Design Of Oil Pipeline Intrusion Monitoring System With Gsm Module-Based Remote Flow Valve Activation Mechanism

Nnanna Charles Okpo[1]
Department Of Electrical/Electronic And Computer Engineering,
University of Uyo, Akwa Ibom State Nigeria

Kufre M. Udofia[2]
Department of Electrical/Electronic and Computer Engineering,
University of Uyo, Nigeria
kmudofia@uniuyo.edu.ng

Silas Abraham Friday[3]
Department of Electrical/ Electronic Engineering
Adekeke University, Ede Osun State
silas.abraham@adelekeuniversity.edu.ng

***Abstract*— In this paper, the design of oil pipeline intrusion monitoring system with GSM module-based remote flow valve activation mechanism is presented. The essence of the system is to detect when there is leakage or leakages in the oil pipeline and to alert the control personnel who sends appropriate control command to close the flow valve in the system. The system comprises of the power supply module, the fluid or oil flow and leakage/intrusion sensing and detection mechanism and the GSM 900 module-based remote flow valve switching mechanism. The system is designed to operate in the auto-mode whereby the system does not require to alert the control personnel to issues the command to activate the flow valve but rather the system automatically activates the flow valves in accordance with the intrusion detection signal results. The paper focused on the design of the hardware part of the system which is the platform that will enable the leakage detection algorithms to be implemented. The entire circuit design is modeled in Proteus software and presented along with the model of the circuit showing the two sensors that are used to detect the flow velocity and pressure differentials that will enable the software part of the system to determine when and where leakage has occurred in the pipeline.**

Keywords— Oil Pipeline, Leakage Detection, Intrusion Monitoring, GSM Module, Flow Valve, Multiple Leakage, Proteus Software

1. Introduction

Wireless and electronic technologies are the backbone of today's satellite communication, wireless sensor networks, Internet of Things and smart applications [1,2,3, 4,5,6, 7,8,9, 10,11, 12,13,14,15,16,17,18,19,20,21,22,23,24,25]. Despite the challenges of propagation loss and other associated loses that wireless signals are subjected to, designers have developed numerous ways to accommodate those losses and still deliver reliable quality of service [26, 27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45, 46]. Hence, nowadays, remote monitoring and protection of essential facilities can be conveniently implemented using various forms of embedded systems and Internet of Things (IoT) or wireless sensor network [47,48,49,50].

Basically, the embedded system with requisite sensors and actuators can be used both for monitoring and remote control of the target facility while the wireless network or IoT setup can be used to provide connection for remote access, data collection, communication and control of the facility [51,52,53,54]. In this paper, oil pipeline intrusion monitoring system is considered [55.56,57]. Particularly, the wireless technology employed in this stud is the GSM technology.

The oil pipeline intrusion monitoring system presented in this paper is a form of data acquisition system with control mechanism for remotely closing the flow valve when intrusion is detected [58,59,60,61]. The intrusion monitoring system is a combination of a microcontroller-based electronic device with GSM module that enable the intrusion detection signal to be communicated to a remote control personnel who will issue the command to close the flow valve [62,63,64]. Also, the system can operate in automatic mode whereby the manual control by a control personnel is bypassed. The operations of the system are controlled by the microcontroller based on the program written in line with the desired functionalities and design specifications. Notably, the program development for the system includes the requirement elicitation and analysis phase during which the desired functionalities and design specifications are obtained. Also, the program is coded and loaded into the microcontroller memory from where it is implemented as embedded software.

The detailed design of the oil pipeline intrusion monitoring system is presented. The details include the block diagram showing the key modules that make up the system, the operating flow diagram of the system, the circuit diagrams, and the description of the various components that are used in the system development. Finally, the description of how the system operates to assist in monitoring pipeline intrusion is presented.

2. Methodology

This design of the oil pipeline intrusion monitoring system comprises of the power supply module, the fluid or oil flow and intrusion sensing and detection mechanism and the GSM module-based remote flow valve switching mechanism. The block diagram of the system showing the interconnection of the major modules in the system is presented in Figure1.

