International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 10 (2018) pp. 7868-7873


# Development of Gas Leakage Monitoring and Localization System in Pipelines using LabVIEW

**Anjali. M**

*B.Tech, Electronics and Instrumentation Engineering,*
*SASTRA Deemed to be University, Tirumalaisamudram, Thanjavur, Tamil Nadu, India.*

**Abstract:**

Pipelines are one of the most reliable means of transport of water, crude oil, natural gas and other petroleum products. However, internal and external corrosion at construction joints, cracking, locations with imperfections, accidents or sabotage can lead to pipeline leakage causing explosions, health problems, fatalities, pollution and huge economic losses. In order to detect and locate such leaks within short period of time, leakage detection plays a key role in the pipeline management system. For the development of this system, the gas sensor (MQ6) is used for detection of gas (here, LPG) and for measuring humidity and temperature, the sensor (DHT11) is used. The sensor will detect the concentration of the gas and sent to the Arduino UNO as voltage output. The LabVIEW GUI will monitor the values and take suitable action based on whether the concentration is in normal, precaution or critical range. Also, the dynamic parameters such as pressure and flow at the upstream and downstream of the pipe are acquired. Transient simulation model is developed using LabVIEW and equations are formulated by observing the changes in the continuity equation and law of conservation of momentum. This system helps in determining the leak location and the leak flow rate.

**Keywords:** LabVIEW, Monitoring System, Arduino, MQ6, DHT11, LIFA, Leakage detection, Leakage location, Transient simulation

## INTRODUCTION

Leakage in industrial and domestic environment can occur in several ways during the handling of storing and transmitting equipments like tanks, pipelines and machinery. Hence, monitoring and control of leakage is essential to reduce resource, energy and economic loss. Major leaks mainly occur in transmission pipeline which might go unnoticed due to the vast networks and inaccessible locations, for example underground pipelines. Pipelines may develop leak due to ageing over time, corrosion, design faults, accidents, and operation outside limits or sabotage. Depending on the kind of material being transported and the depth of the leak, the results can be catastrophic, ranging from minor injuries, ill health, and property loss to major explosions and severe fatalities. So, an efficient leak detection system is necessary to detect, quantify and locate leaks.

Leak detection systems (LDS) can be broadly divided into two: Internal LDS and External LDS. [2][8] The internal methods include:

1. Balancing Methods: line balance, compensated volume balance, mass balance based on measurement of discrepancy between the inlet and outlet product volumes of the pipeline section under study.
2. Statistical Method: Hypothesis method of computation
3. Pressure Flow Monitoring: Analysis of refraction waves produced at the time of leak.
4. Real Time Transient Model (RTTM): Enhancing the balancing method by including the conservation of mass, momentum and energy principles.
5. Extended RTTM: (E-RTTM): Combination of RTTM with statistical method

The external methods include:

1. Acoustic Emissions: Acoustic sensors detect the signal as the leaking fluid passes through a hole in the network.
2. Fiber optic sensing: The probes are placed in contact with the pipeline. The escaping fluid causes the cooling of the area surrounding the leak and the probes are used in the detection of this temperature change.
3. Infrared Radiometric Pipeline Testing: The different surface temperatures are measured in the vicinity of the leak location.
4. Digital Oil Leak detection cable: Leaking fluids flow through the external permeable braid and makes contact with the internal semi permeable conductors, causing change in the electrical properties of the cable that can be detected.

## LEAK DETECTION SYSTEM OVERVIEW

The gas concentration is detected with the help of **MQ6 sensor**. This sensor has high sensitivity to propane, butane, LPG and LNG. It has lower conductivity in clean air and increases with increase in gas concentration. Detection scope is 300-10000 ppm. [3] Along with the gas concentration, the temperature and humidity is also observed for the surroundings with the help of **DHT11 sensor**. [4] The temperature and humidity sensor has calibrated digital signal output connected to 8 bit microcontroller and offers fast response and anti interference ability. Measurement range is 20-90% RH and 0-50 ˚C. It has a resistive type humidity measurement and an NTC temperature measurement. The sensors are connected to **Arduino UNO** which acts as the data acquisition unit in this system. It boasts of open source electronic prototyping platform based on flexible hardware and software. It has 14 digital input or output pins, 6 analog inputs, a USB connection, a power jack, an ICSP header and a reset button [1] [11]. For acquiring data from Arduino and processing with LabVIEW GUI, the add-on LIFA (LabVIEW Interface for Arduino) has to be installed from the VI Package Manager and the LIFA Base has to be burned to the Arduino. [1][2]

