00	129.14	21.34	23.01	107.80	107.80	12.99

A	B	C	D	E	F	G	H	I	J	K	L	M	N
23-Oct-15	32.84	29.65	26.60	37.93	94.18	64.53	0.00	138.55	19.05	20.67	119.50	119.50	15.33
24-Oct-15	32.92	18.20	27.05	37.93	83.18	64.98	0.00	126.55	21.34	22.69	105.22	105.22	13.31
25-Oct-15	32.92	20.39	27.95	37.93	86.28	65.88	0.00	129.25	21.34	23.46	107.91	107.91	12.54
26-Oct-15	33.21	14.94	26.66	39.79	81.40	66.45	0.00	126.07	20.73	22.65	105.34	105.34	13.35
27-Oct-15	33.20	18.37	26.21	39.79	84.37	66.00	0.00	129.82	21.95	23.66	107.88	107.88	12.34
28-Oct-15	32.25	17.00	25.75	40.35	83.10	66.10	0.00	121.06	21.95	23.69	99.12	99.12	12.31
29-Oct-15	31.24	17.10	22.67	38.63	78.39	61.29	0.00	108.13	22.10	23.83	86.03	86.03	12.17
30-Oct-15	29.39	18.35	25.60	37.65	81.60	63.25	0.00	112.05	18.29	20.06	93.76	93.76	15.94
31-Oct-15	28.12	26.42	22.84	39.51	88.77	62.35	0.00	127.63	18.29	20.57	109.34	109.34	15.43
1-Nov-15	28.12	15.14	23.35	39.79	78.27	63.13	0.00	118.24	19.05	21.03	99.19	99.19	14.97
2-Nov-15	28.40	25.16	24.93	39.79	89.88	64.72	0.00	130.68	19.05	21.13	111.63	111.63	14.87
3-Nov-15	27.97	23.54	26.60	38.86	89.00	65.46	0.00	131.03	19.05	20.58	111.98	111.98	15.42
4-Nov-15	29.47	36.37	28.35	37.56	102.28	65.91	0.00	130.24	21.34	22.88	108.91	108.91	13.12
6-Nov-15	27.78	29.67	18.94	38.49	87.09	57.42	0.00	127.28	19.05	20.57	108.23	108.23	15.43
7-Nov-15	27.96	32.82	17.13	38.76	88.72	55.90	0.00	129.08	19.05	20.94	110.03	110.03	15.06
8-Nov-15	29.03	32.52	16.68	40.62	89.82	57.31	0.00	132.92	19.05	20.39	113.87	113.87	15.61
9-Nov-15	33.38	24.74	18.94	38.49	82.16	57.42	0.00	127.94	19.05	20.27	108.89	108.89	15.73
10-Nov-15	29.03	28.58	21.19	38.76	88.53	59.95	0.00	132.18	19.05	20.20	113.13	113.13	15.80
11-Nov-15	33.30	23.13	21.19	39.04	83.37	60.23	0.00	129.06	19.05	20.36	110.01	110.01	15.64
12-Nov-15	27.54	25.52	21.19	39.04	85.76	60.23	0.00	125.70	19.05	20.72	106.65	106.65	15.28
13-Nov-15	26.81	26.35	16.68	40.90	83.93	57.58	0.00	124.81	19.05	20.21	105.76	105.76	15.79
14-Nov-15	25.91	31.74	18.03	40.90	90.68	58.94	0.00	127.32	19.05	20.06	108.27	108.27	15.94
15-Nov-15	25.91	32.40	16.77	40.90	90.08	57.68	0.00	128.39	18.90	20.27	109.49	109.49	15.73
16-Nov-15	27.16	33.67	18.03	36.63	88.33	54.66	0.00	129.55	19.05	21.18	110.50	110.50	14.82
17-Nov-15	27.59	35.80	18.03	38.76	92.60	56.80	0.00	134.26	19.05	21.28	115.21	115.21	14.72
18-Nov-15	29.43	28.36	21.19	40.62	90.18	61.81	0.00	133.67	19.05	20.52	114.62	114.62	15.48
19-Nov-15	29.43	19.37	20.19	39.04	78.60	59.23	0.00	117.48	19.05	20.78	98.43	98.43	15.22
20-Nov-15	27.68	27.64	19.74	36.63	84.01	56.36	0.00	110.19	19.05	21.64	91.14	91.14	14.36
21-Nov-15	27.68	26.24	18.89	38.49	83.61	57.38	0.00	109.80	19.05	21.44	90.75	90.75	14.56

A	B	C	D	E	F	G	H	I	J	K	L	M	N
22-Nov-15	27.68	18.41	19.80	39.04	77.25	58.85	0.00	114.34	19.81	24.12	94.52	94.52	11.88
23-Nov-15	27.26	26.76	21.09	37.18	85.03	58.27	0.00	126.36	19.05	23.61	107.31	107.31	12.39
24-Nov-15	27.26	28.54	19.04	37.18	84.76	56.22	0.00	122.75	19.05	23.87	103.70	103.70	12.14
25-Nov-15	26.81	26.75	22.09	37.18	86.03	59.27	0.00	123.57	19.05	23.81	104.52	104.52	12.19
26-Nov-15	27.70	28.68	21.29	35.32	85.29	56.61	0.00	127.62	19.05	22.90	108.57	108.57	13.10
27-Nov-15	28.15	26.55	22.68	35.32	84.56	58.01	0.00	127.89	18.90	22.55	108.99	108.99	13.45
28-Nov-15	28.15	30.78	21.29	35.32	87.40	56.61	0.00	130.73	19.05	22.60	111.68	111.68	13.40
29-Nov-15	28.15	30.44	21.29	35.32	87.05	56.61	0.00	131.50	18.29	21.99	113.21	113.21	14.01
30-Nov-15	28.66	25.16	20.37	35.32	80.85	55.70	0.00	125.80	17.53	21.83	108.28	108.28	14.17
1-Dec-15	29.29	23.27	21.39	35.32	79.98	56.71	0.00	124.45	18.29	22.55	106.17	106.17	13.46
2-Dec-15	29.11	27.32	20.02	35.32	82.66	55.34	0.00	126.94	16.76	20.72	110.18	110.18	15.28
3-Dec-15	29.11	22.05	19.79	42.76	84.60	62.56	0.00	128.89	19.81	23.00	109.08	109.08	13.00
4-Dec-15	29.49	29.36	18.04	33.48	80.88	51.52	0.00	125.55	16.76	19.65	108.79	108.79	16.35
5-Dec-15	30.37	24.88	22.55	37.20	84.62	59.75	0.00	130.17	18.29	20.21	111.88	111.88	15.79
6-Dec-15	30.37	20.74	24.80	35.34	80.88	60.14	0.00	126.43	17.53	20.96	108.91	108.91	15.04
7-Dec-15	31.09	16.79	27.05	33.48	77.33	60.53	0.00	123.60	19.05	22.08	104.55	104.55	13.92
8-Dec-15	31.26	16.01	24.80	37.20	78.01	62.00	0.00	124.46	22.86	25.89	101.60	101.60	10.11
9-Dec-15	25.06	47.13	13.53	23.55	84.21	37.07	0.00	124.45	22.86	26.14	101.59	101.59	9.86
10-Dec-15	1.50	4.85	0.00	0.00	4.85	0.00	14.11	27.29	7.01	7.92	20.28	20.28	42.19
11-Dec-15	1.50	0.97	0.00	0.00	0.97	0.00	14.35	23.66	7.01	7.62	16.65	16.65	42.73
12-Dec-15	1.55	0.97	0.00	0.00	0.97	0.00	11.83	22.11	7.01	7.62	15.10	15.10	40.21
13-Dec-15	1.50	0.97	0.00	0.00	0.97	0.00	12.37	22.65	7.01	7.62	15.64	15.64	40.75
14-Dec-15	1.55	0.65	0.00	0.00	0.65	0.00	5.01	14.64	3.05	3.65	11.59	11.59	37.35
15-Dec-15	1.50	0.65	0.00	0.00	0.65	0.00	5.37	15.01	3.05	3.65	11.96	11.96	37.72
16-Dec-15	1.32	0.65	0.00	0.00	0.65	0.00	10.55	20.19	3.05	3.65	17.14	17.14	42.90
17-Dec-15	1.50	0.65	0.00	0.00	0.65	0.00	7.82	14.67	3.05	4.56	11.62	11.62	39.26
18-Dec-15	1.50	0.97	0.00	0.00	0.97	0.00	1.18	14.24	3.05	4.56	11.19	11.19	32.62
19-Dec-15	1.50	0.97	0.00	0.00	0.97	0.00	0.49	14.66	3.05	4.56	11.61	11.61	31.93
20-Dec-15	2.39	0.65	0.00	0.00	0.65	0.00	4.31	16.51	3.05	3.65	12.56	12.56	35.76

