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A PROPOSED SIMPLIFIED TECHNIQUE FOR ACCURATE CALCULATION OF FLARED GAS VOLUME. CASE STUDY OF AN OIL AND GAS PROCESSING PLANT IN NIGER DELTA.

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ABSTRACT

A simplified technique for an accurate calculation of flared gas volume has been established. Although the regulatory agencies in the oil and gas industry has placed some financial and cost measures to minimize the amount of standard cubic feet of gas flared per day by operating companies yet some operators and contractors could not keep an accurate measurement on the actual amount of gas flare from their production facilities. These shortcomings are partially caused due to lack of technologies, equipment malfunctions, equipment inefficiencies, human resource deficiencies. However, gas flaring is by no means a simple measurement process on its own. This is primarily due to the large variations in conditions often found in a flare stack. Measurement difficulties could also arise through the flare type based on changes in the flow profile and Reynolds number caused by variation in the physical properties of the gases and errors due to installation effects. From the aforementioned points, it is clear that the accurate measurement of the flared gas is a rigorous and complex process with several challenges to be considered. This paper presents a technique for measuring flared gas volume based on PVs (pressure valves) present in process plants. A similar approach has been applied in South Pars gas development projects in Iran; utilizing the design information in PVs datasheet as well as actual plant data for opening percentage values which have been utilized from plant Distributed Control System (DCS) and PIMS (Plant Integrated Management System) via excel and visual basic.[5] However, in this study, a new/robust software program that has the ability of extracting data from the plant DCS and PIMS server has been developed using Java, correlation used by this software was generated using Hysys for a particular process plant model in Niger-Delta and the correlation was regressed using excel. An iteration time-step of 1440 minutes has been chosen for greater accuracy. Features of this program include flexibility, less run-time error, user friendly, less memory space and real-time. Assumptions made during these calculations were stated clearly in this paper. Key inputs to this program are valve percentage openings per minute. Key outputs are average percentage opening per day and amount of flared per day in million standard cubic feet (MMscf).

Keywords: Pressure valves (PVs), Valve Openings, Java, Gas Flare, Hysys.

INTRODUCTION

Due to environmental, economic and social cost of hydrocarbon leaks, the oil and gas industry places great importance to the need to minimize ugly events of gas flaring from occurring. The causes of gas flaring could be categorized into four main classes: Operational, structural, intended or unintended damages.

Operational include equipment malfunction, human error etc. Equipment malfunction can result in environmental hazards due to the release of petroleum and natural gas products. Flaring as a result of equipment malfunction has less negative impact in the ecosystem. An equipment malfunction may involve a valve, compressor or chilling component. Sometimes a part on the piece of equipment fails resulting in a release, and sometimes the piece of equipment itself fails to perform its function properly resulting also in a release. The concept of human error, whether intentional or unintentional, is defined as, any human action or lack thereof that exceeds or fails to achieve some limit of acceptability, where limits of human performance are defined by the system[1]. Human error plays a significant and sometimes overriding role in flare causation. Statistics that attribute accidents or losses to human error are varied and are reported to be as high as 85 %.[2]

Structural problems include instrument failure; this often results to high release of flared gas into the atmosphere and invariably has high negative impact in the ecosystem. Structural is often characterized by complete breakdown of one or two of the processing equipment. This is usually minimized by equipment spare philosophy.

Intended form of gas flaring can be seen in companies where gas processing mostly in non-associated gas has been deemed non-viable or non-economical. This often results in transition from low to high release of flue gas into the atmosphere as production declines and production point tends towards the two phase region.

Unintended flaring causes can be seen during start-ups and emergency shut down situations. This usually also result to a high release of flue gas into the atmosphere. Mitigations include increasing the expertise knowledge of operator's during start-ups and shut-downs operations.

In order to generally mitigate the effect resulting from different causes of gas flaring, governments has agreed to set up regulatory bodies, some legally and some not legally binding. One of the first was the United Nations Framework Convention on Climate Change (UNFCCC). This was set up in an international treaty set up at "Earth Summit" held in Rio de Janeiro in 1992. Followed by this is the Kyoto protocol which extended the premise of UNFCCC by holding member countries responsible for their GHG reductions. However, In order to comply with regulations guiding GHG emissions in oil and gas operations, accurate measurement is essential to substantiate reported emissions from environmentalists. To ensure transparency and consistency, measurement technologies shall be selected in accordance with set standards and compliance manuals by the regulatory bodies. Each well has its unique and constantly changing characteristics that include depth, temperature, pressure, flow rate, soot content and changing gas composition. This makes accurate flare gas measurement very challenging. To comply with these stringent regulations, engineers must assess which flow measurement technology yields the highest accuracy with the lowest installation and cost-of-ownership over the lifetime of the well.[3]

Most of the conventional flare gas measurement systems to date, have in general failed to perform optimally within the criteria of accuracy, robustness, reliability, sensitivity, position precision and cost. A flare gas measurement system, by itself, has no effect on the quantity and quality of the gas flared or technical integrity of the flare system, as it is only installed to make the operator aware of an emission, its quantity and location in order for the operator to manage the risk therein and salvage situation. For the meantime, accurate measurement of the amount of gas flared is inevitable to the reduction of the amount of gas flared in our process plants. However less calculation of the amount of gas flared can be devastating in the area of production reconciliation, determining the present or future impact of the amount of gas flared and also jeopardize the integrity of the company towards maintaining a sustainable environment in its operations. On the other hand, over calculation of the amount of gas flared will lead to surplus tax charges against operating company as well as false forecasting of the present/future impact of these gases flared on the environment thereby putting the country in unnecessary fear. In anyway accurate measurement of the amount of gas flared is vital to the owner of the assets, the environmentalists and the country at large.