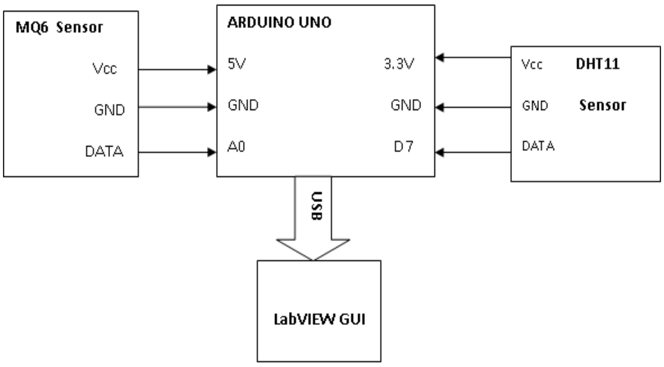


**Figure 1:** Hardware connections

The MQ6 sensor uses the analog input pin A0 whereas the DHT11 output is received via the digital pin D7. This data is transferred to the LabVIEW monitoring environment via VISA com port connected to the Arduino. The analog voltage output of the MQ6 sensor is converted into the corresponding concentration value by the formula:

$$ppm = \left(\left(\frac{Vcc}{V0} - 1\right) * \left(\frac{RL}{R0} * 10^{-c}\right)\right)^{\frac{1}{m}} \text{ [3][5]}$$

where $Vcc$ = Supply Voltage, $V0$ = Output Voltage, $RL$ = Load resistance, $R0$ = Sensor Resistance in controlled conditions (i.e. 24 ˚C and 35% RH) and c and m are the slope constants calculated from the sensitivity characteristics graph of MQ6 Datasheet [3].

These measured concentration values are compared to the threshold values based on the standards from Occupational Safety and Health Administration (OSHA) [1] [6]. Based on this, when the gas concentration is below 500 ppm, representing "Safety" mode the green indicator turns on. When the gas concentration is in between 500 and 1000 ppm, representing the "Precaution" mode the yellow indicator LED turns on. After 5 minutes, the exhaust fan is switched on to ventilate the extra gas to try and bring the concentration to the safety limit. But if the concentration keeps on increasing and crosses the "Danger" limit, the red indicator turns on. If the situation continues, then after 5 minutes, the LED starts to blink and buzzer turns on to alert the user of the leak. Eventually, after 10 minutes of user inaction, the power supply as well as the gas supply is automatically switched off for safety [1]. The operator can rectify the source of the leak and then manually, switch on the system for normal process.