A	B	C	D	E	F	G	H	I	J	K	L	M	N
21-Dec-15	5.74	1.62	0.00	0.00	1.62	0.00	26.07	47.36	3.05	3.96	44.31	44.31	58.11
22-Dec-15	5.74	6.02	4.51	0.00	10.53	4.51	18.56	51.55	9.14	10.05	42.40	42.40	44.51
23-Dec-15	14.47	12.80	5.64	2.79	21.23	8.43	0.00	52.65	9.14	10.66	43.51	43.51	25.34
24-Dec-15	9.60	3.16	5.64	15.62	24.42	21.26	3.09	51.30	9.14	9.90	42.16	42.16	29.19
25-Dec-15	10.07	4.50	6.76	24.18	35.45	30.94	3.09	60.32	8.38	8.99	51.94	51.94	30.10
26-Dec-15	11.86	5.15	4.51	29.76	39.42	34.27	0.00	60.97	9.14	10.66	51.83	51.83	25.34
27-Dec-15	25.01	6.56	9.02	29.76	45.34	38.78	0.00	82.94	18.29	19.80	64.65	64.65	16.20
28-Dec-15	26.80	13.99	18.04	29.76	61.79	47.80	0.00	101.83	19.05	21.78	82.78	82.78	14.22
29-Dec-15	34.26	10.96	18.04	29.76	58.76	47.80	0.00	106.26	18.29	19.80	87.97	87.97	16.20
30-Dec-15	34.71	22.57	18.94	27.90	69.41	46.84	0.00	111.91	21.34	22.85	90.57	90.57	13.15
31-Dec-15	36.03	15.82	13.53	29.76	59.11	43.29	0.00	98.37	22.86	23.47	75.51	75.51	12.53
1-Jan-16	34.69	11.52	19.16	26.04	56.73	45.20	0.00	97.13	21.34	24.37	75.79	75.79	11.63
2-Jan-16	37.27	12.75	17.59	30.69	61.02	48.28	0.00	107.99	22.86	24.38	85.13	85.13	11.63
3-Jan-16	38.70	15.54	20.29	31.62	67.45	51.91	0.00	125.37	21.34	23.76	104.04	104.04	12.24
4-Jan-16	39.15	20.91	20.29	27.90	69.10	48.19	0.00	122.37	24.38	27.11	97.99	97.99	8.89
5-Jan-16	38.72	14.89	17.59	29.76	62.24	47.35	0.00	104.92	18.29	19.20	86.63	86.63	16.80
6-Jan-16	44.44	7.88	18.04	32.55	58.47	50.59	0.00	105.51	28.19	29.71	77.32	77.32	6.29
7-Jan-16	44.93	11.12	19.16	29.76	60.05	48.92	0.00	110.23	28.96	32.74	81.27	81.27	3.26
8-Jan-16	37.68	22.74	12.63	19.34	54.71	31.97	0.00	96.10	19.81	21.02	76.29	76.29	14.98
9-Jan-16	40.44	24.41	11.27	19.34	55.02	30.62	0.00	100.05	27.43	28.34	72.62	72.62	7.66
10-Jan-16	40.79	27.97	11.27	26.04	65.28	37.31	0.00	110.66	28.96	30.47	81.71	81.71	5.53
11-Jan-16	40.57	33.16	12.40	30.50	76.06	42.90	0.00	124.54	27.43	28.64	97.11	97.11	7.36
12-Jan-16	40.46	18.80	11.27	29.76	59.84	41.03	0.00	115.02	19.05	19.50	95.97	95.97	16.50
13-Jan-16	40.59	37.81	18.94	29.76	86.51	48.70	0.00	143.02	22.86	23.16	120.16	120.16	12.84
14-Jan-16	40.49	22.11	18.94	29.76	70.81	48.70	0.00	128.73	25.91	26.91	102.82	102.82	9.09
15-Jan-16	41.99	18.73	18.94	30.50	68.17	49.44	0.00	126.37	27.43	28.39	98.94	98.94	7.61
16-Jan-16	40.44	21.99	20.29	30.50	72.78	50.79	0.00	129.59	27.43	28.39	102.16	102.16	7.61
17-Jan-16	42.91	18.74	18.04	29.76	66.53	47.80	0.00	125.90	25.91	27.47	100.00	100.00	8.53
18-Jan-16	42.68	16.18	18.04	29.76	63.98	47.80	0.00	123.35	25.91	27.47	97.44	97.44	8.53