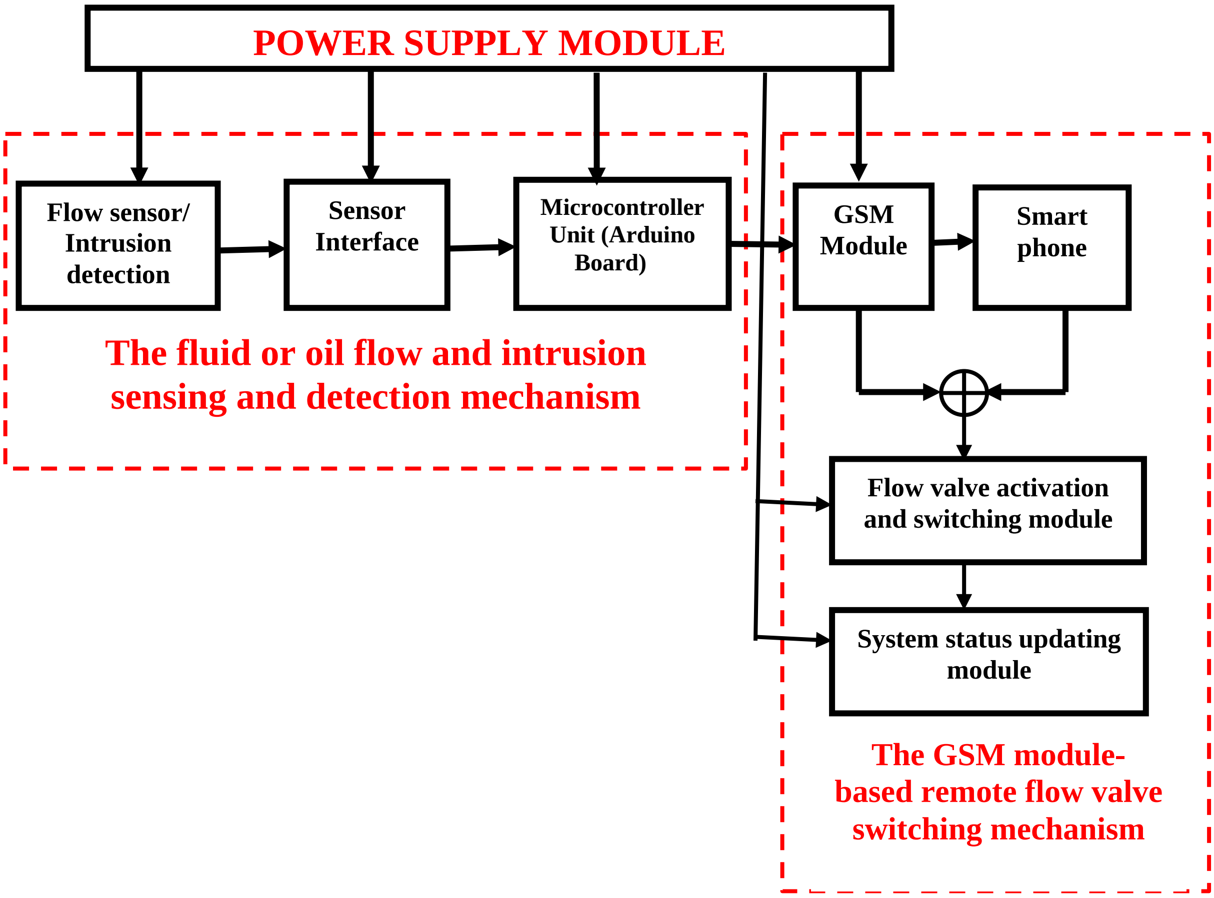

Figure1 The block diagram of the oil pipeline intrusion monitoring system

The system utilizes flow sensors that monitors the drop or difference in the pressure of the oil flowing through the pipeline. The flow sensors are interfaced with a microcontroller, which in this work is Arduino board). When intrusion is sensed by detecting pressure drop, the system response can be an automated valve activation process or a manual valve activation process. In the manual valve activation procedure, when intrusion is sensed, alert signals is sent to a dedicated GSM smartphone in the form of call to the control engineer, who activates the valve switching system. On the other hand, in the automatic valve activation procedure, the intrusion signal is sent directly to the switching control system where the system would be automatically switched off. When this occurs flow valves are shut down. As such, there will be no flow of fluid along the region of intrusion; while the system status is updated in the central control panel for further action by the system operators. The flow diagram of the procedure used in the oil pipeline intrusion monitoring system for the detection of intrusion and control of the pipeline flow valves is presented in Figure 2.

The switching subsystem consist of the Arduino target board-based switching controller and the GSM module, as shown in the block diagram of Figure 3. Specifically, through the Arduino target board-based switching controller, appropriate signal that corresponds to a command for an SMS that indicate OPEN VALVE or CLOSE VALVE is generated and subsequently switching action is taken by the system to either close or open the flow valves based on the GSM module interpretation of the switching signal from the Arduino target board-based switching controller output.