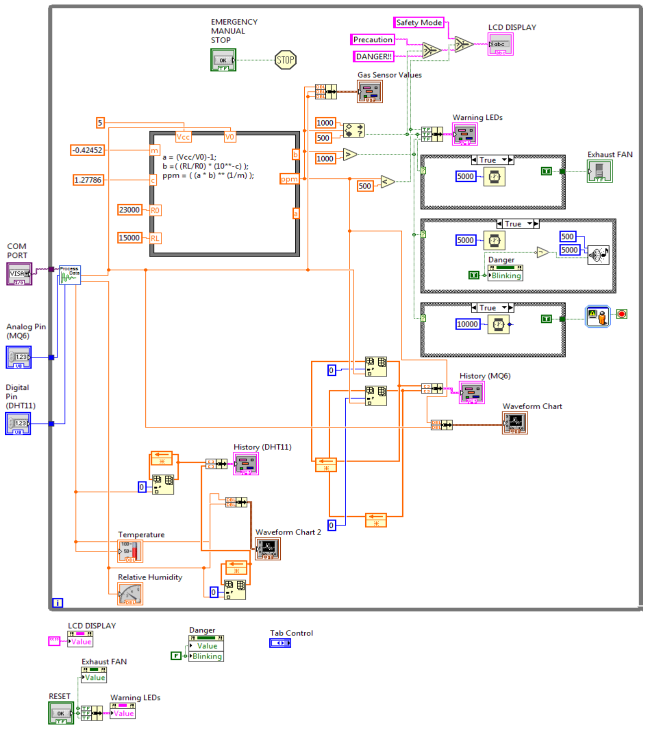


**Figure 2:** Gas leak detection block diagram

## LEAK LOCALIZATION OVERVIEW

In this project, the Real Time Transient Modeling (RTTM) is used for localization of the leak in the pipeline section. RTTM makes use of mathematical models based on physical laws such as conservation of mass, momentum and energy. It computes real time values of mass flow, pressure, density and temperature at every point along the pipeline segment with the help of mathematical algorithm [12]. Using RTTM, leaks can be detected and localized during steady state and transient conditions in gas pipelines [12]. One of the main advantages of the RTTM is that the model can include all of the dynamic fluid characteristics like flow, pressure and temperature and the other extensive physical pipeline characteristics (length, diameter, thickness etc.) and product characteristics(density, viscosity etc) [7]. Another advantage is that presence of transients along the pipeline does not affect the system and hence is more prone to false alarms [12].

The measured dynamic parameters namely pressure and temperature data are given as input to the transient model. With this data, the flow rate is calculated for no leak condition. The difference between calculated and measured values is zero when there is no leak. When there is a leak, the estimated values will differ from actual values and this discrepancy is noted down [7]. This is because the pressure and correspondingly, the estimated mass flow rate changes when there is a leak, but the measured flow rate remains constant [12].

$$Ei = Mi - mi$$

$$Eo = Mo - mo$$

$Ei =$ Inlet mass flow discrepancy, $Eo =$ Outlet mass flow discrepancy, $Mi$ , $Mo =$ estimated flow rate at inlet and outlet, $mi, mo =$ measured flow rate at inlet and outlet. For a pipeline section, the system takes the two measured pressures as inputs and the state pressure at any point x along the length can be calculated as: [7] [9]

$$Px = \sqrt{Pi^2 + (Po^2 - Pi^2)\frac{x}{L}}$$

$Pi =$ Inlet pressure, $Po =$ outlet pressure, L= length of the pipe. The model estimates the upstream and downstream mass flow rates with the help of this data. It obtains the frictional factor by the Goudar-Sonnad equation and uses the Darcy-Weisbach equation to calculate the flow rate [7] [8].

$$M_i^j = \sqrt{\frac{\pi^2 \rho_i^j D^5 \Delta P_i^j}{8 f x_i^j}}$$

where $\rho_i^j$ is the density of the fluid at mesh point (i, j) and assumed to be constant throughout the pipeline, $\Delta P_i^j$ is the pressure drop from the upstream end to the i segment at j time index. For each index of time, the leak location is calculated by the following formula which is a function of flow rate discrepancies and length of the pipe.

$$X_{leak}^j = \frac{L}{1 - \frac{E_i}{E_o}}$$

When there is no leak, this value changes randomly. But when a leak occurs, it can be determined by the boundary conditions [8] and its mass flow rate at the j time index can be calculated by [7][8]:

$$\frac{Ei}{Eo} = \begin{Bmatrix} < 0 & leak \\ \geq 0 & no\ leak \end{Bmatrix}$$

$$M_{leak}^j = Ei - Eo$$

Thus, a more accurate leak position can be located with the help of the above formula and boundary conditions. The algorithm for leak localization is shown in Fig 3. The modeling and simulation is done by using LabVIEW environment and the results are both displayed on the front panel and plotted as a waveform graph.

**LabVIEW** is a powerful graphical development environment for signal acquisition, measurement analysis, data presentation giving the flexibility of programming language without the complexity of traditional development tools [10]. It boasts of advantages over other software in terms of modularity, performance, platform independent nature, flexibility, cost efficiency, plug and play configuration, integration of virtual instrument to the internet, minimal setup and configuration time and ease of application software development. It helps to infuse intelligence and decision-making capabilities into instruments so that they can adapt easily to change in measures signals and at less processing power [10].