A	B	C	D	E	F	G	H	I	J	K	L	M	N
19-Jan-16	43.82	11.80	21.64	30.50	63.95	52.15	0.00	123.38	27.43	29.35	95.95	95.95	6.65
20-Jan-16	45.93	15.96	21.64	30.50	68.11	52.15	0.00	131.00	27.43	30.61	103.57	103.57	5.39
21-Jan-16	45.57	13.15	21.64	30.50	65.29	52.15	0.00	129.02	27.43	30.00	101.58	101.58	6.00
22-Jan-16	45.06	13.20	21.64	30.88	65.72	52.52	0.00	128.34	27.43	30.61	100.91	100.91	5.39
23-Jan-16	46.40	11.97	22.55	31.62	66.13	54.17	0.00	129.95	25.91	28.94	104.04	104.04	7.06
24-Jan-16	43.14	9.91	23.45	31.62	64.97	55.07	0.00	126.97	25.91	28.33	101.06	101.06	7.67
25-Jan-16	44.57	16.86	18.94	31.62	67.42	50.56	0.00	129.05	25.91	28.33	103.14	103.14	7.67
26-Jan-16	46.26	16.87	19.39	30.50	66.76	49.89	0.00	130.64	27.43	30.46	103.21	103.21	5.54
27-Jan-16	44.66	14.67	19.16	32.74	66.57	51.90	0.00	133.94	27.43	30.16	106.51	106.51	5.84
28-Jan-16	46.59	15.47	20.29	31.99	67.75	52.28	0.00	132.96	28.19	29.41	104.77	104.77	6.59
29-Jan-16	48.38	12.14	20.29	32.36	64.79	52.65	0.00	132.33	29.46	30.37	102.86	102.86	5.63
30-Jan-16	45.40	13.91	20.74	33.48	68.13	54.22	0.00	134.10	28.96	30.47	105.14	105.14	5.53
31-Jan-16	40.52	15.08	18.49	32.55	66.11	51.04	0.00	128.58	28.96	30.02	99.62	99.62	5.98
1-Feb-16	42.79	15.27	16.68	33.48	65.43	50.16	0.00	129.53	28.35	29.86	101.18	101.18	6.14
2-Feb-16	41.92	17.33	17.13	33.48	67.94	50.61	0.00	130.31	29.57	30.78	100.75	100.75	5.22
3-Feb-16	42.35	14.42	17.59	33.48	65.48	51.07	0.00	129.88	28.65	30.44	101.23	101.23	5.56
4-Feb-16	42.54	14.05	18.04	33.48	65.57	51.52	0.00	130.02	26.67	29.43	103.35	103.35	6.57
5-Feb-16	43.03	16.29	19.00	35.61	70.90	54.61	0.00	133.58	26.67	29.45	104.04	104.04	3.68
6-Feb-16	43.89	11.87	19.64	39.04	70.55	58.68	0.00	133.99	26.67	29.48	107.32	107.32	6.52
7-Feb-16	41.19	12.74	20.09	38.35	71.17	58.44	0.00	133.92	26.67	28.57	107.25	107.25	7.43
8-Feb-16	42.18	12.04	18.94	37.18	68.16	56.12	0.00	129.62	27.43	30.24	102.19	102.19	5.76
9-Feb-16	43.20	12.07	19.04	37.26	68.36	56.29	0.00	131.79	25.91	28.41	105.88	105.88	7.59
10-Feb-16	45.45	11.90	20.36	37.97	70.24	58.34	0.00	135.80	27.43	29.48	108.36	108.36	6.52
11-Feb-16	55.65	31.21	20.59	5.01	56.80	25.59	0.00	131.45	27.43	29.19	104.01	104.01	6.81
12-Feb-16	46.59	21.98	20.24	23.44	65.66	43.68	0.00	131.20	27.43	29.24	103.77	103.77	6.76
13-Feb-16	43.02	11.44	20.46	38.21	70.11	58.67	0.00	131.89	27.43	29.27	104.45	104.45	6.73
14-Feb-16	43.71	14.61	20.53	37.14	72.28	57.67	0.00	135.47	27.43	30.62	108.04	108.04	5.38
15-Feb-16	42.43	13.35	19.29	37.28	69.91	56.56	0.00	132.65	27.43	30.18	105.22	105.22	5.82
16-Feb-16	39.53	10.11	19.04	35.23	64.37	54.27	0.00	120.35	19.81	20.72	98.21	98.21	12.95

A	B	C	D	E	F	G	H	I	J	K	L	M	N
17-Feb-16	38.05	9.58	19.04	36.01	64.63	55.05	0.00	114.94	24.38	25.37	90.55	90.55	10.63
18-Feb-16	38.20	8.42	15.78	33.85	58.06	49.63	0.00	108.00	22.86	23.90	85.14	85.14	12.10
19-Feb-16	42.10	10.53	18.37	33.29	62.19	51.66	0.00	116.15	22.86	24.00	91.19	91.19	9.90
20-Feb-16	39.59	7.64	18.84	37.93	64.41	56.77	0.00	112.39	22.86	24.00	89.53	89.53	12.00
21-Feb-16	41.73	8.15	18.88	34.30	61.32	53.18	0.00	113.77	23.62	25.07	90.14	90.14	10.93
22-Feb-16	40.45	8.09	21.29	36.67	66.06	57.97	0.00	116.66	23.62	24.46	93.04	93.04	11.54
23-Feb-16	42.57	7.82	20.04	36.51	64.38	56.55	0.00	117.10	25.15	26.24	91.95	91.95	9.76
24-Feb-16	40.55	10.55	19.04	35.64	65.23	54.68	0.00	118.84	25.91	26.55	92.93	92.93	9.45
25-Feb-16	38.49	8.90	19.94	34.21	63.05	54.15	0.00	113.30	24.38	24.98	88.92	88.92	11.03
26-Feb-16	41.33	9.44	19.94	37.84	67.21	57.77	0.00	120.19	28.19	29.03	91.99	91.99	6.97
27-Feb-16	45.13	10.47	22.19	34.77	67.43	56.96	0.00	123.36	28.96	29.89	94.40	94.40	6.11
1-Mar-16	40.88	8.45	19.08	38.23	65.75	57.30	0.00	120.68	25.91	26.85	94.78	94.78	9.15
2-Mar-16	39.89	10.23	19.90	36.35	66.48	56.25	0.00	117.03	25.91	27.25	91.12	91.12	8.75
3-Mar-16	40.58	8.80	19.53	37.50	65.83	57.03	0.00	116.40	27.43	28.93	88.97	88.97	7.07
4-Mar-16	35.32	11.58	19.94	37.18	68.70	57.12	0.00	116.04	27.43	29.19	88.61	88.61	6.81
5-Mar-16	34.52	11.48	23.55	42.76	77.79	66.31	0.00	121.35	27.43	32.52	93.92	93.92	3.48
6-Mar-16	32.84	8.07	22.68	40.62	71.37	63.31	0.00	115.59	27.43	30.89	88.16	88.16	5.11
7-Mar-16	40.44	7.77	20.16	36.21	64.14	56.37	0.00	115.46	27.43	30.80	88.03	88.03	5.20
8-Mar-16	44.57	8.43	20.02	38.76	67.22	58.78	0.00	121.85	27.43	31.05	94.41	94.41	4.95
9-Mar-16	46.65	6.18	19.99	38.76	64.93	58.75	0.00	121.94	27.43	29.63	94.51	94.51	6.37
10-Mar-16	45.73	8.63	19.14	38.49	66.26	57.62	0.00	121.99	28.19	30.65	93.79	93.79	5.35
11-Mar-16	46.42	8.22	19.12	38.49	65.82	57.60	0.00	122.45	28.19	31.35	94.25	94.25	4.65
12-Mar-16	48.66	8.80	19.00	38.49	66.28	57.48	0.00	125.38	28.19	29.84	97.18	97.18	6.16
13-Mar-16	49.91	8.39	19.14	39.74	67.27	58.88	0.00	127.14	27.43	29.08	99.71	99.71	6.92
14-Mar-16	49.02	8.86	19.14	41.00	69.00	60.13	0.00	128.13	27.43	29.68	100.70	100.70	6.32
15-Mar-16	48.20	9.50	20.54	34.54	64.58	55.08	0.00	124.26	27.43	29.89	96.83	96.83	6.11
16-Mar-16	45.61	7.41	22.09	40.62	70.13	62.71	0.00	126.81	28.96	31.37	97.85	97.85	4.63
17-Mar-16	45.96	8.32	20.74	40.62	69.68	61.36	0.00	126.57	28.96	31.09	97.61	97.61	4.91
18-Mar-16	45.18	9.14	24.35	38.63	72.11	62.97	0.00	126.87	28.96	31.32	97.92	97.92	4.68