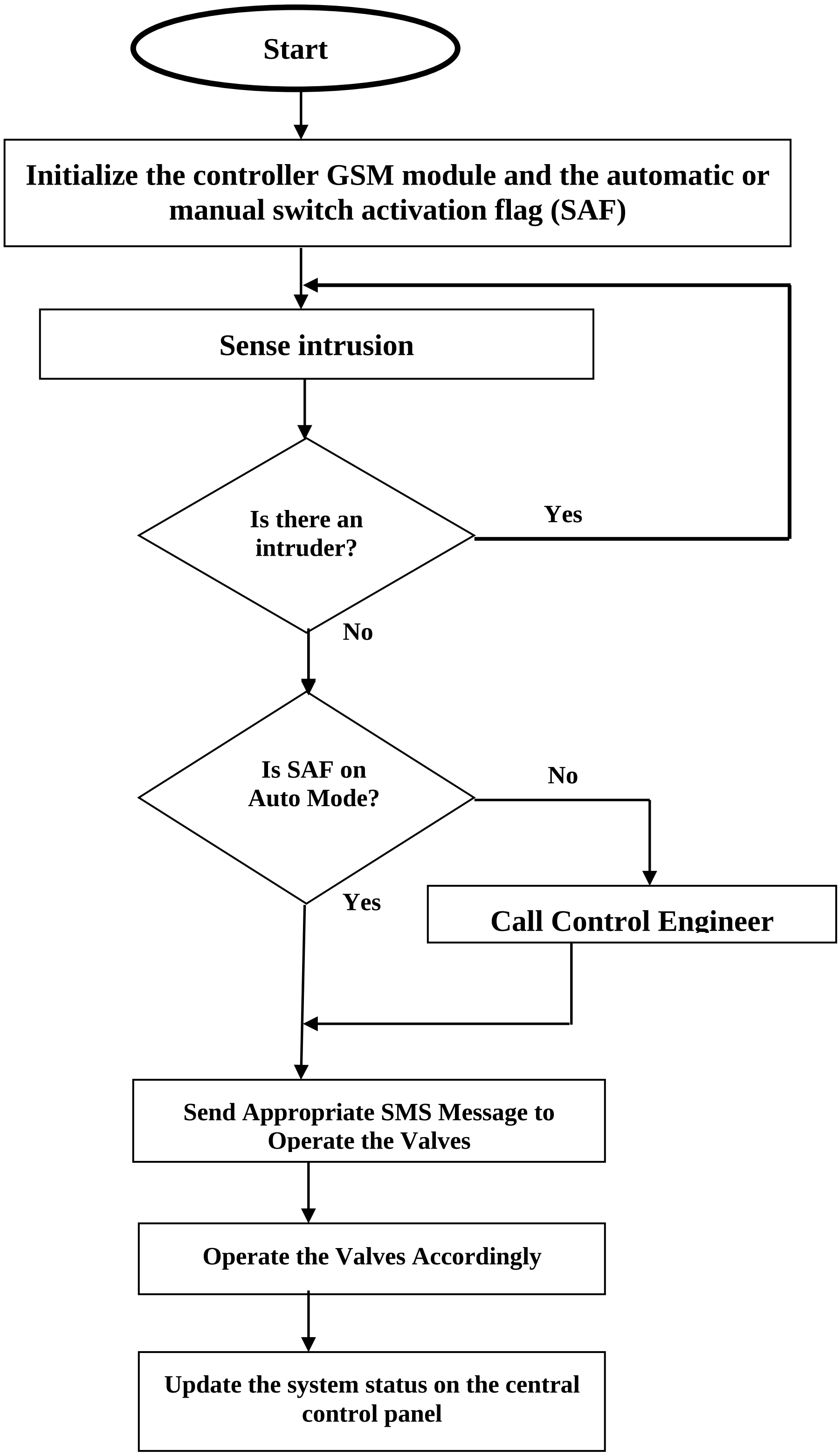

Figure 2 The flow diagram of the procedure used in the oil pipeline intrusion monitoring system for the detection of intrusion and control of the pipeline flow valves

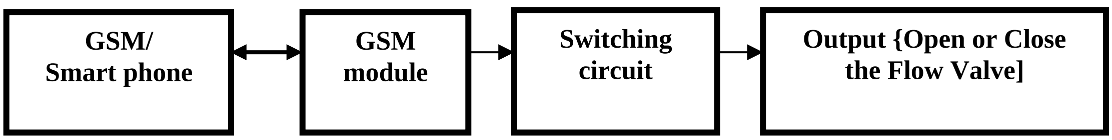

Figure 3 Block diagram of the switching subsystem

The major materials used in the system design are in modules and they include: the power supply module, the power sensor module, the flow sensors, Arduino Target board module and the GSM (Global System for Mobile Communications) Module. It is assumed that the flow valves part of the oil pipeline system and it has its relays which are only turned on or off by the control signal that originates from the oil pipeline intrusion monitoring system. Proteus software was used to model circuit of the system and its operations.

Power Supply Module: The system power is derived from either a battery or the mains power source. In each case, voltage regulator is included to maintain the supply voltage to the circuits at a safe value appropriate for the various components in the system. A12V, 1.3Ah battery is used. For the voltage regulator, the 180 KHz fixed frequency XL4015 PWM buck (step-down) DC/DC converter IC is used. It can efficiently drive a 5A load with, low ripple and very good line and load regulation. In requires DC input range of 3V-35V and it gives DC output range of 5V

Power Sensor Module: The power sensor module is designed to produce 5V output which is used to represent logic 1. The module is responsible for differentiating when the system is powered from mains supply or from battery supply.

The Flow Sensors: In this work two flow sensors which are referred to as sensor A and B are used and they placed at the two ends of the flow pipeline. Notably, sensor A monitors the pipeline inflow pressure while sensor B monitors the pipeline outflow pressure. The pressure differential in the two sensors activates the sensors as intrusion detected which in turn cause the signal to be passed to the GSM module. At this point the system response depends on whether the automatic response flag otherwise known as the **switch activation flag (SAF)**) is set, in which case the system automatically send the flow valve control signal via the GSM module to the flow valve switching subsystem. If on the other hand the SAF is not set, the manual response is used in which case the system sends a call across to the control personnel who sends the appropriate switching signal via the GSM module to the flow valve switching subsystem.

Arouino Uno Module : The Arduino Uno which is a popular and versatile microcontroller board that is based on the ATmega328 technology. It is used in the design to provide the overall control of the entire system modules. The image of an Arduino Uno module is shown in Figure 4.