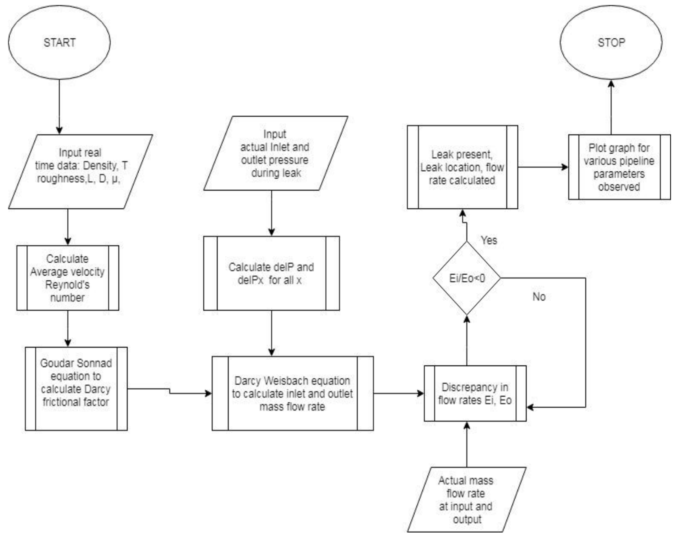


**Figure 3:** Leak Location Algorithm

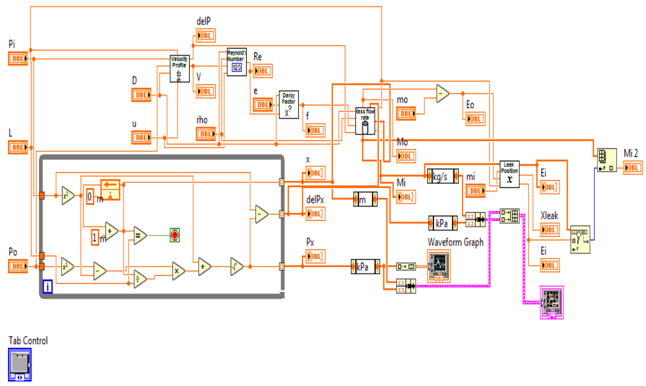


**Figure 4:** Transient Model Block Diagram

## RESULTS

The sensors are designed to be placed close to pipeline so that they can immediately detect the sudden changes in various parameters, send to the data acquisition unit and display this on the monitoring system so as to prompt the operator to take action.

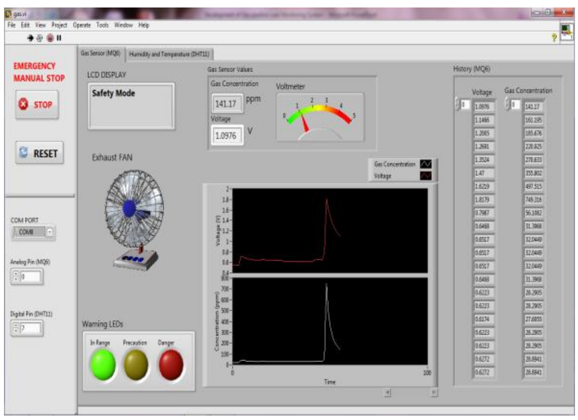


**Figure 5:** Front panel during Safety conditions

**Figure 6:** Front Panel during Precaution Mode

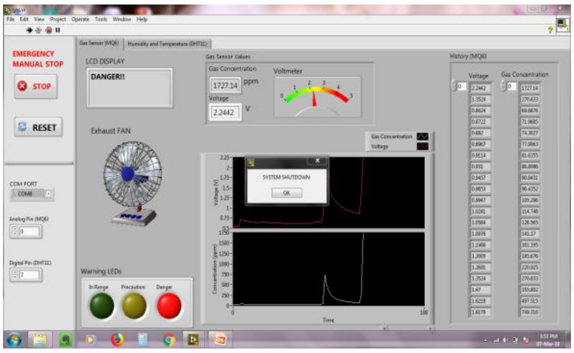

**Figure 7:** Front Panel during Danger Mode

Fig 6 indicates the precaution mode triggering on the yellow LED and the virtual exhaust fan on the front panel. The system includes a manual STOP button and a RESET button for restarting the system. The LCD display on front panel lets the user know the current condition. The waveform chart plots the gas concentration, temperature and relative humidity trends over time. The history values are also stored in an array for reference. Analog voltage output from the MQ6 sensor is displayed on the virtual analog voltmeter as well as the digital voltmeter. Similarly, digital output of the DHT11 sensor is displayed both on analog and digital meter (Fig 8). Fig 7 indicates the danger condition with the red LED blinking and buzzer on. After five more minutes of inaction, the system stops with the pop-up user message indicating the automatic shut down.