A	B	C	D	E	F	G	H	I	J	K	L	M	N
19-Mar-16	44.29	7.63	23.34	41.69	72.67	65.04	0.00	125.66	27.43	30.25	98.23	98.23	5.75
20-Mar-16	42.95	9.43	21.54	40.20	71.17	61.74	0.00	123.69	26.67	30.04	97.02	97.02	5.96
21-Mar-16	41.52	8.25	19.74	39.69	67.68	59.43	0.00	117.90	22.86	25.83	95.04	95.04	10.17
22-Mar-16	42.48	7.92	21.79	40.62	70.33	62.41	0.00	122.94	22.86	24.36	100.08	100.08	11.64
23-Mar-16	43.58	8.44	20.94	39.85	69.23	60.79	0.00	121.51	23.62	25.63	97.89	97.89	10.37
24-Mar-16	44.80	8.73	19.89	40.20	68.81	60.08	0.00	121.52	24.38	27.40	97.14	97.14	8.60
25-Mar-16	43.72	8.93	20.09	40.62	69.65	60.71	0.00	122.71	24.38	27.35	98.33	98.33	8.65
26-Mar-16	42.26	8.30	20.52	40.62	69.45	61.14	0.00	121.05	24.38	26.79	96.66	96.66	9.21
27-Mar-16	43.85	9.56	20.42	40.62	70.61	61.04	0.00	123.04	27.43	28.28	95.61	95.61	7.72
28-Mar-16	43.02	7.52	19.54	39.40	66.45	58.93	0.00	117.36	25.91	28.43	91.46	91.46	7.57
29-Mar-16	43.85	9.22	20.54	42.76	72.52	63.30	0.00	126.53	27.43	29.39	99.10	99.10	6.61
30-Mar-16	44.24	8.14	19.64	41.91	69.68	61.54	0.00	124.40	25.91	27.57	98.49	98.49	8.43
31-Mar-16	43.34	10.98	19.74	42.76	73.48	62.50	0.00	124.93	30.48	32.69	94.45	94.45	3.31
1-Apr-16	44.30	8.74	19.34	42.76	70.84	62.10	0.00	122.99	27.43	29.76	95.56	95.56	6.24
2-Apr-16	43.08	8.90	21.02	38.43	68.35	59.45	0.00	121.70	27.43	35.21	94.27	94.27	0.79
3-Apr-16	44.26	9.19	23.85	38.49	71.52	62.33	0.00	127.24	27.43	32.57	99.81	99.81	3.43
4-Apr-16	45.44	10.14	23.59	38.49	72.22	62.08	0.00	128.65	28.96	32.50	99.69	99.69	3.50
5-Apr-16	45.38	9.37	20.89	40.62	70.88	61.51	0.00	125.40	28.96	34.09	96.49	96.49	1.95
6-Apr-16	43.80	9.52	19.90	33.10	62.51	53.00	0.00	118.17	28.96	32.27	89.22	89.22	3.73
8-Apr-16	0.76	1.47	0.00	0.00	1.47	0.00	20.42	30.97	16.15	17.96	14.82	14.82	38.47
9-Apr-16	0.76	2.54	0.00	0.00	2.54	0.00	20.71	31.83	16.15	17.65	15.68	15.68	39.05
10-Apr-16	0.76	3.29	0.00	0.00	3.29	0.00	17.90	29.71	16.15	18.01	13.56	13.56	35.90
11-Apr-16	0.76	3.45	0.00	0.00	3.45	0.00	19.12	31.09	16.15	18.47	14.94	14.94	36.66
12-Apr-16	0.76	3.87	0.00	0.00	3.87	0.00	17.72	31.08	16.15	17.56	14.93	14.93	36.16
13-Apr-16	0.76	4.90	0.00	0.00	4.90	0.00	16.37	31.47	16.15	17.61	15.32	15.32	34.76
14-Apr-16	0.76	8.58	0.00	0.00	8.58	0.00	8.37	30.55	16.15	17.21	14.39	14.39	27.16
15-Apr-16	0.86	3.63	0.00	0.00	3.63	0.00	26.85	39.09	16.15	19.83	22.93	22.93	43.01
16-Apr-16	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
17-Apr-16	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00