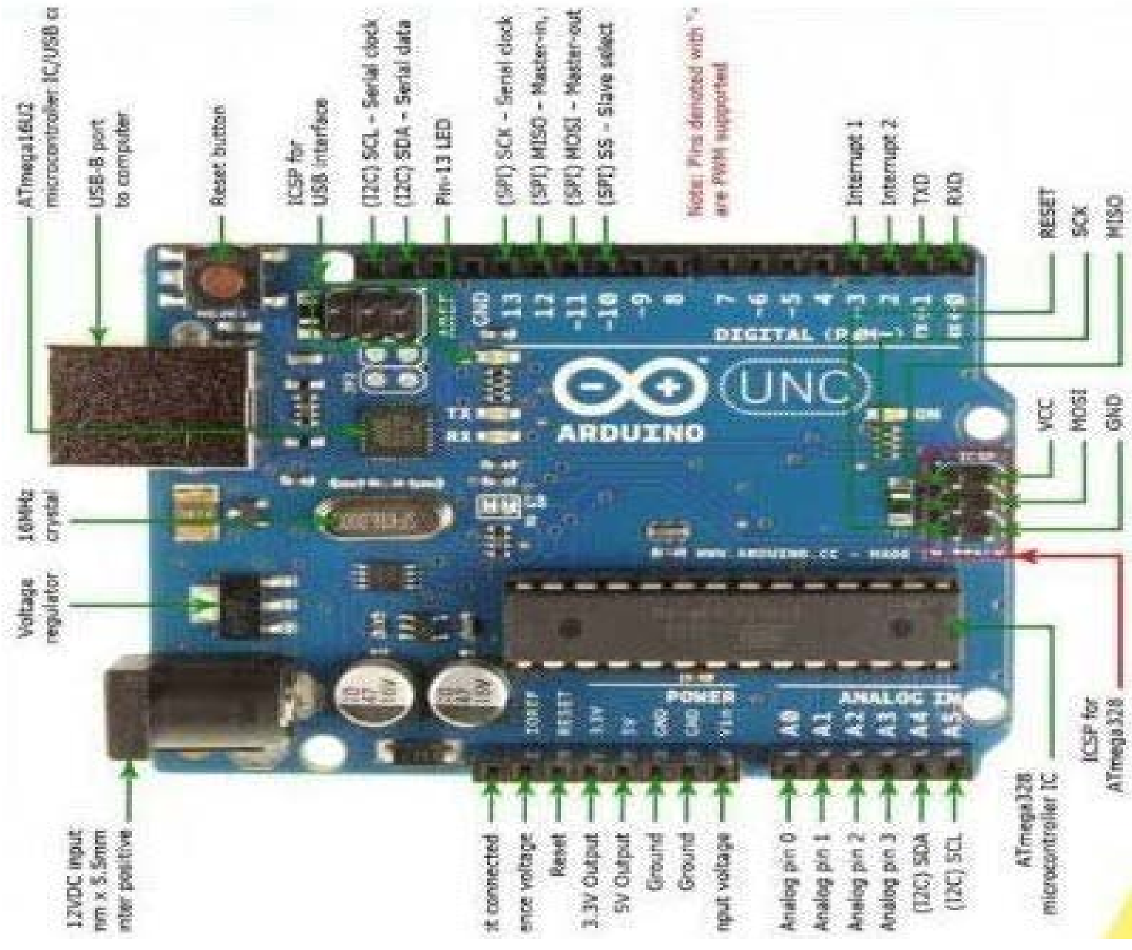

Figure 4 Image of an Arduino Uno Module

GSM Module : The SIM (Subscriber Identity Module) 900 is the GSM interface that is used in the design to t allow the system to communicate with the remote receiver system (which in this design is a cell phone of the control engineer). The image of the GSM Module is shown in Figure 5. The GSM module is interfaced with the Arduino board via the Arduino board serial interface.

Figure 5 The image of the GSM Module

3. Results and Discussions

Proteus 8.4 was used for the purpose of simulation of the designed system. The Proteus software has repository of the requisite components of the systems and the ability to simulate the flow intrusion and detection scenarios. The diagram of the Proteus software modeled circuit for the GSM module-based remote flow valve switching unit connected to the solenoid valve is shown in Figure 6. The circuit diagram in Figure 6 shows the GSM SIM 900 (labeled GSM 2) interfaced with the Arduino Uno board (labeled ARD 2) as well as the bridge rectifier-based AC to DC converter consisting of the bridge rectifier (labeled BR1), the transformer (labeled TR1), the smoothing capacitor (labeled C3) and the three pin voltage regulator IC (labeled U2) with the three pins labeled as VI, VO and GND. The circuit diagram also shows the solenoid valve relay (labeled RL1) with the a 12 V switching transistor (labeled Q1) along with the transistor base driver 1kΩ resistor R3 connect from the Arduino boar to the solenoid valve relay.

As stated earlier, in this work two flow sensors which are referred to as sensor A and B are used and they placed at the two ends of the flow pipeline. Notably, sensor A monitors the pipeline inflow pressure while sensor B monitors the pipeline outflow pressure. The two flow sensors are modeled in the Proteus software as flow measurement terminal 1 and flow measurement terminal 2 and their corresponding circuit diagrams, as modelled in the Proteus software are shown in Figure 7 and figure 8 respectively.

Figure 6 The circuit diagram of the GSM module-based remote flow valve switching unit connected to the solenoid valve