Several flare gas measurement technologies are based on the continuous analysis of pressure gradients between the upstream and downstream of the sensor installed. Large flare gas volume causes significant change in pressure gradients and substantial differences in mass flow rates at measurement points, and therefore easy to detect. On the other hand small flare gas volumes causes insignificant changes in pressure gradients (<100 psi) and negligible difference in mass flow rates, and therefore hard to detect. However, flare gas as low as 0-100 psi can lead to the flaring of a large amount of flue gas during continuous operation before they are detected, usually by the impact they have on the surrounding environment.

Many methods for creating flare gas measurement systems in process facilities have been proposed ranging from hardware based method, software based method and then promising/proposed technologies.

The hardware method which can also be referred to as a direct flare measurement method involves the use of a dedicated flare gas meter installed in the flare stack to directly measure the total volume in mass of gas passing through the flare line. This poses severe operational and safety challenge as the meter cannot block or impede the flow at any point. Therefore, any device that is significantly intrusive into the flow or causes a pressure drop cannot be used. This eliminates all differential pressure devices for use within the flare stack. Generally, many traditional metering techniques, including differential pressure meters, coriolis meters and turbine meters fall short in one way or another of the measurement requirements.[4] Few metering technologies like Transit-time ultrasonic meter (USM), Cross-correlation optical meter, Averaging pitot tubes, Insertion meters and Thermal mass meters (TMM) match all criteria for flaring. They also have significant limitations over certain operating conditions. Limited information was located in the literature concerning their modes of operation. However an investigative study by Craig Marshall reveals that transit USM is the most common flare gas meter in operation today. USMs operate on the principle of transit time between an upstream and downstream transducer. Each transducer, in turn, sends an ultrasonic pulse across the flow to the other. The time taken to reach the other transducer is directly dependent on the velocity of the medium it is passing through. The transit time of each traverse is measured and the difference used to calculate the velocity of the flow. Limitations can be seen measurement uncertainty due to changing operating conditions of very low volume and pressure, (<100psi). This is still a debate in the oil and gas industry regarding the extent to which it is possible to measure gas flow rates accurately under such varied conditions with the measuring devices presently available on the market. Although some oil companies and equipment manufacturers would disagree, low-pressure gas rate measurement can be a significant problem especially while using ultrasonic meters. Others believe that the best way to obtain consistent data is to base it on estimates and calculations[12].

Also Ibeh et al[11] (2014) in their study stated that Ultrasonic flow meters have the ability to measure process and flare gas without been affected by square root induced error. This has given them a competitive advantage over the years as they are the most commonly used flare gas meter Craig Marshal[4] (2012) as can be seen in Craig Marshall"s review. Special considerations were given to multi-path Ultrasonic flow meters as it has been used for flare gas measurement. Since multi-path ultrasonic meters are built into in-line pipe sections, called spool pieces, the entire meter must be removed to clean them. This degrades the flow measurement accuracy without obvious indicators. Susceptibility to the effects of flow profile, especially swirl, will also cause degraded accuracy. Multi-path ultrasonic meters are distinguished by the number of paths they use to compute the flow rate. Multiple paths enable more precise calculation of the gas velocity and the speed of sound (and thus density), but each set of paths substantially increases the cost.

The software method which can also be referred to as indirect flare measurement approach involves the estimation of gas passed through the flare using alternative methods to that of having a meter installed directly in the flare stack. Two different approaches were investigated under this method, this include measurement based on mass balance and measurement based on pressure valve. In his review, the estimation of total gas flared using mass balance involves calculating the difference between the total gas produced and the total gas used on site and/or exported; these streams being measured with sufficient accuracy. Any remained gas is assumed to be directed through the flare stack. He also talked about inventory calculation method where the amount of gas flared is estimated through the gas contained in process vessels and equipment on the plant. Uncertainties in the use of this approach arise from inaccuracies in the measurement of the amount of gas produced, sold/used and exported. This however is dependent on the hardware device. Nevertheless at higher volumes of gas flared, the mass balance out performs any direct measurement technique. This is also beneficial during blow down conditions when dedicated flare meters fail.

M. Khazaei and M. Pakizehsereht[5] (2009) in their work developed a computational model based on PV's opening. This computation uses the design information in PV's datasheet as well as actual plant data for opening percentage values which has been utilized from plant DCS system and PIMS (Plant Integrated Management System). Added advantages aside flare gas volume measurement are reporting the exact location of gas conducted to flare header, gas operating conditions of temperature and pressure, molecular weight and composition. Limitations to their method was that the information provided in the PVs datasheet by the vendor which has been calculated and tested based on upstream conditions of the valve. This can bring some error in calculation results if the operating condition has considerable difference from design values.