A	B	C	D	E	F	G	H	I	J	K	L	M	N
18-Apr-16	0.76	3.94	0.00	0.00	3.94	0.00	27.47	33.35	15.24	16.15	18.11	18.11	47.32
19-Apr-16	9.13	4.86	3.20	0.00	8.06	3.20	7.65	31.99	6.10	7.34	25.90	25.90	36.31
20-Apr-16	12.50	24.01	11.27	0.00	35.29	11.27	0.00	56.89	3.05	4.76	53.84	53.84	31.25
21-Apr-16	10.80	21.71	11.27	3.50	36.48	14.77	0.00	57.77	4.57	6.33	53.20	53.20	29.67
22-Apr-16	12.98	7.13	12.40	14.51	34.04	26.91	0.00	54.29	4.57	7.24	49.72	49.72	28.76
23-Apr-16	13.75	8.86	11.27	24.18	44.32	35.45	0.00	68.03	4.57	7.19	57.45	57.45	22.81
24-Apr-16	13.57	17.01	13.53	22.32	52.86	35.85	0.00	75.60	4.57	6.07	71.03	71.03	29.93
25-Apr-16	14.26	9.07	13.53	23.06	45.66	36.59	0.00	69.83	4.57	5.37	65.25	65.25	30.63
26-Apr-16	13.77	13.53	12.63	23.06	49.22	35.69	0.00	71.94	4.57	5.72	67.36	67.36	30.28
27-Apr-16	27.26	8.93	18.98	26.78	54.70	45.77	0.00	91.60	15.24	17.97	76.36	76.36	18.03
28-Apr-16	25.63	6.93	25.24	34.58	66.75	59.82	0.00	101.11	15.24	16.49	85.87	85.87	19.52
29-Apr-16	28.01	5.22	21.48	37.65	64.35	59.13	0.00	100.86	15.24	17.80	85.62	85.62	18.20
30-Apr-16	31.38	7.92	17.63	36.27	61.82	53.91	0.00	102.57	15.24	16.49	87.33	87.33	19.52
1-May-16	30.40	7.78	16.34	37.55	61.68	53.90	0.00	101.98	15.24	17.09	86.74	86.74	18.91
2-May-16	30.40	5.58	17.77	39.41	62.76	57.19	0.00	103.07	15.24	17.09	87.83	87.83	18.91
3-May-16	32.10	5.72	19.09	38.39	63.20	57.48	0.00	105.21	15.24	17.44	89.97	89.97	18.56
4-May-16	30.58	8.83	20.15	35.97	64.95	56.12	0.00	104.42	15.24	17.19	89.18	89.18	18.81
5-May-16	32.19	6.96	22.79	37.74	67.50	60.54	0.00	108.80	18.29	20.59	90.51	90.51	15.41
6-May-16	34.12	13.30	20.15	37.37	70.82	57.52	0.00	113.23	22.86	24.52	90.37	90.37	11.48
7-May-16	34.32	11.20	18.84	37.74	67.78	56.58	0.00	110.04	18.29	20.35	91.75	91.75	15.65
8-May-16	33.28	7.83	19.78	38.67	66.28	58.45	0.00	107.57	18.29	20.00	89.28	89.28	16.01
9-May-16	32.98	6.45	20.48	37.55	64.48	58.03	0.00	106.54	18.29	19.95	93.96	93.96	21.77
10-May-16	32.42	16.11	21.11	33.46	70.69	54.57	0.00	111.93	21.34	23.00	90.59	90.59	13.01
11-May-16	32.31	11.71	22.44	33.46	67.62	55.91	0.00	109.28	18.29	19.95	90.99	90.99	16.05
12-May-16	31.87	12.20	21.07	33.46	66.73	54.53	0.00	108.92	18.29	19.95	90.64	90.64	16.05
13-May-16	32.64	17.44	19.84	35.32	72.60	55.16	0.00	115.56	21.34	23.00	94.22	94.22	13.01
14-May-16	33.89	15.01	19.78	37.18	71.97	56.96	0.00	115.21	21.34	23.00	93.87	93.87	13.01
15-May-16	35.46	12.39	18.90	37.55	68.84	56.45	0.00	114.20	21.34	23.00	92.87	92.87	13.01
16-May-16	32.99	7.50	22.44	36.90	66.85	59.35	0.00	109.19	15.24	17.51	93.95	93.95	18.50

A	B	C	D	E	F	G	H	I	J	K	L	M	N
17-May-16	31.69	9.52	23.35	34.88	67.74	58.22	0.00	110.77	18.29	19.64	92.48	92.48	16.36
18-May-16	33.27	6.87	25.40	34.71	66.98	60.11	0.00	109.05	15.24	16.60	93.81	93.81	19.40
19-May-16	28.69	10.88	24.68	35.32	70.88	60.00	0.00	108.37	15.24	16.29	93.13	93.13	19.71
20-May-16	31.28	6.85	22.85	34.02	63.72	56.88	0.00	104.91	15.24	16.39	89.67	89.67	19.61
21-May-16	31.48	6.32	21.09	32.72	60.13	53.81	0.00	101.75	15.24	16.29	86.51	86.51	19.71
22-May-16	29.51	7.54	24.74	31.79	64.07	56.53	0.00	102.85	15.24	16.34	87.61	87.61	19.66
23-May-16	28.77	5.91	18.82	32.46	57.18	51.28	0.00	93.55	15.24	16.25	78.31	78.31	19.76
24-May-16	20.87	5.84	11.21	29.93	46.99	41.14	0.00	76.65	7.62	8.32	69.03	69.03	27.68
25-May-16	21.19	6.97	13.48	33.84	54.28	47.31	0.00	85.37	11.89	12.69	73.49	73.49	23.31
26-May-16	23.69	6.47	12.03	29.99	48.50	42.02	0.00	81.54	7.62	8.67	73.92	73.92	27.33
27-May-16	23.85	6.93	11.17	28.91	47.01	40.08	0.00	80.21	9.14	10.25	71.06	71.06	25.76
28-May-16	25.97	7.17	10.17	26.66	43.99	36.83	0.00	80.05	9.14	10.55	70.91	70.91	25.45
29-May-16	25.80	7.21	10.97	30.49	48.67	41.46	0.00	82.57	9.14	10.74	73.42	73.42	25.26
30-May-16	26.88	5.57	19.21	30.04	54.82	49.25	0.00	88.20	9.14	11.32	79.06	79.06	24.68
31-May-16	36.79	7.01	20.03	31.68	58.72	51.71	0.00	102.39	10.06	11.11	92.33	92.33	24.89
1-Jun-16	33.23	6.76	23.31	32.24	62.30	55.54	0.00	103.83	10.06	12.01	93.77	93.77	23.99
2-Jun-16	32.07	10.60	20.29	37.18	68.07	57.47	0.00	109.13	15.24	16.84	93.89	93.89	19.16
3-Jun-16	36.65	17.53	22.99	37.18	77.71	60.18	0.00	122.71	15.24	15.99	94.56	94.56	7.10
4-Jun-16	34.35	7.34	23.35	36.07	66.76	59.41	0.00	110.06	15.24	16.12	94.82	94.82	19.88
5-Jun-16	36.54	7.26	22.93	33.84	64.03	56.77	0.00	108.73	15.24	16.04	93.49	93.49	19.96
6-Jun-16	41.43	8.08	20.43	36.81	65.32	57.24	0.00	114.45	17.37	18.63	97.08	97.08	17.37
7-Jun-16	41.34	10.80	19.97	31.99	62.76	51.96	0.00	112.64	18.29	20.46	94.35	94.35	15.54
8-Jun-16	41.59	6.85	23.25	34.21	64.31	57.46	0.00	114.00	19.81	21.68	94.18	94.18	14.32
9-Jun-16	38.46	8.12	22.45	34.02	64.60	56.48	0.00	109.77	13.72	15.66	96.05	96.05	20.34
10-Jun-16	40.23	7.45	20.16	33.65	61.26	53.82	0.00	110.58	15.24	16.85	95.34	95.34	19.15
11-Jun-16	38.61	6.71	22.74	34.21	63.67	56.95	0.00	116.05	18.29	20.15	97.76	97.76	15.85
12-Jun-16	38.44	8.17	23.19	33.93	65.29	57.12	0.00	115.76	19.81	21.62	95.95	95.95	14.38
13-Jun-16	39.44	8.18	24.09	33.84	66.10	57.92	0.00	116.39	19.81	21.11	96.57	96.57	14.90
14-Jun-16	39.58	12.55	22.73	31.98	67.26	54.71	0.00	114.81	19.81	21.81	95.00	95.00	14.19