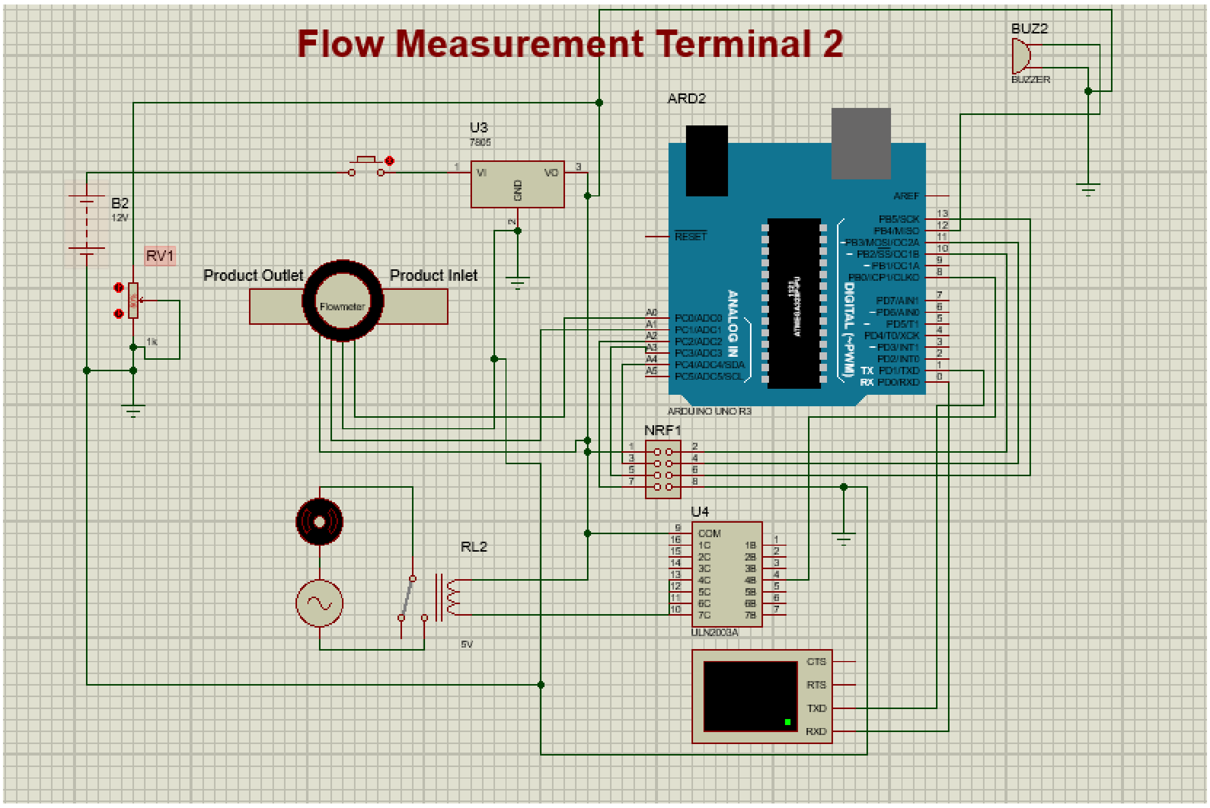

Figure 7 The circuit diagram of the flow sensor A referred to as flow measurement terminal 1 in the Proteus software model of the system

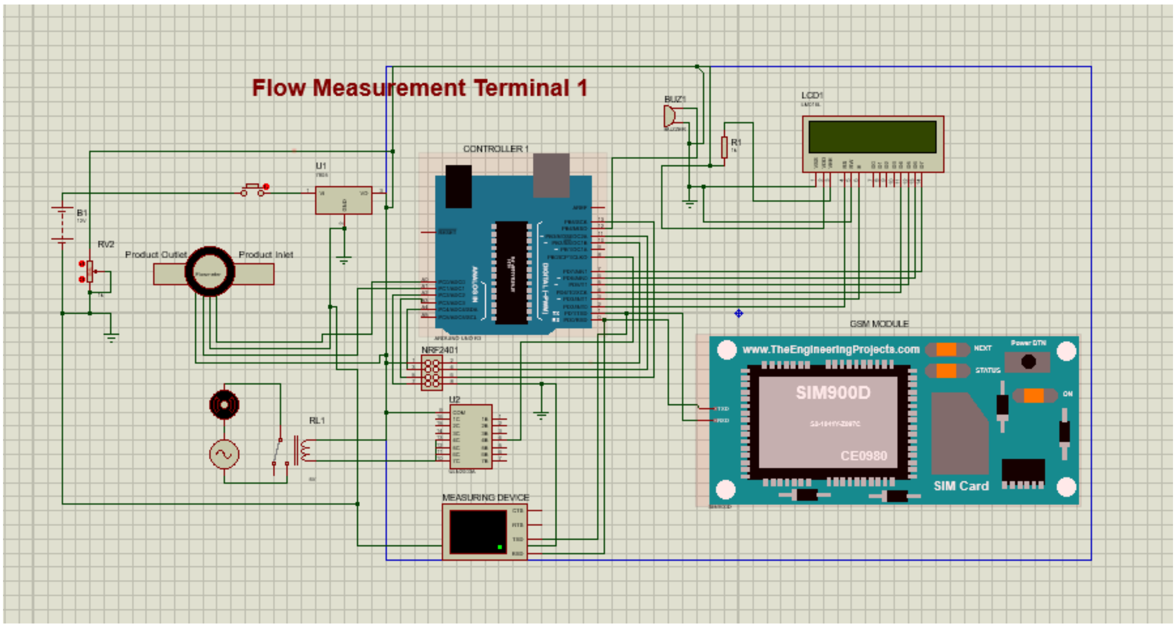

Figure 8 The circuit diagram of the flow sensor B referred to as flow measurement terminal 2 in the Proteus software model of the system

4 Conclusion

The design of the hardware component of an oil pipeline intrusion monitoring system is presented. The hardware is part of an oil pipeline intrusion detection system which requires some analytical model to run on top of the hardware components to detect the occurrence of leakage or leakages in the pipeline and hence trigger a response sequence that can lead to closure of the flow valve in the pipeline and hence stop further leakage or stop the intruder from further stealing of the oil through the leakage points. The system is designed using Arduino microcontroller board and GSM 900 module for communicating the oil leakage status and flow valve activation commands in accordance to the system design specifications. The entire circuit components, the components connections and system operations are modeled and simulated in Proteus software.