The Proposed Model

This include the four-sensor thermal technology coupled with an advanced mathematical model algorithm that works in tandem with the American gas association compliant gas property database. In combination, their technologies allow the user to adjust the instrument retain accuracy of flare gas compositions change in the field over time. This significantly lowers the cost alternative to four-path ultrasonic meters[3].

This paper however presents a modified technique for measuring flared gas volume based on PVs (pressure valves) present in process plants by removing the limitations place on varying operating conditions of temperature, pressure and flow rate. Name plate valve information was utilized in Hysys to run simulation at current operating conditions of pressure, temperature and flow rate. Results obtained were used to prepare a table which defined the amount of gas transfer vs. valve opening. See table 1. A robust software program that has the ability of extracting data from the plant DCS and PIMS server was developed using Java. Regression analysis was carried out in Excel to give the equation of Line-of-Best-Fit with an R-squared of 0.99. Afterwards, the calculation carried out according to the correlation formula linear trend line which was derived from the plotted curve. An iteration time-step of 1440 minutes was used for greater accuracy. Features of this program include flexibility, less run-time error, user friendly, less memory space and real-time. Assumptions made during these calculations were stated clearly in this paper.

METHODOLOGY

L'Ecole Production System Field Background

L"Ecole Production Station (Note: Actual names omitted for confidential reasons) is one of the major IOC"s production station located in the L'Ecole field. It was commissioned in 1965 as a double bank 2-stage [HP-LP] separation station with a design capacity of 60Mbpd. It processes hydrocarbon fluids from the L'Ecole field which is located in OML-17, about 16 Km north of Port Harcourt in Rivers state. Forty five (45) conduits are currently produced from the L'Ecole production station. Production from L"Ecole Production station is currently 47Mbpd of liquid and 33.403 MMscfd of gas with a BS&W of 49% (July 2013 IPSC). Associated gas (HP & LP) is produced from the flow station to L"Ecole AGG plant for compression and dehydration while the surge vessel gas is flared.

L'Ecole Production System Process Description:

L'Ecole production system is basically a crude oil stabilization unit. It does that in three stages that are through the High temperature separator, low temperature separator and the surge vessel.

Liquids from the surge vessel are then pumped by reciprocating pumps at about 21bar into the delivery line to Bonny Terminal via TNP for final processing.

Associated gas separated from the HP and LP separators are sent to the AGG plant through the HP and LP gas lines for further processing. Residual gas further separated at the surge vessels is sent to the flare knockout vessel and then to the flare.

Liquid from the FLKO is pumped back to the surge vessel.

Below is a schematic of the process described above.