A	B	C	D	E	F	G	H	I	J	K	L	M	N
15-Jun-16	38.91	10.22	22.73	31.98	64.93	54.71	0.00	111.67	16.46	19.06	95.21	95.21	16.94
16-Jun-16	39.61	8.48	22.73	33.56	64.77	56.29	0.00	111.24	18.29	21.28	92.96	92.96	14.72
17-Jun-16	40.00	10.30	24.54	33.56	68.39	58.09	0.00	115.02	20.42	24.54	94.60	94.60	11.46
18-Jun-16	39.62	8.14	25.64	33.37	67.16	59.02	0.00	114.13	19.81	22.61	94.32	94.32	13.39
19-Jun-16	38.34	8.23	26.34	34.12	68.68	60.46	0.00	114.86	21.34	24.09	93.53	93.53	11.91
20-Jun-16	41.16	10.49	24.46	33.00	67.95	57.46	0.00	116.47	21.34	24.07	95.13	95.13	11.93
21-Jun-16	42.14	16.04	26.27	33.65	75.96	59.92	0.00	126.58	21.34	23.02	105.24	105.24	12.98
22-Jun-16	41.91	23.90	25.94	13.66	63.50	39.60	0.00	115.81	21.34	23.63	94.47	94.47	12.37
23-Jun-16	39.96	10.47	27.05	29.76	67.29	56.81	0.00	116.20	24.38	26.78	91.82	91.82	9.22
24-Jun-16	41.13	9.62	27.50	32.36	69.49	59.87	0.00	119.14	28.60	30.74	90.54	90.54	5.26
25-Jun-16	41.89	9.48	26.60	30.13	66.22	56.74	0.00	116.35	28.80	30.94	87.55	87.55	5.06
26-Jun-16	43.62	7.84	28.72	34.72	71.28	63.44	0.00	122.15	26.90	28.93	95.25	95.25	7.07
27-Jun-16	42.09	7.29	21.98	33.78	63.05	55.76	0.00	108.06	20.70	23.06	87.36	87.36	12.94
28-Jun-16	42.03	9.33	25.71	30.13	65.18	55.84	0.00	108.87	20.70	22.12	88.17	88.17	13.88
29-Jun-16	40.39	9.27	27.43	34.49	71.19	61.92	0.00	114.50	20.70	22.42	93.80	93.80	13.58
30-Jun-16	39.23	9.45	27.18	34.58	71.21	61.76	0.00	115.72	17.50	18.99	98.22	98.22	17.02
1-Jul-16	39.79	8.47	23.35	34.32	66.14	57.67	0.00	112.24	14.90	16.78	97.34	97.34	19.22
2-Jul-16	39.49	9.96	25.05	34.03	69.03	59.08	0.00	113.41	15.80	17.73	97.61	97.61	18.27
3-Jul-16	43.56	9.70	25.70	31.62	67.02	57.32	0.00	113.63	17.30	19.79	96.33	96.33	16.21
4-Jul-16	43.23	8.98	23.96	34.75	67.70	58.71	0.00	115.34	18.30	20.15	97.04	97.04	15.85
5-Jul-16	42.31	7.34	22.67	33.28	63.29	55.96	0.00	110.86	14.80	16.74	96.06	96.06	19.26
6-Jul-16	45.39	7.92	22.09	34.68	64.69	56.76	0.00	115.88	17.40	19.00	98.48	98.48	17.00
7-Jul-16	45.19	8.39	22.66	36.63	67.68	59.29	0.00	114.62	17.10	19.23	97.52	97.52	16.77
8-Jul-16	45.46	6.57	23.31	33.65	63.53	56.96	0.00	113.63	16.10	17.89	97.53	97.53	18.11
9-Jul-16	37.22	10.60	24.62	34.95	70.18	59.58	0.00	113.83	17.10	18.84	96.73	96.73	17.16
10-Jul-16	37.22	9.32	24.85	35.79	69.96	60.64	0.00	114.71	18.50	21.00	96.21	96.21	15.00
11-Jul-16	38.34	9.91	24.82	36.63	71.36	61.45	0.00	114.15	16.00	18.00	98.15	98.15	18.01
12-Jul-16	38.11	9.02	27.47	35.98	72.46	63.45	0.00	116.41	19.70	21.97	96.71	96.71	14.03
13-Jul-16	38.42	11.33	28.66	37.37	77.36	66.03	0.00	122.42	19.70	22.56	102.72	102.72	13.44

