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Development of a Gas Flow Line System to End Users - An Innovation on Smart Infrastructural Development

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ABSTRACT

The reliability and efficiency of gas flow line systems are pivotal for ensuring a consistent and uninterrupted supply of natural gas to consumers via cylinders. However, cylinders are susceptible to injuries and sometimes explode causing loss of lives and properties. The aim of this study is to develop a gas flow line system to connect generating plant to consumers, using an innovation on smart infrastructural development. A gas flow system was developed to mimic gas transportation from generating plant to the end consumer. The experimental set up consisting a cylinder (3 Kg), water tank (50 Cm^3), DC pump, temperature sensor, pressure sensor, pipes, Arduino uno board, Nodemcu micro-controller. Arduino programming was written to interface with hardware and display values for the measuring parameters (pressure, temperature, flow rate and amount of gas dispensed to the consumer). Three 3m-long pipes were connected to the gas cylinder (serving as base station) at angles 45 ^{o}, second at 0 ^{o} and third at -45 ^{o} respectively, relative to the horizontal. Pressure, temperature and flow rate were measured at inlet and outlet of the pipes. The system was designed to activate water sprinkler when temperature at the base station exceeds 40 ^oC. Data on the gas monitoring dashboard were obtained for the analysis. The base pressure ranges from 0.2 to 2.0 (cm Hg), the line pressure ranges from 0.17 to 1.93 (cm Hg), the upstream pressure from 0.12 to 1.63 and down slope pressure from 0.19 to 1.97; while the base temperature varies from 21.79 to 24.70 °C, starting temperature varies from 26.20 to 27.00 °C, line temperature varies from 21.71 to 24.59 °C, up slope temperature varies from 26.30 to 27.57 °C and down slope temperature varies from 27.10 to 28.00 °C. The volume of 0.0042 to 0.0410 m^3/s was obtained for fixed diameter and length of 0.0158 m and 9 m, respectively. The temperature sensor that monitors the safe temperature at which the pump supply water to cool the gas storage tank at the base triggered at 40 °C sounding the alarm. The volume of 58 m^3 was dispensed to the end user at a cost N65 as show from the smart system. Gas flow line system was modeled indicates that as the pressure in the base cylinder is increased, the pressure and temperature falls across the gas flow line system. This research is applicable in the gas industry for gas distribution to end users in Nigeria with ease and eliminates the problem of moving cylinder from one place to another.

Keywords: Gas flow-line system, Arduino programming, Internet of a thing (IoT), End-users

Aims Research Journal Reference Format:
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1. INTRODUCTION

The global energy landscape has shifted significantly in recent years, with growing demand for cleaner and more reliable energy sources like natural gas. Gas flow line systems now play a crucial role in transporting this eco-friendly fuel from production sites to residential, industrial, and commercial end-users (Zakari *et al*.,2022). As the world evolves towards a more energy-conscious future, Natural Gas (NG) stands at the forefront of this transition. Accounting for 24 % of the world's primary energy consumption in 2015, NG is anticipated to grow its share to 25 % by 2035, positioning it as a crucial component next to coal in the global energy hierarchy (EIA,2018;Esen and Oral,2016).Reliability of gas supply through pipeline systems is of utmost importance for meeting customer demand for gas. (Yu *et al.,* 2018).

Natural gas gathering, transmission and distribution infrastructure in the domestic, regional and international networks is critical to environmental management for the socioeconomic benefits of the local population (Odumugbo, 2010). Therefore, an accurate measurement of gas supply capacity and market demand, as well as consideration of their uncertainty, are crucial for determining the reliability of gas supply. However, most existing approaches neglect the complex behavior of the gas pipeline system when measuring gas supply capacity. In particular, high-pressure gas pipelines have significantly slower dynamics due to the large volume of natural gas contained in the pipelines, which are often referred to as line packs. The presence of a line pack is one of the most important distinctions between the gas pipeline system and other energy supply networks (Kurasov and Burkov 2022).

The reliable and efficient distribution of gas to end users is a vital component of modern infrastructure, influencing economic development, energy security, and environmental sustainability. Traditional gas pipeline system, especially in developing countries, often face numerous challenges such as leakages, irregular supply, maintenance delays, and safety concerns. Some of these author have not taken into consideration aspects of protection due to the large-scale danger of fire, explosion, and environmental contamination, given the impossibility of utterly removing the destruction of storage tanks and pipelines. (Kurasov and Burkov 2022). As a rule, gas consumption by industrial and especially household consumers is uneven and fluctuates throughout a day, week, and year. The change in the flow rate is a gradual process because of the system's dynamic behavior. In addition, due to various external factors, such as calendar and weather factors, as well as demographic and economic factors and parameters characterizing the system, market demand tends to change over time (Zoplik,2015; Thaler *et al .,* 2005).

The concept of smart gas infrastructure integrates intelligent monitoring, automated control, and real-time data analytics into conventional gas flow systems. These innovations allow for precise regulation of flow rates, early detection of leaks, and enhance user control, resulting in improved safety, efficiency, and sustainability (Gungor *et al.,* 2010; Farooq *et al.,* 2015). Smart gas system also supports predictive maintenance and operational optimization, contributing to reduced operational costs and environmental risks (Ayeni and Ayogu, 2020). In the context of smart city development intelligent gas flow systems play a pivotal role by providing responsive utility services that align with the principles of sustainability and digital innovation (Hashem et al., 2016; Al-Fuqaha *et al.,* 2015).