References

1. Maduka, N. C., Simeon Ozuomba, and E. E. Ekott. . (2020) "Internet of Things-Based Revenue Collection System for Tricycle Vehicle Operators." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020.
2. Zion, Idongesit, Simeon Ozuomba, and Philip Asuquo. (2020) "An Overview of Neural Network Architectures for Healthcare." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020
3. Chikezie, Aneke, Ezenkwu Chinedu Pascal, and Ozuomba Simeon. (2014). "Design and Implementation Of A Microcontroller-Based Keycard." *International Journal of Computational Engineering Research (IJCER) Vol, 04 Issue, 5 May – 2014*
4. Otumdi, Ogbonna Chima, Kalu Constance, and Ozuomba Simeon (2018). "Design of the Microcontroller Based Fish Dryer." *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 4 Issue 11, November - 201*
5. Ozuomba, Simeon, and Etinamabasiyaka Edet Ekott. (2020). "Design And Implementation Of Microcontroller And Internet Of Things-Based Device Circuit And Programs For Revenue Collection From Commercial Tricycle Operators." *Science and Technology Publishing* (SCI & TECH) Vol. 4 Issue 8, August – 2020
6. Ozuomba, Simeon, Ekaette Ifiok Archibong, and Etinamabasiyaka Edet Ekott (2020). Development Of Microcontroller-Based Tricycle Tracking Using Gps And Gsm Modules. *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 1, January - 2020*
7. Archibong, E. I., Ozuomba, Simeon, & Ekott, E. E. (2020). Life Cycle Cost And Carbon Credit Analysis For Solar Photovoltaic Powered Internet Of Things-Based Smart Street Light In *Uyo. International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 1, January - 2020*
8. Kalu, C., Ozuomba, Simeon. & Udofia, K. (2015). Web-based map mashup application for participatory wireless network signal strength mapping and customer support services. *European Journal of Engineering and Technology, 3 (8)*, 30-43.
9. Thompson, E., Simeon, O., & Olusakin, A. (2020). A survey of electronic heartbeat electronics body temperature and blood pressure monitoring system. Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 8, August – 2020
10. Archibong, Ekaette Ifiok, Simeon Ozuomba, and Etinamabasiyaka Ekott. (2020) "Internet of things (IoT)-based, solar powered street light system with anti-vandalisation mechanism." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020.
11. Sylvester Michael Ekpo, Kingsley M. Udofia, Ozuomba Simeon (2019) Modelling and Simulation of Robust Biometric Fingerprint Recognition Algorithm. *Universal Journal of Applied Science 6(2): 29-38, 2019*
12. Simeon, Ozuomba. (2018) “Sliding Mode Control Synthesis For Autonomous Underwater Vehicles” *Science and Technology Publishing (SCI & TECH*
13. Anietie Bassey, Simeon Ozuomba & Kufre Udofia (2015). An Effective Adaptive Media Play-out Algorithm For Real-time Video Streaming Over Packet Networks. European. *Journal of Basic and Applied Sciences Vol, 2(4).*
14. Uduak Idio Akpan, Constance Kalu, Simeon Ozuomba, Akaninyene Obot (2013). Development of improved scheme for minimising handoff failure due to poor signal quality. *International Journal of Engineering Research & Technology (IJERT), 2(10), 2764-2771*
15. Samuel, W., Ozuomba, Simeon, & Constance, K. (2019). SELF-ORGANIZING MAP (SOM) CLUSTERING OF 868 MHZ WIRELESS SENSOR NETWORK NODES BASED ON EGLI PATHLOSS MODEL COMPUTED RECEIVED SIGNAL STRENGTH. *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 6 Issue 12, December - 2019*
16. Johnson, Enyenihi Henry, Simeon Ozuomba, and Ifiok Okon Asuquo. (2019). Determination of Wireless Communication Links Optimal Transmission Range Using Improved Bisection Algorithm. *Universal Journal of Communications and Network, 7(1), 9-20.*
17. Ogbonna Chima Otumdi , Ozuomba Simeon, Philip M. Asuquo (2020) Device Hardware Capacity And Rssi-Based Self Organizing Map Clustering Of 928 Mhz Lorawan Nodes Located In Flat Terrain With Light Tree Densities *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 9, September - 2020*
18. Njoku, Felix A., Ozuomba Simeon, and Fina Otosi Faithpraise (2019). Development Of Fuzzy Inference System (FIS) For Detection Of Outliers In Data Streams Of Wireless Sensor Networks. *International Multilingual Journal of Science and Technology (IMJST) Vol. 4 Issue 10, October - 2019*
19. Simeon, Ozuomba. (2020). "APPLICATION OF KMEANS CLUSTERING ALGORITHM FOR SELECTION OF RELAY NODES IN WIRELESS SENSOR NETWORK." *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 6, June - 2020*
20. Samuel, Wali, Simeon Ozuomba, and Philip M. Asuquo (2019). EVALUATION OF WIRELESS SENSOR NETWORK CLUSTER HEAD SELECTION FOR DIFFERENT PROPAGATION ENVIRONMENTS BASED ON LEE PATH LOSS MODEL AND K-MEANS ALGORITHM. EVALUATION, 3(11). *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 11, November - 2019*
21. Simeon, Ozuomba. (2020). "Analysis Of Effective Transmission Range Based On Hata Model For Wireless Sensor Networks In The C-Band And Ku-Band." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 12, December - 2020*
22. Ogbonna Chima Otumdi , Ozuomba Simeon, Kalu Constance (2020). Clustering Of 2100 Mhz Cellular Network Devices With Som Algorithm Using Device Hardware Capacity And Rssi Parameters *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 2, February – 2020*
23. Atakpo, F. K., Simeon, O., & Utibe-Abasi, S. B. (2021) A COMPARATIVE ANALYSIS OF SELFORGANIZING MAP AND K-MEANS MODELS FOR SELECTION OF CLUSTER HEADS

IN OUT-OF-BAND DEVICE-TO-DEVICE COMMUNICATION. *Journal of Multidisciplinary Engineering Science Studies (JMESS)*.