A	B	C	D	E	F	G	H	I	J	K	L	M	N
14-Jul-16	40.06	18.13	29.19	32.59	79.91	61.78	0.00	123.82	21.90	25.55	101.92	101.92	10.45
15-Jul-16	48.88	24.39	35.11	5.56	65.06	40.67	0.00	117.46	23.80	26.15	93.66	93.66	9.85
16-Jul-16	47.29	23.04	35.66	10.03	68.73	45.69	0.00	120.07	29.80	31.54	90.27	90.27	4.46
17-Jul-16	40.33	16.82	25.25	35.69	77.77	60.94	0.00	121.69	26.80	28.59	94.89	94.89	7.41
18-Jul-16	42.12	9.63	23.12	35.14	67.89	58.26	0.00	115.08	21.60	24.24	93.48	93.48	11.76
19-Jul-16	42.50	10.73	23.90	35.10	69.73	59.00	0.00	117.06	19.30	22.22	97.76	97.76	13.78
20-Jul-16	39.98	11.42	23.74	38.67	73.83	62.41	0.00	116.99	19.30	21.50	97.69	97.69	14.50
21-Jul-16	39.21	16.46	23.66	38.40	78.51	62.05	0.00	121.97	19.70	22.25	102.27	102.27	13.75
22-Jul-16	39.90	10.10	24.01	37.97	72.07	61.98	0.00	115.63	22.40	24.60	93.23	93.23	11.40
23-Jul-16	41.37	9.79	26.92	38.21	74.91	65.13	0.00	119.14	21.40	24.21	97.74	97.74	11.79
24-Jul-16	42.41	9.41	25.07	37.94	72.42	63.01	0.00	117.17	17.80	20.79	99.37	99.37	15.21
25-Jul-16	43.52	10.45	21.75	37.93	70.13	59.68	0.00	118.18	17.70	20.60	100.48	100.48	15.40
26-Jul-16	44.50	8.35	22.37	34.96	65.67	57.33	0.00	114.34	17.00	19.48	97.34	97.34	16.52
27-Jul-16	31.32	22.26	14.82	23.18	60.26	38.00	0.00	95.47	17.80	20.48	77.67	77.67	15.52
28-Jul-16	20.65	5.14	12.17	12.65	29.96	24.82	0.00	51.19	11.80	12.71	39.39	39.39	23.29
29-Jul-16	29.15	6.08	11.27	18.04	35.39	29.31	0.00	64.96	14.30	14.91	50.66	50.66	21.09
30-Jul-16	31.29	6.06	18.09	22.61	46.75	40.69	0.00	78.81	13.50	14.41	65.31	65.31	21.59
31-Jul-16	34.89	9.62	21.93	30.68	62.24	52.61	0.00	100.46	29.70	31.22	70.76	70.76	4.79
2-Aug-16	4.57	3.35	0.00	0.00	3.35	0.00	5.50	19.24	0.40	1.29	18.84	18.84	40.20
3-Aug-16	2.11	1.62	0.00	0.00	1.62	0.00	8.47	19.44	0.00	0.94	19.44	19.44	43.53
4-Aug-16	22.88	3.10	7.67	5.58	16.35	13.25	0.00	46.11	4.50	5.44	41.61	41.61	30.56
5-Aug-16	15.16	3.76	13.98	13.02	30.76	27.00	0.00	52.08	4.20	5.02	47.88	47.88	30.98
6-Aug-16	15.02	4.90	13.53	18.60	37.03	32.13	0.00	58.03	3.60	5.16	54.43	54.43	30.84
7-Aug-16	13.79	4.68	11.70	25.93	42.31	37.63	0.00	62.78	2.40	2.75	56.01	56.01	28.88
8-Aug-16	15.09	6.37	16.45	26.40	49.22	42.85	0.00	71.22	4.10	5.71	67.12	67.12	30.29
9-Aug-16	32.18	5.98	16.56	30.50	53.03	47.06	0.00	94.02	12.20	13.56	81.82	81.82	22.44
10-Aug-16	35.06	6.86	20.43	27.96	55.25	48.39	0.00	98.31	12.90	13.86	85.41	85.41	22.14
11-Aug-16	35.45	7.86	17.15	31.06	56.07	48.21	0.00	98.37	12.50	13.76	85.87	85.87	22.24
12-Aug-16	31.65	7.38	18.68	30.40	56.45	49.08	0.00	93.45	9.50	10.13	83.95	83.95	25.87

A	B	C	D	E	F	G	H	I	J	K	L	M	N
13-Aug-16	31.65	5.92	19.60	28.26	53.79	47.86	0.00	91.96	7.50	8.13	84.46	84.46	27.87
14-Aug-16	34.34	6.18	20.23	27.10	53.51	47.33	0.00	94.97	10.80	11.43	84.17	84.17	24.57
15-Aug-16	31.62	6.52	20.69	31.89	59.11	52.59	0.00	101.70	17.60	17.93	84.10	84.10	18.07
16-Aug-16	31.59	5.55	17.38	30.12	53.06	47.51	0.00	94.21	12.50	13.11	81.71	81.71	22.89
17-Aug-16	28.73	6.20	18.61	31.33	56.14	49.94	0.00	91.73	5.70	6.66	86.03	86.03	29.34
18-Aug-16	30.07	5.66	18.36	32.82	56.84	51.18	0.00	92.98	8.00	9.24	84.98	84.98	26.76
19-Aug-16	29.72	6.53	16.02	31.33	53.88	47.35	0.00	91.18	7.50	8.30	83.68	83.68	27.70
20-Aug-16	29.77	4.77	18.39	32.54	55.70	50.93	0.00	91.44	8.56	9.65	82.88	82.88	26.34
21-Aug-16	28.30	5.59	16.58	31.52	53.69	48.10	0.00	88.46	2.90	4.20	85.56	85.56	31.80
22-Aug-16	29.19	5.12	17.58	30.24	52.94	47.82	0.00	84.27	1.60	3.05	82.67	82.67	32.95
23-Aug-16	30.19	5.27	18.65	31.71	55.62	50.36	0.00	88.07	6.45	7.90	81.62	81.62	28.10
24-Aug-16	29.64	5.08	19.10	32.73	56.91	51.82	0.00	90.40	8.30	10.06	82.10	82.10	25.95
25-Aug-16	34.65	5.86	16.52	32.54	54.93	49.06	0.00	93.82	10.90	15.38	82.92	82.92	20.62
26-Aug-16	29.67	5.82	16.62	37.81	60.25	54.44	0.00	93.84	10.90	15.69	82.94	82.94	20.32
27-Aug-16	34.67	7.07	17.48	35.51	60.07	53.00	0.00	98.65	14.50	17.77	84.15	84.15	18.23
28-Aug-16	40.20	6.11	16.63	37.19	59.92	53.82	0.00	104.69	16.90	20.78	87.79	87.79	15.22
29-Aug-16	35.26	4.99	16.34	37.04	58.37	53.38	0.00	94.97	9.80	13.12	85.17	85.17	22.88
30-Aug-16	35.01	5.55	14.58	29.99	50.11	44.56	0.00	85.54	3.50	6.91	82.04	82.04	29.09
1-Sep-16	44.62	40.72	25.50	5.56	71.78	31.06	0.00	119.30	12.80	14.65	106.50	106.50	21.35
2-Sep-16	44.27	52.62	25.60	3.89	82.11	29.49	0.00	128.72	22.00	24.66	106.72	106.72	11.34
3-Sep-16	42.71	63.54	21.15	4.45	89.14	25.60	0.00	134.74	23.00	26.27	111.74	111.74	9.73
4-Sep-16	43.22	60.74	21.19	5.56	87.49	26.75	0.00	133.05	22.80	26.53	110.25	110.25	9.47
5-Sep-16	45.20	59.39	18.94	5.56	83.89	24.50	0.00	131.43	23.50	25.96	107.93	107.93	10.04
6-Sep-16	44.73	55.41	17.91	9.19	82.51	27.11	0.00	131.93	15.70	17.51	116.23	116.23	18.49
7-Sep-16	43.90	24.41	16.69	33.58	74.68	50.27	0.00	125.69	5.30	7.43	120.39	120.39	28.57
8-Sep-16	44.25	13.77	17.58	5.56	36.92	23.15	0.00	84.85	23.50	25.91	75.94	75.94	24.68
9-Sep-16	44.89	21.56	19.68	41.53	82.77	61.21	0.00	133.33	9.20	11.06	124.13	124.13	24.94
10-Sep-16	53.20	15.59	22.03	41.59	79.21	63.62	0.00	138.09	9.60	11.51	128.49	128.49	24.49
11-Sep-16	51.86	14.07	21.21	42.76	78.04	63.97	0.00	135.58	11.00	12.96	124.58	124.58	23.04