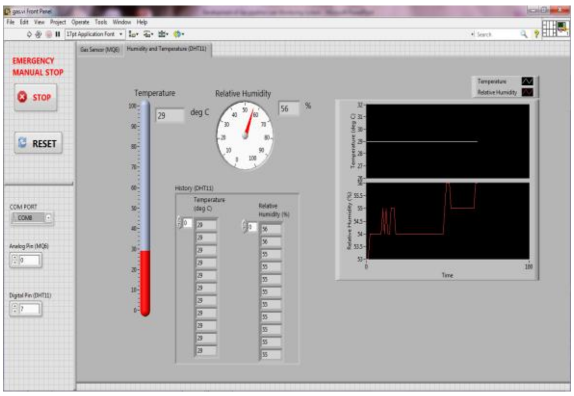

**Figure 8:** Front panel displaying temperature and humidity

The dynamic parameters of the pipeline as specified in the case studies (Table 2 and Table 3, Courtesy [7] [8]) is taken into study and according to the RTTM algorithm (Fig 2), the leak location is calculated (Table 1). In the case study 1[7], the leak is found to be at a distance of 1104.71m from upstream (Fig 9). The discrepancy between actual leak point and calculated leak point is only 4.71m as compared to 11.88m according to [7]. Similarly, in the case study 2[8], the leak is localized at 1404.4m by this model (Table1). The discrepancy is calculated to be 10.59m compared to 18.527m as in [8].

**Table 1:** Summary of values calculated in the proposed LabVIEW model

| **Quantity** | **Value (Case study 1 [7])** | **Value (Case study 2 [8])** | **Unit** |
|---|---|---|---|
| State pressure at x=1m | 119.985 | 119.930 | kPa |
| Pressure drop at inlet and x, $\Delta P_x$ | 0.01493 | 0.06996 | kPa |
| Mass flow rate at inlet, Mi | 81.895 | 72.693 | kg/s |
| Mass flow rate at outlet, Mo | 59.9391 | 70.6046 | kg/s |
| Discrepancy at inlet, Ei | 9.81497 | 0.61296 | kg/s |
| Discrepancy at outlet, Eo | -12.1109 | -1.44539 | kg/s |
| Leak Location, $X_{leak}$ | 1104.71 | 1404.41 | m |

The pressure and flow trends during leak condition and no leak condition are plotted on the X-Y graph and compared (Fig 9). Taking into account the transients that can affect the pipeline, a pressure drop of ±0.5 to 1 kPa pressure is admissible, but here the pressure drop exceed 15 kPa which clearly indicates the presence of leak. Furthermore, the non-linear relation between state pressure changes and calculated mass flow rate can be observed. The mass flow rate profile is overlapped over the pressure profile to find the approximate leak locations from the graphs, Fig 11 and Fig 12.

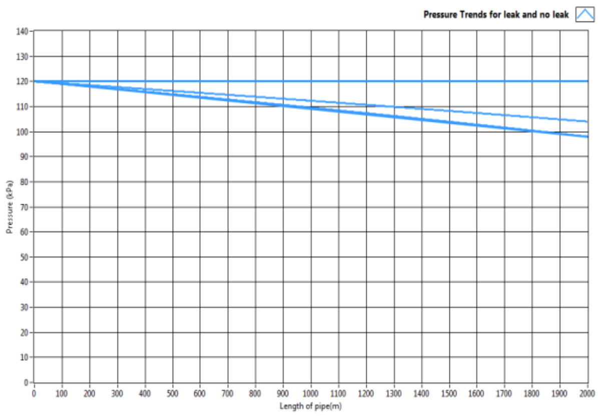


**Figure 9:** Pressure trends during no leak and leak conditions

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 10 (2018) pp. 7868-7873


**Table 2:** Parameters for a straight light crude oil pipeline

| Parameters | Values | Unit |
|---|---|---|
| Density of Fluid, ρ | 834.2 | $kg/m^3$ |
| Dynamic Viscosity μ | 0.00172 | Pa s |
| Diameter of pipe, D | 0.3556 | m |
| Length of pipe, L | 2000 | m |
| Roughness of pipe, $\varepsilon$ | 0.0000457 | m |
| Mass flow rate (input), mi | 72.08 | kg/s |
| Mass flow rate (output), mo | 72.05 | kg/s |