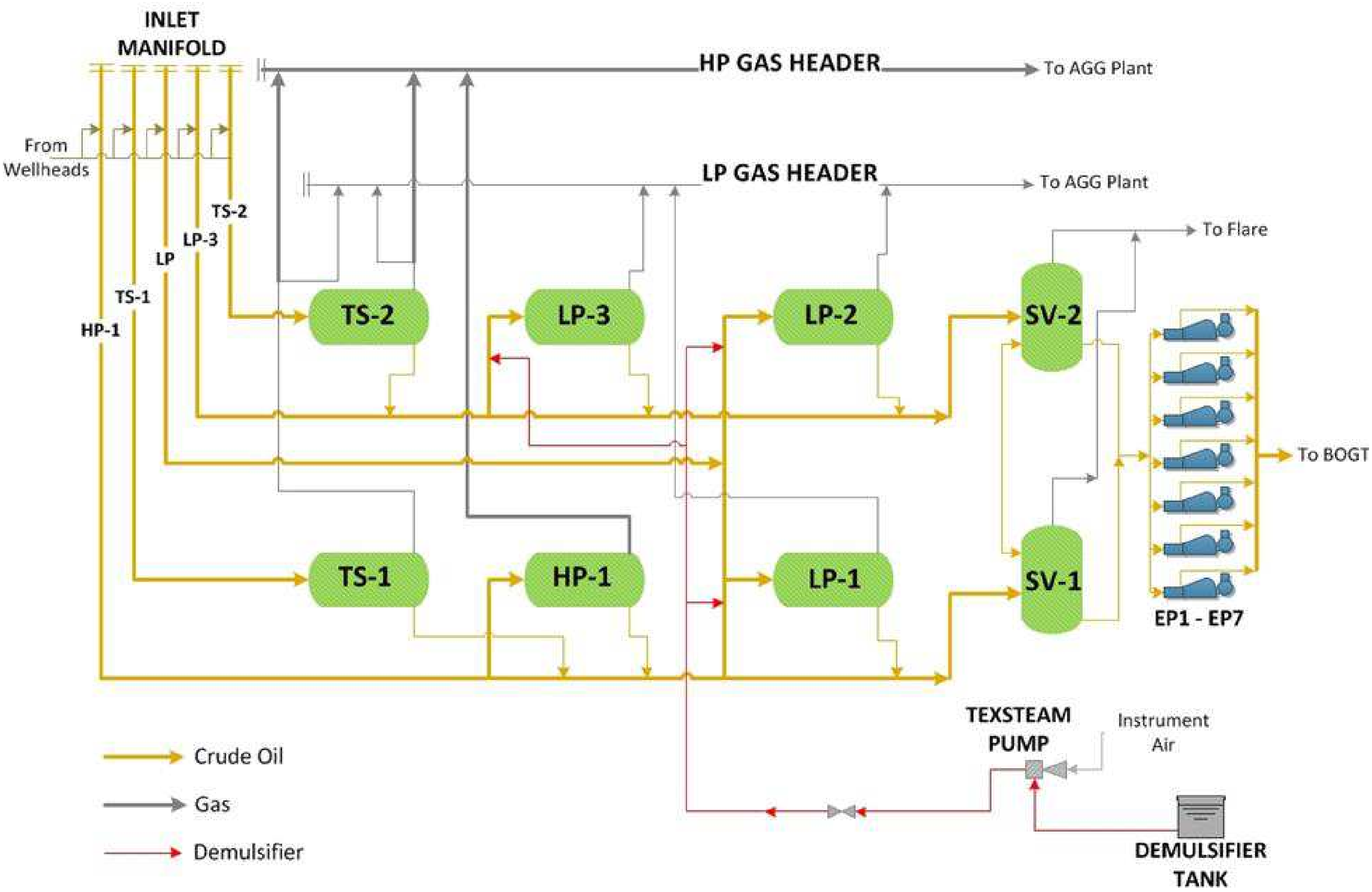


Figure 1- L'Ecole Production System Process flow schematic.

Data Gathering/Validation:

Data used for the Hysys process model calibration was sourced from the following key documents: L'Ecole Flow station As-Built Drawing (2012), L'Ecole Flow station Equipment Data sheet, L'Ecole Flow Stations IPSC for July 2013.

Further data and information were obtained from various sources including PVT reports, Hysys simulation results, Production Chemistry laboratory data, DEPs and surveillance data from site visit.

PVT data validation was done using mole balance plot. Figure 2, below shows the degree of accuracy of the data obtained.

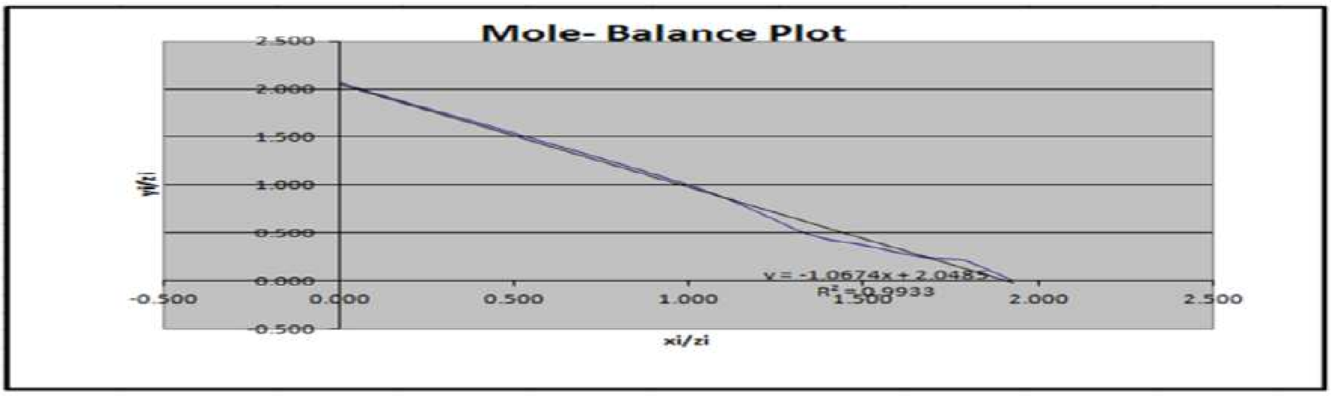


Figure 2 - Fluid Composition validation using mole balance plot.

Other data were also validated using different data validation techniques. The figure below shows a flowchart of the trend followed by the data validation technique.

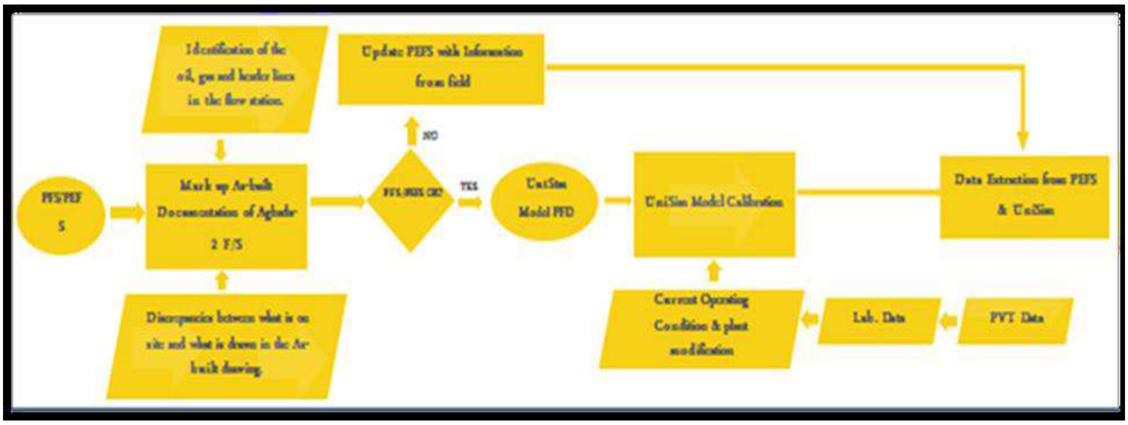


Figure 3 - Basic process chart showing PEFS and Hysys validation technique.