A	B	C	D	E	F	G	H	I	J	K	L	M	N
12-Sep-16	51.59	17.47	23.51	42.76	83.73	66.27	0.00	141.38	16.10	18.56	125.28	125.28	17.44
13-Sep-16	42.93	30.48	20.31	42.76	93.55	63.07	0.00	144.79	16.70	19.29	128.09	128.09	16.71
14-Sep-16	43.84	34.09	22.09	42.39	98.58	64.48	0.00	149.83	13.70	15.71	136.13	136.13	20.29
15-Sep-16	44.40	28.09	22.99	42.39	93.48	65.38	0.00	144.21	13.70	15.86	130.51	130.51	20.14
16-Sep-16	46.15	33.43	21.17	42.33	96.93	63.50	0.00	150.49	20.70	23.72	129.79	129.79	12.28
17-Sep-16	46.25	42.56	21.72	42.22	106.50	63.94	0.00	159.83	19.00	21.72	140.83	140.83	14.28
18-Sep-16	46.70	38.75	19.94	42.39	101.08	62.33	0.00	154.98	17.80	20.22	137.18	137.18	15.78
19-Sep-16	47.95	31.39	20.39	42.60	94.37	62.98	0.00	149.41	14.10	16.10	135.31	135.31	19.91
20-Sep-16	49.51	34.75	19.04	42.65	96.43	61.69	0.00	153.04	14.60	16.95	138.44	138.44	19.05
21-Sep-16	49.49	26.73	22.13	42.76	91.62	64.89	0.00	148.05	16.60	19.21	131.45	131.45	16.79
22-Sep-16	48.41	31.38	21.23	42.76	95.38	63.99	0.00	150.72	19.40	21.45	131.32	131.32	14.56
23-Sep-16	48.53	31.46	21.21	42.76	95.43	63.97	0.00	150.77	18.50	20.21	132.27	132.27	15.79
24-Sep-16	47.97	35.74	21.21	42.76	99.72	63.97	0.00	154.15	19.20	21.15	134.95	134.95	14.85
25-Sep-16	47.09	31.43	21.21	42.76	95.41	63.97	0.00	149.13	16.70	18.30	132.43	132.43	17.70
26-Sep-16	47.46	38.74	20.27	39.04	98.05	59.31	0.00	151.98	15.00	16.45	136.98	136.98	19.55
27-Sep-16	46.62	39.20	20.68	36.56	96.44	57.24	0.00	149.69	14.50	16.96	135.19	135.19	19.04
28-Sep-16	46.62	38.55	18.90	37.80	95.25	56.70	0.00	148.53	14.60	16.41	133.93	133.93	19.59
29-Sep-16	31.06	29.02	3.26	23.03	55.31	26.29	10.32	100.42	12.00	13.23	88.42	88.42	33.09
30-Sep-16	14.11	5.36	3.38	16.00	24.73	19.38	46.64	92.66	3.30	4.10	89.36	89.36	78.54

APPENDIX C

Data for the Cost analysis

Year/month		LPG Price - LKR / kg	Peak demand - kwh	Cost for peak loads	Day demand - kwh	Cost for day loads	Off peak demand - kwh	Cost for off peak loads	kVa	Cost for kVa	Current Total Cost for electricity- LKR/ month	Total Electricity demand from CEB- per month
2014	Aug	117.63	72,657	1,743,768	254,834	2,675,757	114,092	684,552	1,508	1,508,000	6,615,077	441,583
	Sep	114.83	89,596	2,150,304	299,498	3,144,729	148,999	893,994	1,534	1,534,000	7,726,027	538,093
	Oct	112.66	81,357	1,952,568	297,536	3,124,128	134,338	806,028	1,469	1,469,000	7,354,724	513,231
	Nov	92.8	80,267	1,926,408	289,882	3,043,761	131,589	789,534	1,396	1,396,000	7,158,703	501,738
	Dec	87.9	71,097	1,670,780	243,543	2,496,316	123,940	731,246	1,281	1,281,000	6,182,341	438,580
2015	Jan	74.03	65,811	1,546,559	198,462	2,034,236	116,051	684,701	1,100	1,100,000	5,368,495	380,324
	Feb	76.48	69,566	1,634,801	203,931	2,090,293	120,259	709,528	1,288	1,288,000	5,725,622	393,756
	Mar	77.17	43,993	1,033,836	138,781	1,422,505	80,661	475,900	1,051	1,051,000	3,986,241	263,435
	May	77.34	61,152	1,437,072	203,762	2,088,561	103,220	608,998	1,503	1,503,000	5,640,631	368,134
	Jun	72.18	77,906	1,830,791	292,288	2,995,952	134,355	792,695	1,678	1,678,000	7,300,438	504,549
	Aug	66.26	80,260	1,886,110	294,929	3,023,022	132,833	783,715	1,498	1,498,000	7,193,847	508,022
	Sep	59.1	72,686	1,708,121	277,765	2,847,091	122,465	722,544	1,426	1,426,000	6,706,756	472,916
	Oct	65.28	65,134	1,530,649	251,335	2,576,184	110,935	654,517	1,396	1,396,000	6,160,349	427,404
	Nov	74.82	83,084	1,952,474	307,881	3,155,780	137,814	813,103	1,602	1,602,000	7,526,357	528,779
	Dec	82.27	85,763	2,015,431	290,621	2,978,865	138,523	817,286	1,420	1,420,000	7,234,581	514,907
2016	Jan	69.41	71,466	1,679,451	272,319	2,791,270	120,184	709,086	1,339	1,339,000	6,521,806	463,969
	Feb	59.37	74,070	1,740,645	277,366	2,843,002	130,051	767,301	1,360	1,360,000	6,713,947	481,487

Year/month		LPG Price - LKR / kg	Peak demand - kwh	Cost for peak loads	Day demand - kwh	Cost for day loads	Off peak demand - kwh	Cost for off peak loads	kVa	Cost for kVa	Current Total Cost for electricity- LKR/ month	Total Electricity demand from CEB- per month
2016	Mar	60.18	70,312	1,652,332	248,776	2,549,954	113,282	668,364	1,390	1,390,000	6,263,650	432,370
	Apr	64.99	73,066	1,717,051	274,430	2,812,908	127,346	751,341	1,466	1,466,000	6,750,300	474,842
	May	67.87	72,686	1,708,121	255,948	2,623,467	113,067	667,095	1,367	1,367,000	6,368,683	441,701
	Jun	67.06	71,281	1,675,104	274,883	2,817,551	121,893	719,169	1,358	1,358,000	6,572,823	468,057
	Jul	59.88	77,790	1,828,065	292,064	2,993,656	129,216	762,374	1,468	1,468,000	7,055,095	499,070
	Aug	57.47	78,585	1,846,748	279,106	2,860,837	126,458	746,102	1,342	1,342,000	6,798,686	484,149
	Sep	60.72	77,813	1,828,606	286,455	2,936,164	128,240	756,616	1,386	1,386,000	6,910,385	492,508