*Source I: NPDC Archive Olomoro field (Courtesy: [7] [8])*

**Table 3:** Leak location as per case study [7] and [8]

| Parameters | Value | Unit |
|---|---|---|
| **Case study 1: Source I: [7] NPDC SCADA data** | | |
| Input pressure, Pi | 120 | kPa |
| Output pressure, Po | 104 | kPa |
| Actual leak Location | 1100 | m |
| Estimated leak location [7] | 1088.12 | m |
| **Case study 2: Source I: [8] NPDC SCADA data** | | |
| Input pressure, Pi | 120 | kPa |
| Output pressure, Po | 98 | kPa |
| Actual leak Location | 1415 | m |
| Estimated leak location [8] | 1433.527 | m |

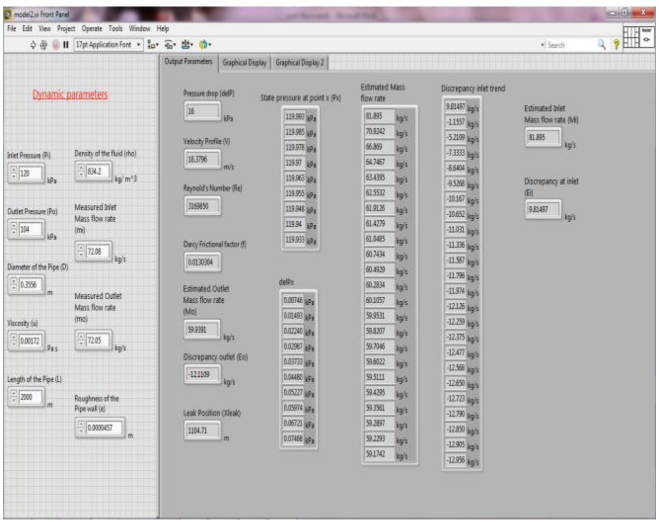


**Figure 10:** Transient Model Front panel

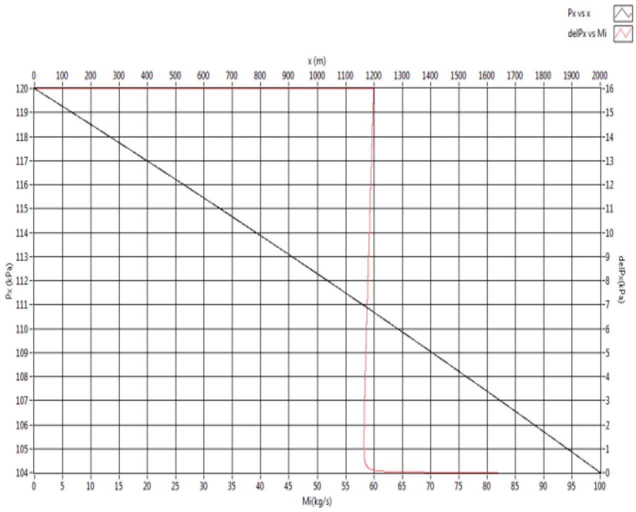


**Figure 11:** Pipeline leak profile (Po=98 kPa)

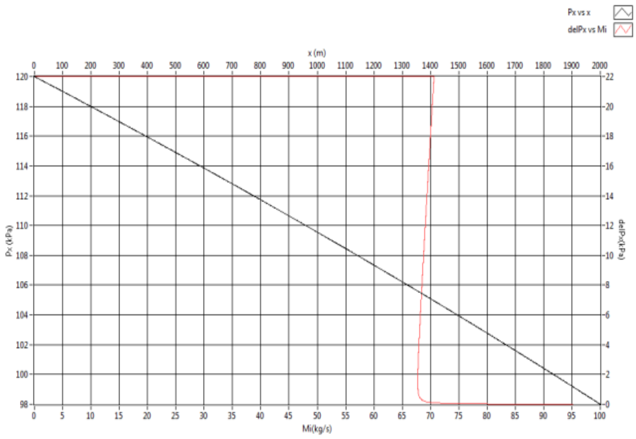


**Figure 12:** Pipeline Leak profile (Po=104 kPa)

## CONCLUSION

The gas leakage was successfully detected using the hardware setup as explained and the monitoring system was able to give out the proper warning in critical situations. The developed system is suited to work well for continuous monitoring of the dynamic parameters. With the help of the simulation model, the location of the leak is approximated within a close range.

## FUTURE WORKS

Use of highly calibrated flow meters and pressure transmitters at the end of the line can yield much more accurate results in terms of localization of the leak. Also, the work can be extended to varieties of configurations other than straight pipeline and detection of multiple leaks on the same network. Other improvements may include remote control of the data monitoring system over internet or other wireless means of communication from field instruments to the LabVIEW GUI without the risk of data breach.