The Internet of Things (IoT) and sensor networks allow real-time surveillance of gas lines, thereby minimizing human intervention and enabling efficient energy management (Mekki *et al.,* 2019). These technologies are increasingly being adopted in developing nations, and there is a growing imperative to for countries like Nigeria to embrace them to bridge infrastructure gaps (Oyedepo, 2012; Eneh and Owo, 2020). Moreover, the Nigerian energy sector faces unique challenges, including inconsistent gas supply, infrastructural decay, and safety lapses. By implementing smart gas flow linen systems tailored to local needs and environments, Nigeria can improve services delivery and support industrialization goals (Agbonifo, 2015).

Challenges such as meter inaccuracies, outdated billing policies affecting over 18 million consumers, gas theft, pipeline leak ages, and aging infrastructure underscore the urgent need for system modernization and improved practices (Shafiq *et al*., 2018). This research developed a model for gas flow line from base station to end user using Arduino programming and Internet of a Thing for measuring quantity of gas and cost to the end user.

2. METHODOLOGY

The modeling of a gas flow system from a substation to the end user's residence was carried out using Arduino programming to monitor the characteristic of the gas parameter along the pipe, (pressure, temperature, and flow rate). The program also measures the effect of gradient (upslope, downslope and zero gradient) on the gas parameter. The program allows the end user to purchase gas online and be cut off using smart innovation. Safety measure was program into the system in which water was released on the gas cylinder when a safe temperature is exceeded.

2.1 Experimental set up

Figure 1-6 shows the set up which consists of a cylinder in which the LPG gas is stored, it has a temperature sensor that alert the system when the temperature is above safe level (35 degree). A water tank fixed with a dc pump is program to released water on the cylinder when the temperature is above safe value.