Hysys Model Building/Calibration

Hysys was used to calibrate the production system current operating conditions of temperature, pressure and flow rates. The model however when ran depicted a higher degree of accuracy with what is on field showing that it is a representative model. The figure below shows an overview of the model and some important parameters used for the calibration.

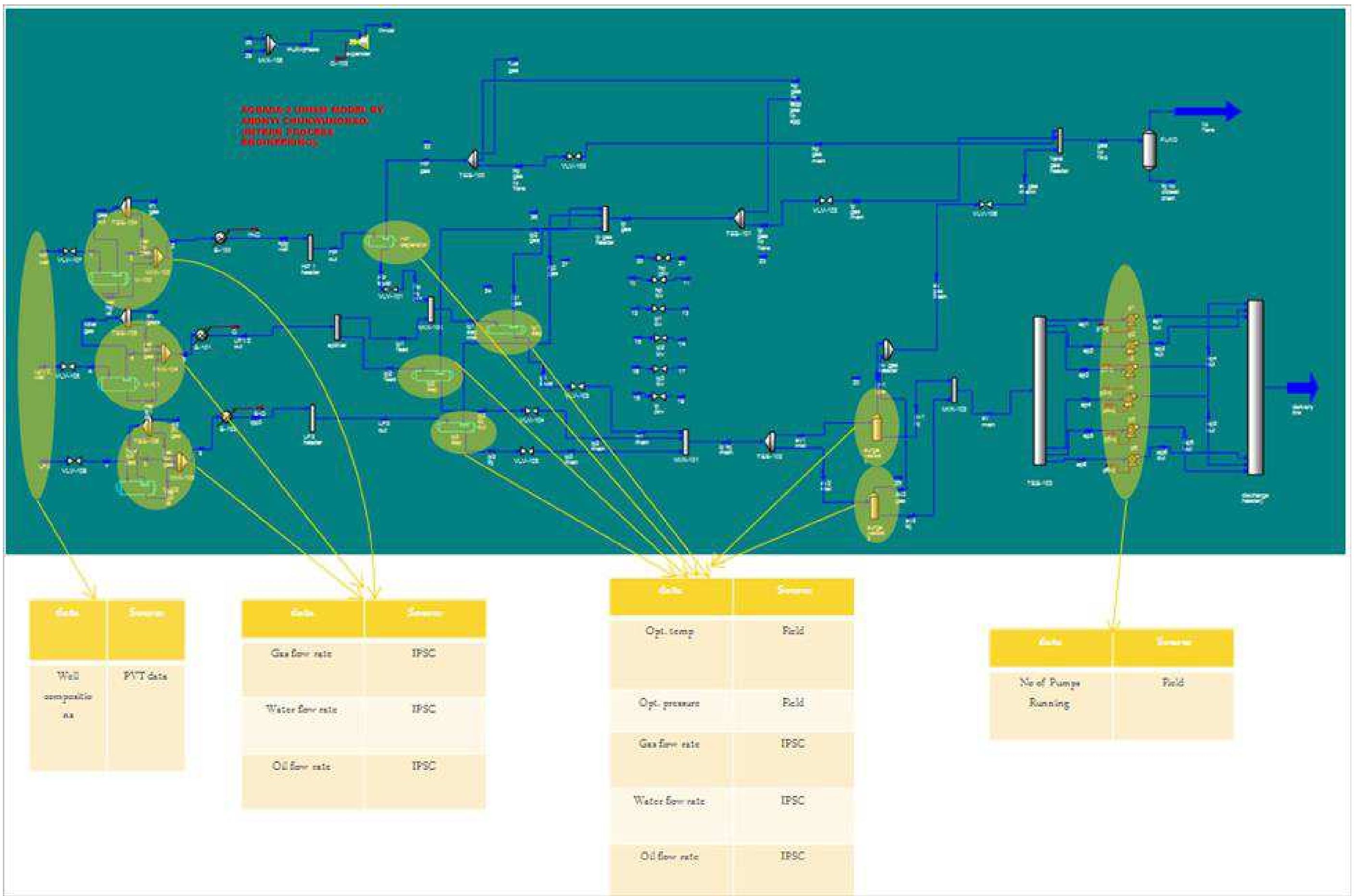


Figure 4 - Snapshot of Hysys model calibration interface.

CALCULATIONS

Assumption

This work assumes a normal and routine running state of the process plant, Hysys process model representative. According to investigation which were carried out on normal and routine plant operation and as can be seen from L'Ecole control valve data table below, the main source of hydrocarbon gas is sent to the flare via the pressure control valves (PCV) which is located on the network lines routed to flare.

Table 1- Overview of basic plant valve details.