## ACKNOWLEDGEMENTS

I am highly indebted to Mrs. Raja Brundha. A, Associate Professor, EIE, SEEE, SASTRA Deemed to be University, for her guidance and insight that greatly assisted in the research.

## REFERENCES

[1] Huan Hui Yan, Yusnita Rahayu, “Design and Development of Gas Leakage Monitoring System using Arduino and Zigbee”, *International Conference on Electrical Engineering, Computer Science and Informatics(EECSI),* August 2014.

[2] Sharma A.K., Adsul S. and Mevekan R.G., “Development of leakage detection system”, *International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT),* 2016.

[3] Technical Data for MQ-6 gas sensor, Hanwei Electronics. Co. Ltd, Retrieved from: http://www.particle-sensor.com/immagini/MQ-6.pdf

[4] Technical Data for DHT11 sensor, Aosong Electronics Co. Ltd. Retrieved from: http://www.micropik.com/PDF/dht11.pdf

[5] Jirage G.B., Jadhav B.T., Kadam P.A., “Calibration of Combustible and toxic gas sensor for Industrial Applications”, *International Journal of Innovative and Emerging Research in Engineering, Vol.3, No.11,* 2016.

[6] Occupational Health Guidelines for LPG, Occupational Safety and Health Administration (OSHA), Retrieved from: https://www.cdc.gov/niosh/docs/81-123/pdfs/0372.pdf

[7] Chinwuko EC et al, “Transient Model based Leak Detection and Localization Technique for crude Oil Pipelines: A Case of N.P.D.C, Olomoro”, *Saudi Journal of Engineering and Technology” Vol.1, No.2,* 2016

[8] Balogun H.A., Oyedeko K.F.K, “Modeling and Simulation of a Leak Detection for Oil and Gas Pipelines via Transient Model: A Case Study of the Niger Delta”, *Journal of Energy Technologies and Policy, Vol.5, No.1,* 2015

[9] Zhao Yang et al, “Research on Leakage Detection and Analysis of Leakage Point in the Gas Pipeline System”, *Open Journal of Safety Science and Technology,* 2011.

[10] Sumathi S., Surekha P., “LabVIEW based Advanced Instrumentation Systems”, ISBN-10 3-540-48500-7, Springer

[11] Arduino UNO Datasheet, Retrieved from: https://www.farnell.com/datasheets/1682209.pdf

[12] Lawrence Boaz, Shubi Kaijage, Ramadhani Sinde, “An overview of pipeline leak detection and location systems”, *Pan African International Conference on Information Science, Computing and Telecommunications,* 2014

[13] Abhulimen K.E., Susu A.A., “Liquid pipeline leak detection system: model development and numerical simulation”, *Chemical Engineering Journal,* 2004

[14] Yang Qibin, Sun Wei, “Systematic Analysis on Pipeline Leak Detection and location”, *International Conference on Artificial Intelligence and Software Engineering (ICAISE),* 2013

[15] Marcia Golmohamadi, “Pipeline leak detection”, *Masters Theses, 7397,* 2015

[16] Odusina E., Akingbola J., Mannel D., “Software Based Pipeline Detection”, *Department of Chemical Engineering and Materials Science, University of Oklahoma,* 2008.

[17] Hu Qiong, Fan Shidong, “Development of Pipeline Leak Detection System based on LabVIEW”, *IEEE International Symposium,* 2008.

[18] Rajeswari Cherukuri, Raghavendra Rao Kanchi, “Design and Development of an Integrated Relative Humidity, Temperature Measurement and Gas (LPG) Sensing System Using PIC18F25K20”, *Research and Reviews: Journal of pure and Applied Physics,* 2015.

[19] Tommy Sugiarto et al., “LabVIEW-Arduino Interfacing for Data Acquisition and Telemetry System”, LAPAN UAV Development, *Aeronautics Technology Center, Indonesian Institute of Aeronautics and Space,* 2016.

[20] Technical data about VISA, NI-VISA Programmer Reference Manual, National Instruments, March 2003.

[21] Heimbach G., “Creating Quality UIs with LabVIEW”, https://ieee.li/pdf/viewgraphs/creating_quality_uis_with_labview.pdf