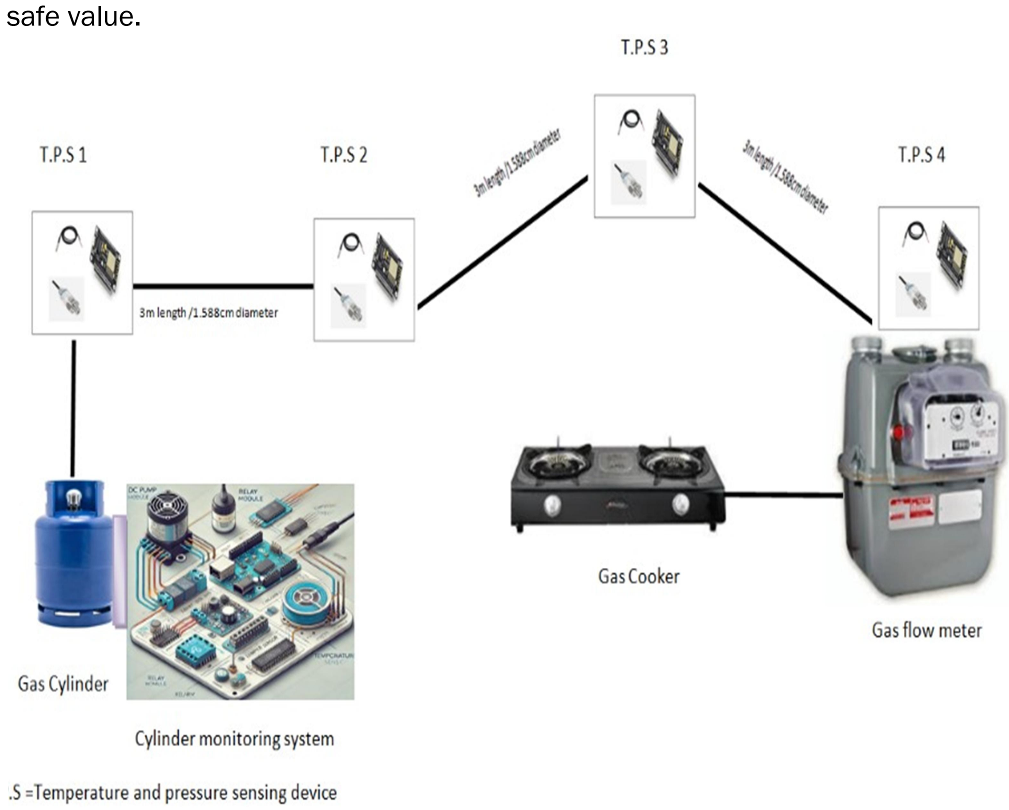

Figure 1: Diagrammatic Structure Of The Gas Flow System

Figure 2: Gas Monitoring Dashboard

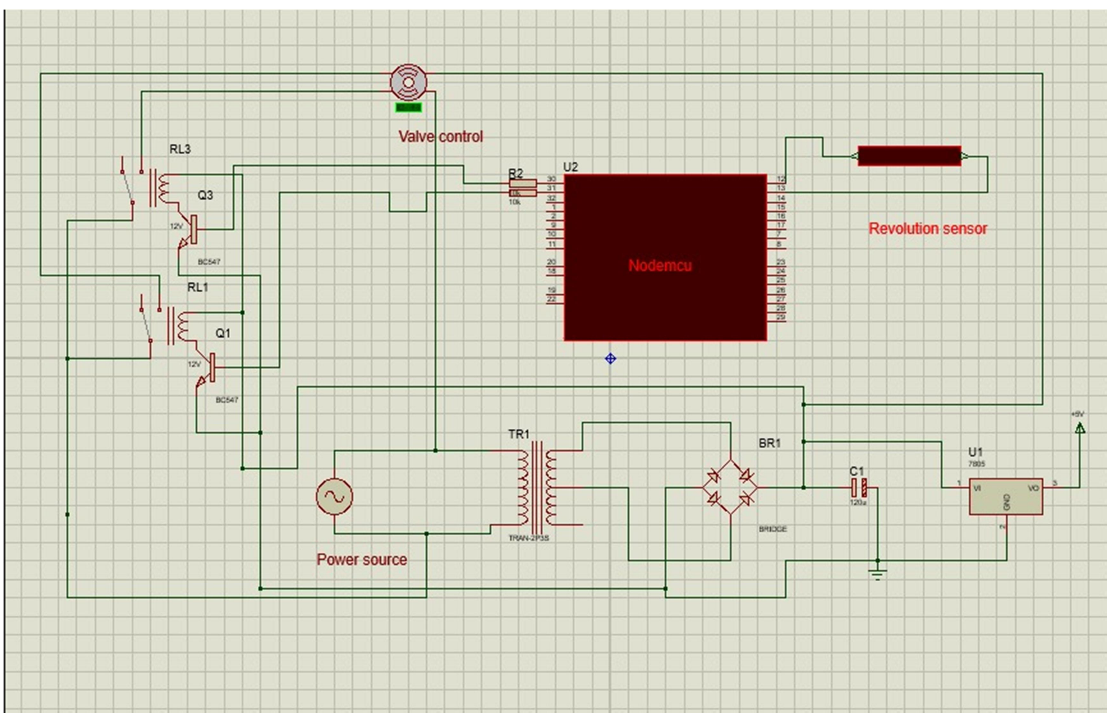

Figure 3: Gas Flow Sensor Circuit Diagram

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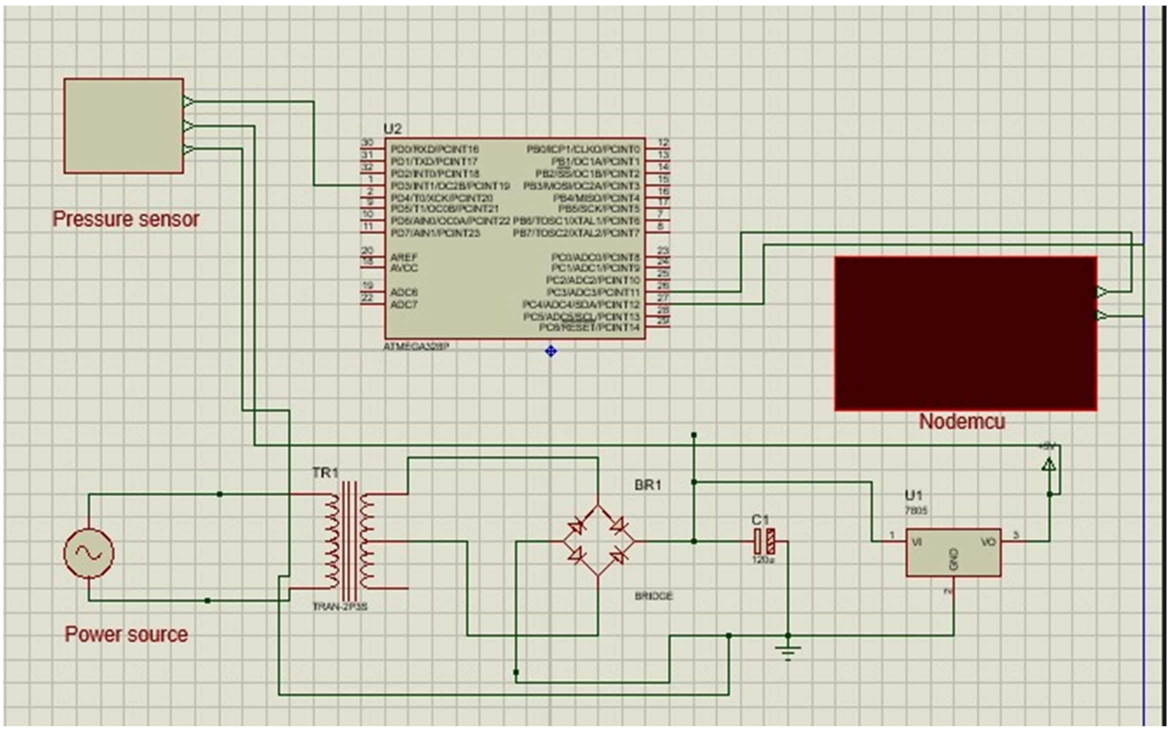