24. Idio, Uduak, Constance Kalu, Akaninyene Obot, and Simeon Ozuomba. (2013) "An improved scheme for minimizing handoff failure due to poor signal quality." In *2013 IEEE International Conference on Emerging & Sustainable Technologies for Power & ICT in a Developing Society (NIGERCON)*, pp. 38-43. IEEE, 2013.
25. Akpan, Itoro J., Ozuomba Simeon, and Kalu Constance (2020). "Development Of A Guard Channel-Based Prioritized Handoff Scheme With Channel Borrowing Mechanism For Cellular Networks." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 2, February - 2020*
26. Kalu, C., Ozuomba, Simeon. & Jonathan, O. A. (2015). Rain rate trend-line estimation models and web application for the global ITU rain zones. *European Journal of Engineering and Technology, 3 (9)*, 14-29.
27. Akaninyene B. Obot , Ozuomba Simeon and Afolanya J. Jimoh (2011); "*Comparative Analysis Of Pathloss Prediction Models For Urban Macrocellular" Nigerian Journal of Technology (NIJOTECH)* Vol. 30, No. 3 , October 2011 , PP 50 – 59
28. Eunice, Akinloye Bolanle, and Simeon Ozuomba (2016) "Evaluation of the Distribution of Terrain Roughness Index for Terrestrial Line of Site Microwave Links in Uyo Metropolis." *Mathematical and Software Engineering* 2.1 (2016): 9-18
29. Ononiwu, Gordon, Simeon Ozuomba, and Constance Kalu. (2015). Determination of the dominant fading and the effective fading for the rain zones in the ITU-R P. 838-3 recommendation. *European Journal of Mathematics and Computer Science Vol, 2(2).*
30. Simeon, Ozuomba. (2016) "Comparative Analysis Of Rain Attenuation In Satellite Communication Link For Different Polarization Options." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 3 Issue 6, June - 2016*
31. Oloyede Adams Opeyemi, Ozuomba Simeon, Constance Kalu (2017) Shibuya Method for Computing Ten Knife Edge Diffraction Loss. *Software Engineering* 2017; 5(2): 38-43
32. Ozuomba, Simeon, Johnson, E. H., & Udoiwod, E. N. (2018). Application of Weissberger Model for Characterizing the Propagation Loss in a Gliricidia sepium Arboretum. *Universal Journal of Communications and Network, 6(2), 18-23.*
33. Egbe Jesam Nna, Ozuomba Simeon, Enyenihi Henry Johnson (2017) Modelling and Application of Vertical Refractivity Profile for Cross River State. *World Journal of Applied Physics* 2017; 2(1): 19-26
34. Ozuomba, Simeon, Enyenihi, J., & Rosemary, N. C. (2018). Characterisation of Propagation Loss for a 3G Cellular Network in a Crowded Market Area Using CCIR Model. *Review of Computer Engineering Research*, 5(2), 49-56.
35. Njoku Chukwudi Aloziem, Ozuomba Simeon, Afolayan J. Jimoh (2017) Tuning and Cross Validation of Blomquist-Ladell Model for Pathloss Prediction in the GSM 900 Mhz Frequency Band , *International Journal of Theoretical and Applied Mathematics*
36. Kalu Constance, Ozuomba Simeon, Umana, Sylvester Isreal (2018). Evaluation of Walficsh-Bertoni Path Loss Model Tuning Methods for a Cellular Network in a Timber Market in Uyo. *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 4 Issue 12, December - 2018*
37. Ozuomba, Simeon, Henry Johnson Enyenihi, and Constance Kalu (2018) "Program to Determine the Terrain Roughness Index using Path Profile Data Sampled at Different Moving Window Sizes.*" International Journal of Computer Applications 975: 8887.*
38. Simeon, Ozuomba, Kalu Constance, and Ezuruike Okafor SF. (2018). "Analysis of Variation in the Vertical Profile Of Radio Refractivity Gradient and its impact on the Effective Earth Radius Factor." *International Multilingual Journal of Science and Technology (IMJST) Vol. 3 Issue 11, November - 2018*
39. Ono, M. N., Obot, A. B., & Ozuomba, Simeon. (2020). ENHANCED BISECTION ITERATION METHOD APPLIED IN FADE MARGIN-BASED OPTIMAL PATH LENGTH FOR FIXED POINT TERRESTRIAL MICROWAVE COMMUNICATION LINK WITH KNIFE EDGE DIFFRACTION LOSS. *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 6, June – 2020*
40. Ozuomba, Simeon. (2019). EVALUATION OF OPTIMAL TRANSMISSION RANGE OF WIRELESS SIGNAL ON DIFFERENT TERRAINS BASED ON ERICSSON PATH LOSS MODEL. *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 12, December - 2019*
41. Constance, Kalu, Ozuomba Simeon, and Ezuruike Okafor SF. (2018). Evaluation of the Effect of Atmospheric Parameters on Radio Pathloss in Cellular Mobile Communication System. Evaluation, 5(11). *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 5 Issue 11, November - 2018*
42. Johnson, Enyenihi Henry, Simeon Ozuomba, and Kalu Constance. (2019). Development of model for estimation of radio refractivity from meteorological parameters. *Universal Journal of Engineering Science* 7(1), 20-26.
43. Ozuomba, Simeon, Constant Kalu, and Henry Johnson Enyenihi. (2018) "Comparative Analysis of the Circle Fitting Empirical Method and the International Telecommunication Union Parabola Fitting Method for Determination of the Radius of Curvature for Rounded Edge Diffraction Obstruction." Communications on Applied Electronics (CAE) *7: 16-21.*
44. Dialoke, Ikenna Calistus, Ozuomba Simeon, and Henry Akpan Jacob. (2020) "ANALYSIS OF SINGLE KNIFE EDGE DIFFRACTION LOSS FOR A FIXED TERRESTRIAL LINE-OF-SIGHT MICROWAVE COMMUNICATION LINK." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 2, February - 2020*