Tag No	Service	Size (")	Manufacturer	Model	Installed Cv
23-PCV-015B	HP to Flare	4	Masoneilan	37-10172	195
23-PCV-001B	LP to Flare	6	Masoneilan	37-10172	450
HP LCV	HP LCV	4	Masoneilan	37-10134	450
LP1 LCV	LP1 LCV	6	Masoneilan	37-10134	450
LP2 LCV	LP2 LCV	6	Masoneilan	37-10134	450
LP3 LCV	LP3 LCV	6	Masoneilan	37-10134	450

However, in specific cases like shutdown conditions, the flaring may happen through Pressure Safety Valves (PSV), Temperature Safety Valves (TSV) and Blowdown Valves (BDV). Since there is no accurate and fast response instrument to record these temporary conditions, there is no need to measure the amount of gas transferred to flare during emergencies[4].

Capacity Calculation

Governing Equation:

$$Q = C_v * N_1 * F_P * \sqrt{\Delta Psizing/\rho} \quad \ldots\ldots 1$$

Where;

Q = mass flow rate under design condition.

C_v = flow coefficient.

N_1 = numerical constants depending on the units used in general sizing equation.

ρ = density of fluid under inlet conditions (standard condition for gas).

ΔP = pressure differential used in computing flow or required flow coefficient for compressible fluids.

The pressure control valve capacity calculations were carried out in Hysys. Results gotten in Kg per hour were converted to million standard cubic feet per day using gas density at standard condition. This compensates for the wide changes in volume due to temperature variations[10].

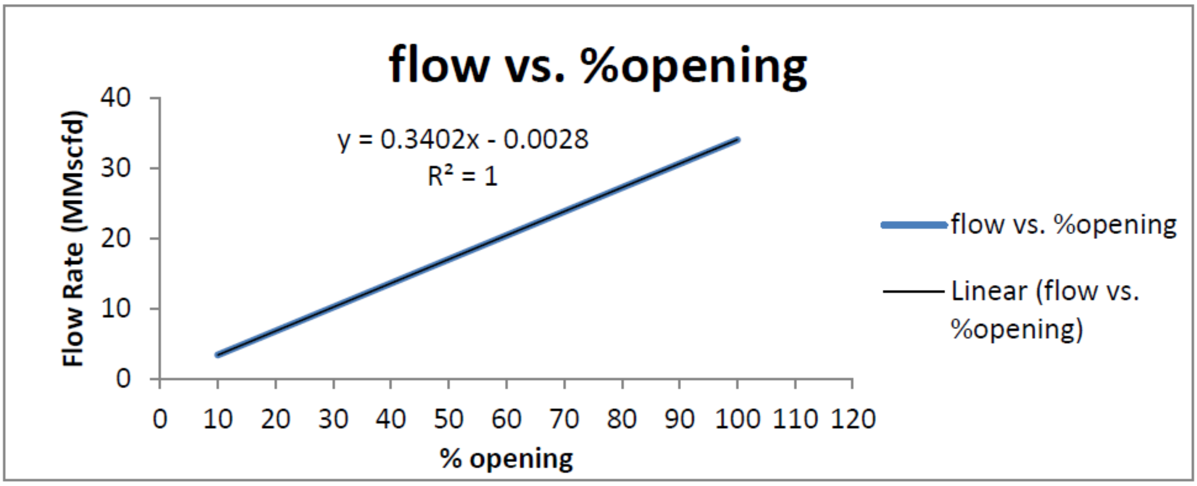
The Hysys software uses the equation for predicting the flow coefficient of compressible and incompressible fluids through control valves as specified in the ANSI/ISA-75.01.01[6].

Datasheet of each PCV as provided in the 10000 series Masoneilan control valves specification data sheet[7] by the vendor was used in association with Hysys to prepare a table which defined the amount of gas transfer vs. valve opening. The capacity calculations for the valves were run as follows; 100% opening for maximum flow, 80% opening for Ideal maximum opening percentage to assure controllability and 10% opening for minimum flow. Below is a table generated for the HP to flare service condition PCV tagged 23-PCV-015B.

Table 2 - Table showing the amount of gas released vs. valve opening.

	Tag No.	HP PCV	LP PCV
	Model No.	37-10172	37-10172
	service	HP to flare	LP to flare
	size	4	6
	Density	0.7501	0.7386
10 % opening	Cv	19.5	45
	Flow rate (kg/hr.)	3010.65	2477.97
	flow rate (MMscfd)	3.4	2.84
80 % opening	Cv	156	360
	Flow rate (kg/hr.)	24085.22	19823.79
	flow rate (MMscfd)	27.21	22.75
100 % opening	Cv	195	450
	Flow rate (kg/hr.)	30106.53	24779.74
	flow rate (MMscfd)	34.02	28.44

Data generated from the Hysys control valve simulation result was exported into excel and used to generate a linear correlation of flow rate against percentage openings. Regression correlation was developed using linear trend line analysis which gave an R-squared of 1. See plot below



Software Development

From the plot above, it can be seen that input data to the correlation developed is the valve percentage opening. This value can be gotten from the Plant Information Management System (PIMS) as this system when employed is capable of recording the valve opening percentage of valves every minute, after an average percentage opening can be taken for every 1440 minutes (1day), then using the pertinent curve, the flow transferred (Q: MMscfd) from the valve is calculated.