Figure 4: Pressure Sensor Circuit Diagram

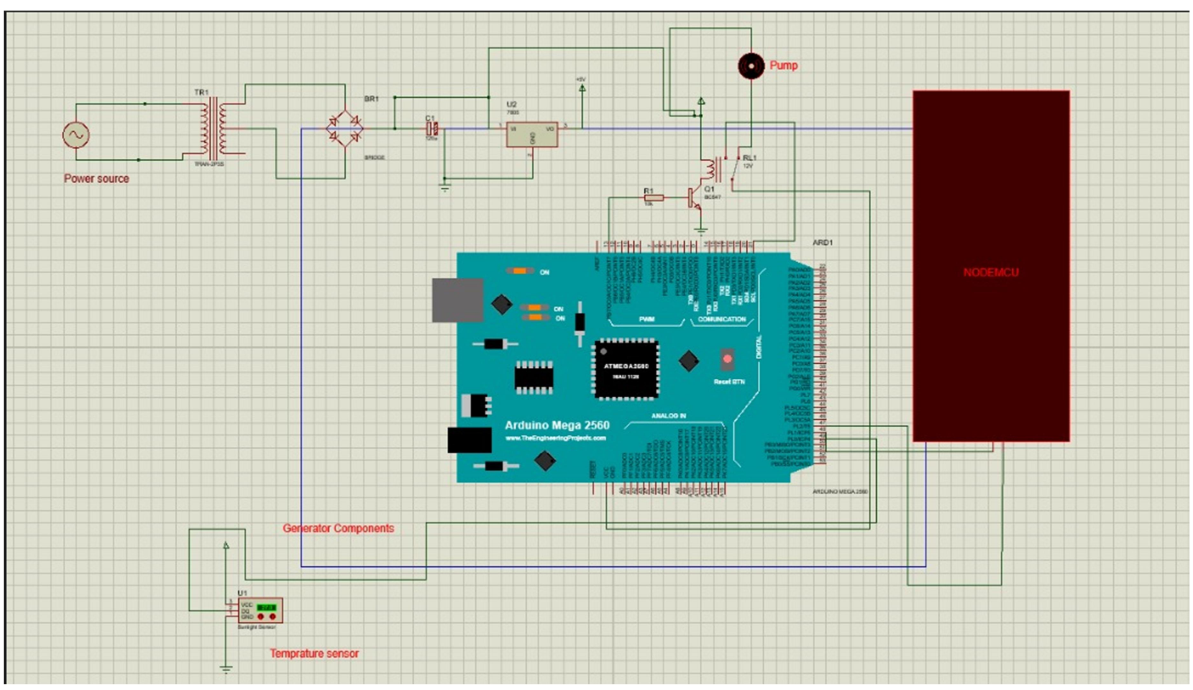

Figure 5: Base Device Circuit Diagram

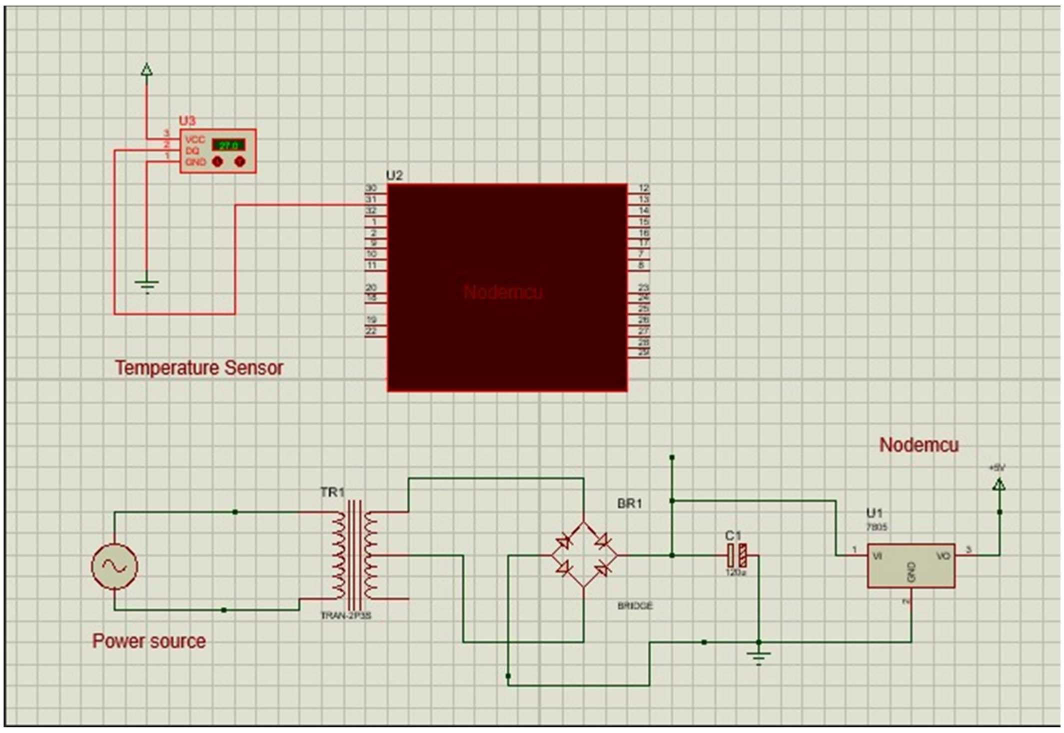

Figure 6: Temperature Sensor Circuit Diagram

2.2 Data Collection Methods
Data collection was from the devices incorporated in the system, such as temperature sensor, pressure sensor, flow meter and the dash board. The IoT sensor uses cloud computing and strategically determines distribution based on cost subscribe to by the end users. These sensors were placed at key points in the distribution network. These sensors continuously captured parameters like pressure, temperature, flow rates, and gas volume.

2.3 Data Validation
Data quality checks were performed for all collected data. We implemented rigorous calibration procedures for the IoT sensors to ensure accuracy and reliability. Additionally, data quality checks were performed to identify and rectify any anomalies or outliers in the datasets.