45. Imoh-Etefia, Ubon Etefia, Ozuomba Simeon, and Stephen Bliss Utibe-Abasi. (2020). "Analysis Of Obstruction Shadowing In Bullington Double Knife Edge Diffraction Loss Computation." *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 1, January – 2020*

46. Simeon, Ozuomba, Ezuruike Okafor SF, and Bankole Morakinyo Olumide (2018). Development of Mathematical Models and Algorithms for Exact Radius of Curvature Used in Rounded Edge Diffraction Loss Computation. Development, 5(12). *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 5 Issue 12, December – 2018*

47. Mahbub, M. (2020). A smart farming concept based on smart embedded electronics, internet of things and wireless sensor network. *Internet of Things*, *9*, 100161.

48. Patil, V. C., Al-Gaadi, K. A., Biradar, D. P., & Rangaswamy, M. (2012). Internet of things (Iot) and cloud computing for agriculture: An overview. *Proceedings of agro-informatics and precision agriculture (AIPA 2012), India*, 292-296.

49. Bo, C., Xin, C., Zhongyi, Z., Chengwen, Z., & Junliang, C. (2014). Web of things-based remote monitoring system for coal mine safety using wireless sensor network. *International Journal of Distributed Sensor Networks*, *10*(8), 323127.

50. Qiu, T., Chen, N., Li, K., Atiquzzaman, M., & Zhao, W. (2018). How can heterogeneous internet of things build our future: A survey. *IEEE Communications Surveys & Tutorials*, *20*(3), 2011-2027.

51. Chobot, E., Newby, D., Chandler, R., Abu-Mulaweh, N., Chen, C., & Pomalaza-Ráez, C. (2013). Design and implementation of a wireless sensor and actuator network for energy measurement and control at home. *arXiv preprint arXiv:1305.1259*.

52. Gautam, I., & Reddy, S. R. N. (2012). Innovative GSM bluetooth based remote controlled embedded system for irrigation. *International Journal of Computer Applications*, *47*(13), 1-7.

53. Wang, M., Zhang, G., Zhang, C., Zhang, J., & Li, C. (2013, June). An IoT-based appliance control system for smart homes. In *2013 fourth international conference on intelligent control and information processing (ICICIP)* (pp. 744-747). IEEE.

54. Gunge, V. S., & Yalagi, P. S. (2016). Smart home automation: a literature review. *International Journal of Computer Applications*, *975*(8887-8891).

55. Dakheel, A. H., Dakheel, A. H., & Abbas, H. H. (2019). Intrusion detection system in gas-pipeline industry using machine learning. *Periodicals of Engineering and Natural Sciences*, *7*(3), 1030-1040.

56. Batzias, F. A., Siontorou, C. G., & Spanidis, P. M. (2011). Designing a reliable leak bio-detection system for natural gas pipelines. *Journal of hazardous materials*, *186*(1), 35-58.

57. Marsden, T., Moustafa, N., Sitnikova, E., & Creech, G. (2018). Probability risk identification based intrusion detection system for SCADA systems. In *Mobile Networks and Management: 9th International Conference, MONAMI 2017, Melbourne, Australia, December 13-15, 2017, Proceedings 9* (pp. 353-363). Springer International Publishing.

58. Morris, T. H., Thornton, Z., & Turnipseed, I. (2015). Industrial control system simulation and data logging for intrusion detection system research. *7th annual southeastern cyber security summit*, 3-4.

59. Teixeira, M. A., Zolanvari, M., Khan, K. M., Jain, R., & Meskin, N. (2021). Flow‐based intrusion detection algorithm for supervisory control and data acquisition systems: A real‐time approach. *IET Cyber‐Physical Systems: Theory & Applications*, *6*(3), 178-191.

60. Morris, T. H., Thornton, Z., & Turnipseed, I. (2015). Industrial control system simulation and data logging for intrusion detection system research. *7th annual southeastern cyber security summit*, 3-4.

61. Morris, T., Vaughn, R., & Dandass, Y. S. (2011, October). A testbed for SCADA control system cybersecurity research and pedagogy. In *Proceedings of the Seventh Annual Workshop on Cyber Security and Information Intelligence Research* (pp. 1-1).

62. Wellem, T., & Setiawan, B. (2012). A microcontroller-based room temperature monitoring system. *International journal of computer applications*, *53*(1).

63. Bharathkumar, V., Irshad, S. M., Gowtham, S., & Geethamani, R. (2017, January). Microcontroller based digital meter with alert system using GSM. In *2017 11th International Conference on Intelligent Systems and Control (ISCO)* (pp. 444-448). IEEE.

64. Hasan, M., Anik, M. H., & Islam, S. (2018, November). Microcontroller based smart home system with enhanced appliance switching capacity. In *2018 Fifth HCT Information Technology Trends (ITT)* (pp. 364-367). IEEE.