A software package with the capability of extracting valve percentage opening data from PIMS and DCS server was developed using Java. Demo simulations were ran for two days with randomly distributed %opening values to ascertain the robustness and extracting capability of this software. Results showed that the software performed well with high value precision. Other features of this software include; less run-time error, real-time, high degree of accuracy, cost-effective and user-friendly. Also an iteration time-step of 1440 minutes has been chosen for accuracy as the software extract percentage opening data for every one minute interval. Below shows a snapshot of the data extraction section of the software.

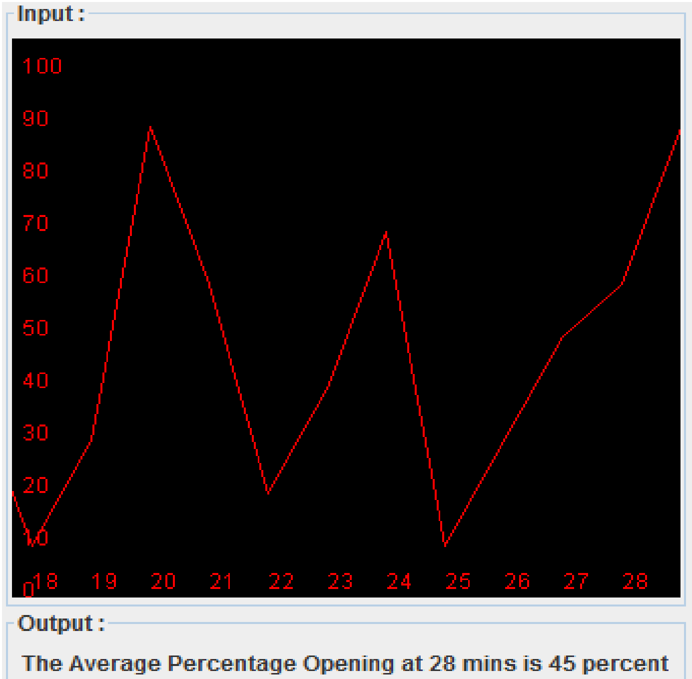


Figure 5 - Input demo Plant Information Management System (PIMS).

After 1440 minutes (1day) the average percentage opening is exported into the output section of the software where the total amount of gas flared per day is calculated according to the correlation formula linear trendline which was derived from the plotted curve. Finally the amount of gas flared from each valve unit can be calculated and added to give the total amount of gas flared in the whole plant. Following is the result of the 2-day demo simulation ran during software testing.

RESULTS

Demo Simulation for One Day

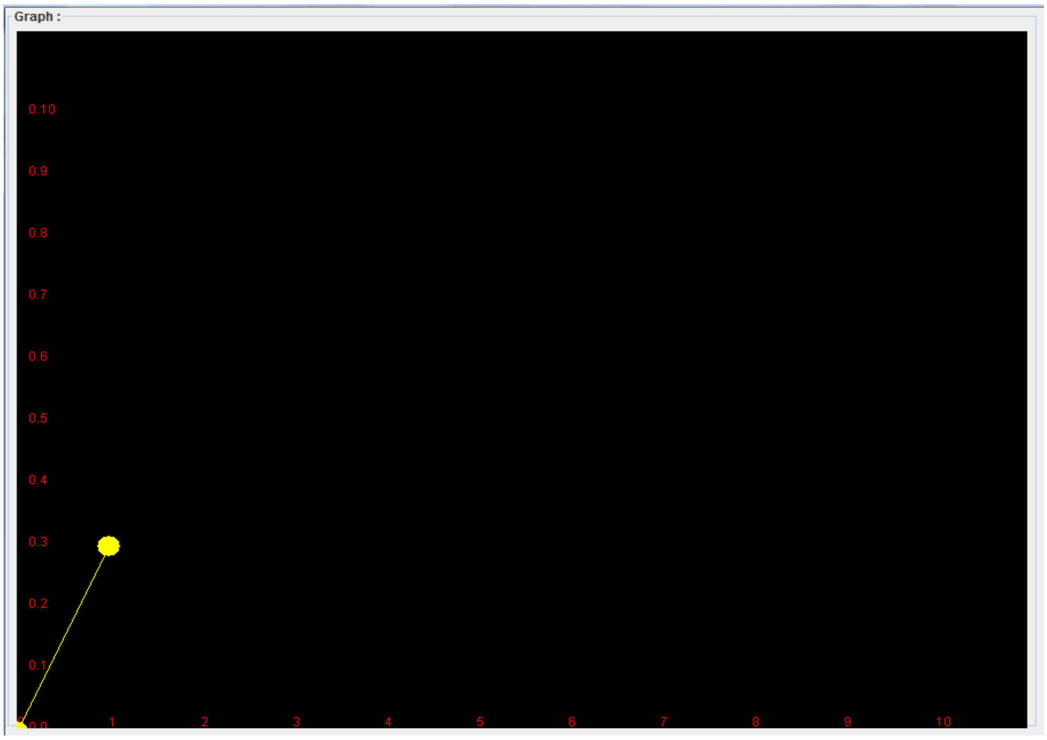


Figure 6 - Output simulation result for one day.

The Amount Flared on Day 1 is 0.32 million SCF

The figure above shows a snapshot of the amount of gas flared for the first demo simulation day as calculated by the software. Result Value of 0.32 MMscfd was validated against manual calculation which gave approximately the same answer.