2.4 Simulation Software or Tools
In this study, Arduino programming was used for interface the hardware to model and simulate the gas distribution pipeline network.

2.5 Data Collection
Data collection for the modeling process involved a combination of sensor data and recording of data from the interface dashboard. The IoT was carried out by cloud computing. Data from the sensors were stored in the cloud and the end user was able to subscribe to gas supply via an interface to order for quantity via cost subscribed. A network of sensors was deployed strategically throughout the gas distribution network. These sensors continuously measured parameters such as pressure, temperature, flow rates, and gas consumption in relation to cost. The collected data was transmitted to the dashboard (Base device).

Figures 7 to 10 show the circuit diagram indicating the sensors and Nodemcu used to develop Internet of Thing (IoT) in the design. It was programmed using the Arduino IDE, to make it accessible to end users.

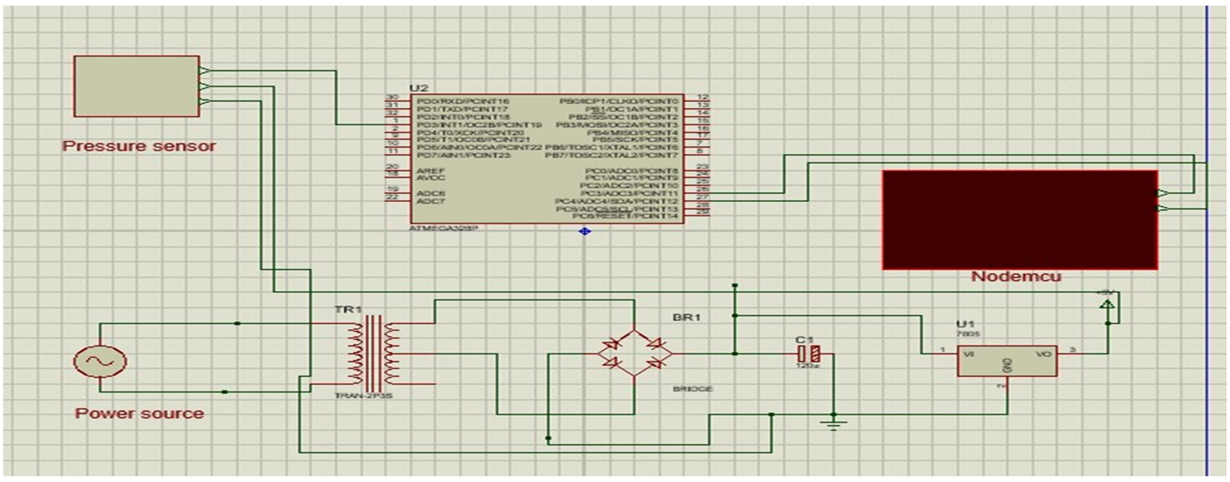

Figure 7: Representation of A Pressure Sensor and Nodemcu Within a Gas Flow Line Simulation System

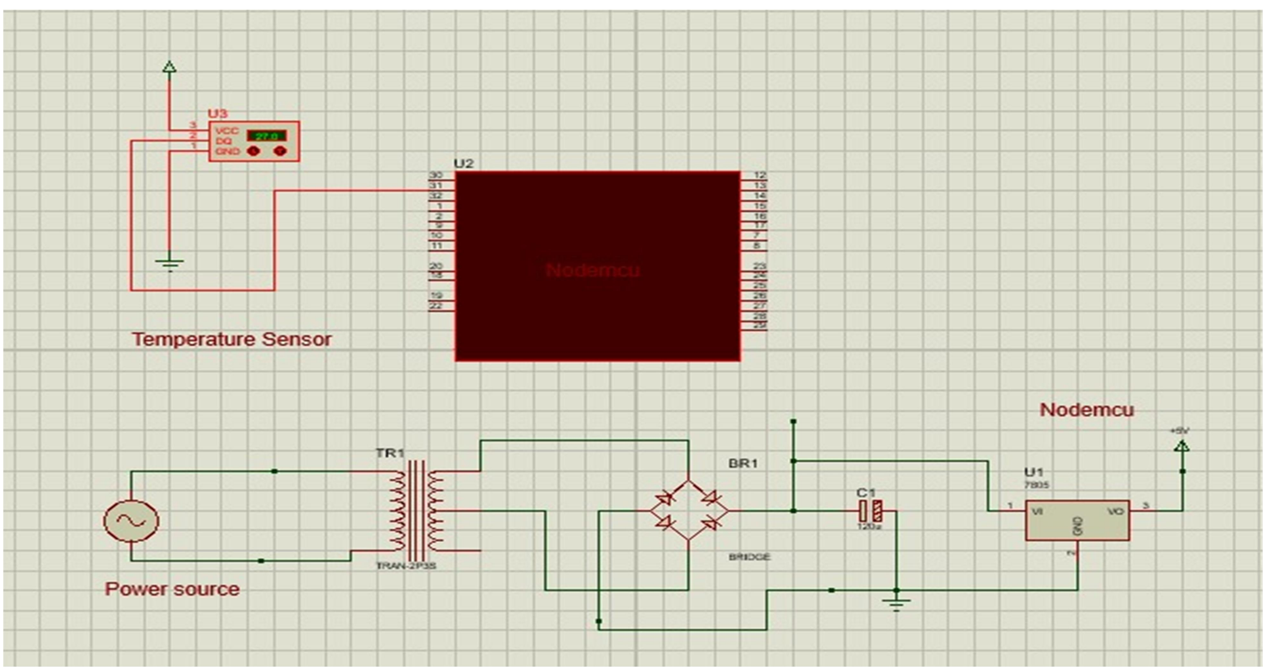

Figure 8: Representation of A Temperature Sensor and Nodemcu Within a Gas Flow Line Simulation System

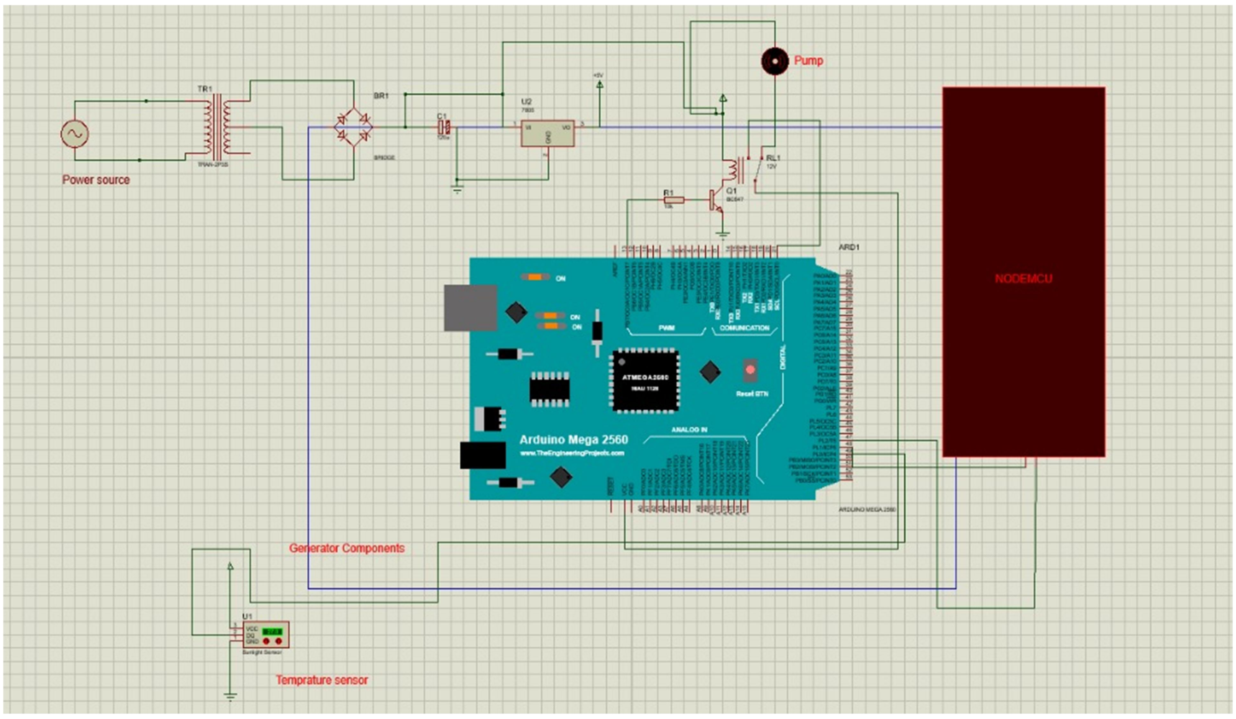

Figure 9: Representation of A Pump Within a Compressor Station in a Gas Flow Line Simulation System