Demo Simulation Result for Two Days

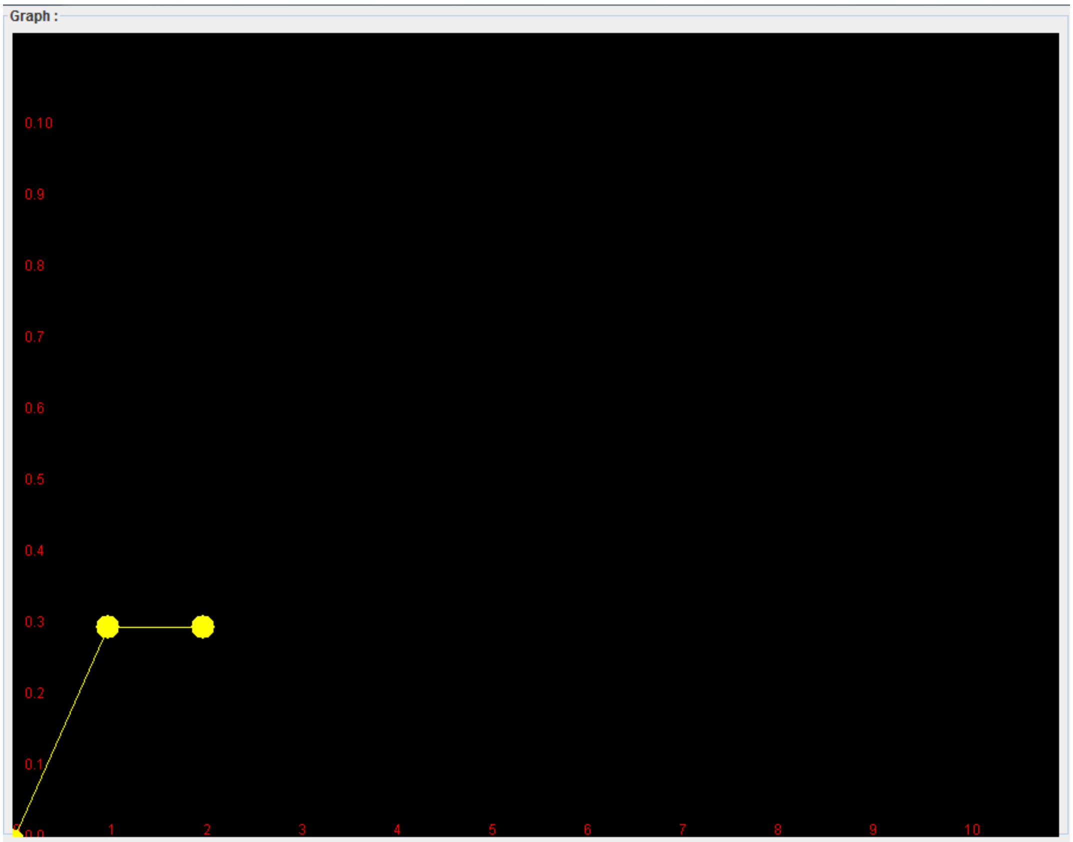


Figure 7 - Output simulation result for two days.

The Amount Flared on Day 2 is 0.32 million SCF

The figure above also shows the amount of gas flared on day 2. This is independent of the amount of gas flared on the first day as it is not a cumulative of the first and second day. Result value validation was also carried as above with a match between the simulated and the manually calculated value.

Pros and Cons

One of the main advantage of this approach is that it meets most of the specification stipulated for flare gas measuring systems as documented in various flare and vent system engineering standards[4,8] some of which include;

Identification of exact location and time of flaring thereby making it possible for operators to take necessarily actions towards rectifying the problem, calculates flare gas rates to an accuracy of +/-5 % in order to assist the operator in monitoring flare, maintainability and possible removal while the flare relief system remains in operation, does not need any sensor device installation that may block the flare header which is a potential source of hazards during emergency depressurization of the flare line. Moreover, the calculations are carried out with updated Hysys model calibrated with current operating conditions of temperature, pressure and flow rate, so the reported value for amount of flaring is more reliable.

High limitation/disadvantage of this software can be seen in background and emergency conditions. Flaring during this condition occurs through the Pressure Safety Valves (PSV), Temperature Safety Valves (TSV) and Blowdown Valves (BDV) other than the Pressure Control Valves which was the basis of our calculation. However, in pressure-relieving and depressurizing systems[9] stated that since there is no accurate and fast response instrument to record these temporary conditions, there is no need to measure the amount of gas transferred to flare during emergencies. Also the dominating quantities of gas flared over a long period of time emanates from normal type events mainly caused by process upsets[4].

CONCLUSION

In conclusion, the general objective which is to mitigate the wide limitations of changing operating condition of pressure, temperature and flow rate placed on many or all flare gas measurement systems has been achieved. Computational software tool was also developed using Java to ease calculation and usability by the operators. This tool can be easily deployed in any process facility with functional Plant Information Management System (PIMS) and DCS server. Finally, process plant model calibration with current operating conditions of pressure, temperature and flow rate are invaluable to the accurate calculation of the amount of gas flared calculated by the tool. Limitations of this approach are clearly stated in the paper as measurement uncertainties will arise in application outside defined assumptions.

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