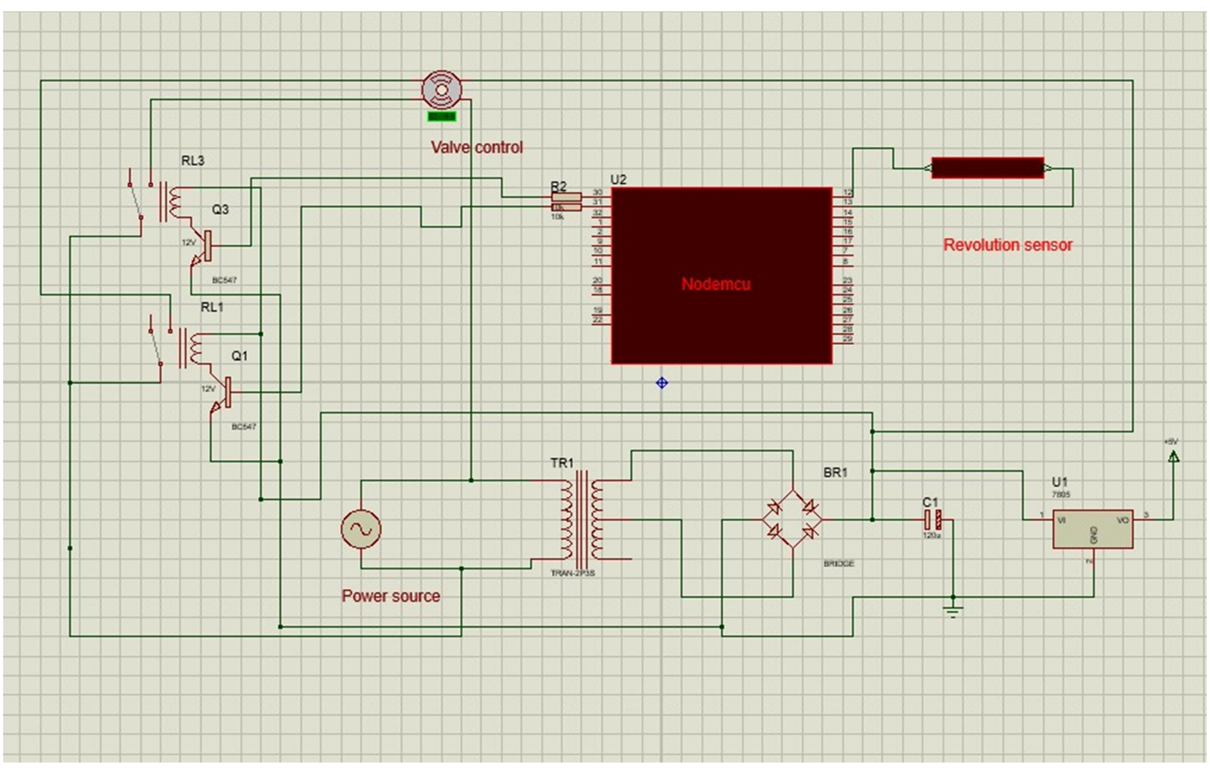

Figure 10: Representation of A Valve Control and Revolution Sensor Within a Gas Flow Line Simulation System

3. RESULTS AND DISCUSSION

The experimental study conducted on flow characteristics of a gas pipeline at 3m apart from the base station to the end user is presented in Table 4.1. The base pressure represents the initial pressure of the gas at the starting point (base station). The line pressure indicates the pressure at the point where the pipe line is inclined at zero degree (0^0) to the horizontal. The up-slope pressure is the pressure in the pipe line that is incline at angle 45 ^{0} to pipe line. It represents the pressure reading when there's a slight upward incline (45 ^{0}) in the pipeline. The down-slope pressure is the pressure in the pipe line inclined at angle - 45 ^{0} to the horizontal pipe line. The base temperature shows the ambient temperature at the starting point (base station). The starting temperature (°C), indicates the initial temperature of the gas at the beginning of the pipe line connected to the cylinder.

The SL temperature represents the temperature of the gas at the point the pipe begins to decline down the slope. The up-slope temperature indicates the gas temperature when there is an upward incline. The down-slope temperature, shows the gas temperature when there is a downward slope. The volume (m^3/s), represents the volume of gas flowing through the pipeline segment at that interval. While D and L are the diameter and length of the pipeline.

Table 1: Gas Monitoring Dashboard

Base Pressure (cm Hg)	Line Pressure (cm Hg)	Up Slope Pressure (cm Hg)	Down Slope Pressure (cm Hg)	Base Temperature (°C)	Starting Temp (°C)	SL Temp (°C)	Up Slope Temp (°C)	Down Slope Temp (°C)	Volume (m^3/5 mins)	Diameter (cm)	Length (m)
0.2	0.17	0.12	0.19	25	27	24.59	27.57	28	0.0042	1.5875	9
0.4	0.35	0.29	0.38	24.7	27.5	24.31	27.9	28.3	0.0081	1.5875	9
0.6	0.52	0.41	0.58	24.25	26.5	23.87	27.6	28	0.0119	1.5875	9
0.8	0.77	0.63	0.72	23.9	27	23.62	27.4	27.8	0.0172	1.5875	9
1	0.94	0.79	0.97	23.5	26.9	23.14	26.95	27.5	0.0199	1.5875	9
1.2	1.12	0.98	1.19	23.15	26.8	22.87	26.85	27.4	0.0258	1.5875	9
1.4	1.33	1.11	1.38	22.83	26.7	22.61	26.75	27.2	0.0296	1.5875	9
1.6	1.55	1.32	1.57	22.49	26.5	22.37	26.6	27.1	0.0341	1.5875	9
1.8	1.71	1.47	1.78	22.14	26.3	21.96	26.4	27	0.0373	1.5875	9
2	1.93	1.63	1.97	21.79	26.2	21.71	26.3	26.9	0.0410	1.5875	9

Table 2: Change in Pressure and Temperature Across the Pipe Line

Base pressure (cm Hg)	Change in pressure in line	Change in pressure up slope	Change in pressure down slope	Starting Temperature (°C)	Change in Temperature in line	Change in temperature up slope	Change in temperature down slope
0.2	0.03	0.08	0.01	27.0	2.41	0.57	1.00
0.4	0.05	011	0.02	27.5	3.19	0.40	0.80
0.6	0.08	0.19	0.02	26.5	2.63	1.10	1.50
0.8	0.03	0.17	0.08	27.0	3.38	0.40	0.80
1.0	0.06	0.21	0.03	26.9	3.76	0.05	0.60
1.2	0.08	0.22	0.01	26.8	3.96	0.05	0.60
1.4	0.07	0.29	0.02	26.7	4.09	0.05	0.50
1.6	0.05	0.28	0.05	26.5	4.13	0.10	0.60
1.8	0.09	0.33	0,02	26.3	4.34	0.10	0.70
2.0	0.07	0.37	0.03	26.2	4.49	0.10	0.70

The base pressure was varied from 0.2 to 2.0 (cm Hg). It was observed that the line pressure, up slope pressure and downslope pressure show a reduction from the initial pressure as they travelled along the pipe. When the gas is moving up the slope they encounter greater reduction in pressure as against down the slope and in the horizontal pipe. This is a confirmation of lost in energy from kinetic and potential energy. The reduction in pressure agrees with the gas law. The temperature across the pipe line reduces as the base pressure is increased from 0.20 to 2.00 cm Hg. The temperature started from 27 °C and fall to 26.2 °C. The line, up slope and down slope temperature across the pipe line all decrease as the starting temperature in the pipe line decreases. Likewise, the temperature drop across the horizontal pipe line increases as the base temperature falls. While change in temperature across the up slope pipe line is stochastic in nature, decrease at a point, stable at another point and constant at a point. There is decrease in change in temperature across the down slope pipe line as the base temperature increases in the pipe line.

The volume of gas passing through the pipe line varies from 0.0042 m3/s to 0.041 m/s. The volume takes an increase trend across the pipe line as the pressure as the base increases. In agreement with Boys' law which states that as pressure increases the volume also increases with other parameters kept constant.
It was observed that at 35 °C the system triggers the release of water from the tank via the pump to cool the cylinder which was heat above 35 °C in order to activate the safety system. The temperature sensor that monitors the safe temperature at which the pump supply water to cool the gas storage tank at the base triggered at 40 °C sounding the alarm. The volume of 58 m^3 was dispensed to the end user at a cost N65 as show from the smart system.

4. CONCLUSIONS

This study has demonstrated the successful development and implementation of a gas flow pipeline simulation system and delivered to end-users. A model for a gas flow in pipe was developed using Arduino programming via Internet of a Thing (IoT) and was connected to the end user via internet. The Internet of a Thing enables the end user to purchase a particular volume at a cost and the system cut of supply when the amount subscribe is exhausted.

REFERENCES

1. Agbonifo P. E. (2015). Opportunities, challenges and obstacles to economic growth and sustainable development through natural gas in Nigeria. Journal of Sustainable Development in Africa, 17(5), 99-114.
2. Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., and Ayyash, M. (2015). Internet of Things: A survey on enabling technologies, protocols, and applications. IEEE Communications Surveys and Tutorials, 17(4), 2347-2376.
3. Ayeni, T. P., and Ayogu, B. A. (2020). Intelligent pipeline monitoring system based on Internet of Things. Scientific Research Journal (SCIRJ), 8(8), 2201-2796
4. Eneh, O. C., and Owo, R. A. (2020). Smart energy infrastructure for sustainable development in Nigeria. Journal of Energy and Development studies, 4(1), 35-44.
5. Farooq, M. U., Waseem, M., Mazhar, S., Khairi, A., and Kamal, T. (2015). A review on Internet of Things (IoT). International Journal of Computer Applications, 113(1), 1-7.
6. Gungor, V. C., Lu, B., and Hancke, G. P. (2010). Opportunities and challenges of wireless sensor networks in smart grid. IEEE Transactions on Industrial Electronics, 57(10), 3557-3564.
7. Hashem, I. A. T., Yaqoob, I., Anuar, N. B., Mokhtar, S., Gani, A., and Khan, S. U. (2016). The rise of “big data” on cloud computing: Review and open research issues. Information Systems, 47, 98-115.
8. Kurasov, O. A and Burkov, P. V (2021) Substantiation of methods of improving safety of pipeline gas transportation, E3S Web of Conferences 266, 01012 (2021). TOPICAL ISSUES 2021 https://doi.org/10.1051/e3sconf/202126601012
9. Mekki, K., Bajic, E., Chaxel, F., and Meyer, F. (2019). A comparative study of LPWAN technologies for large-scale IoT deployment. ICT Express, 5(1), 1-7.
10. Odumugbo, C.A. (2010), Natural gas utilization in Nigeria: Challenges and opportunities. Journal of Natural Gas Science and Engineering, 2(6), 310-316.
11. Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: The way forward. Energy, Sustainability and Society, 2(1), 15.
12. Zakari, A., Tawiah, V., Khan, I., Alvarado, R., and Li, G. (2022). Ensuring sustainable consumption and production pattern in Africa: evidence from green energy perspectives. Energy Pol. 169, 113183.
13. Szoplik, J (2015) Forecasting of natural gas consumption with artificial neural networks. Energy: 208-220
14. Thaler, M., Grabec, I., and Poredoš, A. (2005) Prediction of energy consumption and risk of excess demand in a distribution system. Physica A: Statistical mechanics and its applications355(1): 46-53
15. Esen, V and Oral, B (2016) Natural gas reserve/production ratio in Russia, Iran, Qatar and Turkmenistan: a political and economic perspective, Energy Pol. 93 (2016) 101–109, https://doi.org/10.1016/j.enpol.2016.02.037.
16. Energy Information Administration (EIA), Annual Energy Outlook 2018 with Projections to 2050, U.S. Department of Energy, Washington, D.C., 2018. https://www.Eia.Gov/Outlooks/Archive/Aeo18/Pdf/AEO2018.Pdf.
17. Shafiq, M., Bin Nisar, W., Savino, M., Rashid, Z and Ahmad, Z (2018) Monitoring and controlling of unaccounted for gas (UFG) in distribution networks: a case study of Sui Northern Gas Pipelines Limited Pakistan, IFAC-PapersOnLine 51 (2018) 253–258, https://doi.org/10.1016/j.ifacol.2018.08.284.

18. Yu, W., Song, S., Li, S .,Min, Y.,Huang, W., Wen, K.,Gong, J(2018) Gas supply reliability assessment of natural gas transmission pipeline systems. Energy162: 853-870