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# Dynamic Pressure Monitoring Using a Wireless Sensor Network

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| ARTICLE INFO | ABSTRACT |
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| Published Online: 18 April 2023 | This study introduces the build out and implementation of a wireless sensor network that was used to monitor dynamic pressure of water flowing inside a pipe against leak. At 5 chosen points along a prototype water pipeline, pressure sensors (HK1100C) were used to collect pressure data and its voltage data equivalent. Five locally designed and constructed field sensor nodes made up of pressure sensors, Ardiuno boards containing an 8-bit ATmega328P microcontrollers, GSM SIM800L modules, and power sources were used to process and analyze the pressure data such that when the pressure data falls below 9psi, 9.5psi, 10psi, 10.5psi, and 11psi respectively at the 5 chosen points, the information is processed by the Ardiuno boards containing an 8-bit Atmega328P microcontrollers and then passed on to the GSM SIM800L modules of respective field sensor nodes which then transmit these information as radio waves to the master sensor node of the network that has an LCD JHD162 module and a buzzer.. The received radio waves were converted back into electrical signals by the transceiver contained in the GSM SIM800L module of the master sensor node and used to power the LCD and buzzer to indicate 'low pressure' and sound an alarm simultaneously. The location of the pressure drop is identified and the cause rectified by trained personnel. SIM cards of chosen GSM networks were inserted into the various GSM SIM800L modules contained in the sensor nodes (fields and master nodes) for communication. Also, an experiential evaluation of the relationship between leaks and pressure variations was carried out at one of the chosen 5 points along the prototype water pipeline. |
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**KEYWORDS:** Wireless sensor network, sensor node, pressure data, arduino board, pressure sensor, GSM module.

## 1. INTRODUCTION

Wireless sensor networks (WSNs) development and deployment now find uses in many applications because of their low cost, low power usage, high sensitivity, and multitasking sensor nodes that are small in sizes and can relate both in short and large ranges. Wireless sensor networks find applications in fields such as medicines, military, industries, agriculture, and environmental monitoring (Othman and Shazali, 2012). Buratti, Conti, Dardari, and Verdone (2009) presented a wireless sensor network as an arrangement of sensor nodes (devices), which can sense the environment, gather knowledge about the environment, and convey the knowledge gathered through wireless links to a sink (usually referred to as a controller or a monitor) and the knowledge analyzed boundedly or through a gateway linked to the internet. A wireless sensor network is made up of many sensor nodes having most of them located in the field (field sensor nodes) while one or few are situated in places (sink or master sensor nodes(s)) where the information gathered and communicated from the field sensor nodes are received and analyzed (Okpare, 2019). Akyildiz, Su, Sankarasubramaniam, and Cayirci (2002) opined that the sensor nodes are non dependent and frequency and bandwidth limited. The field and master sensor nodes could be static or move able. A wireless sensor node basically consists of a power source (a battery), a sensor, a microcontroller, and transceiver. Figure 1.1 presents the block diagram of the field sensor node used in the wireless sensor network while figure 1.2 gives the block diagram of a master sensor node.

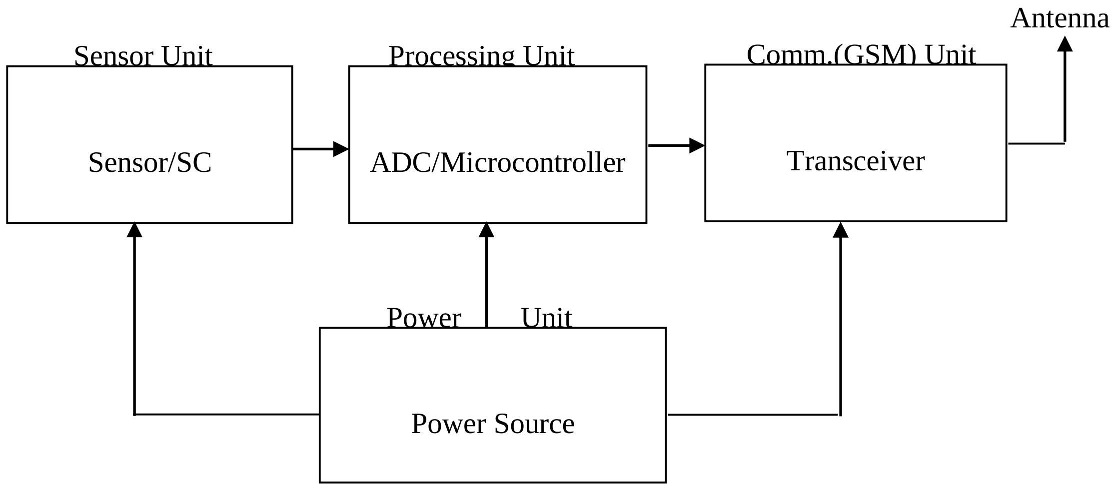



**Figure 1.1: A field sensor node block diagram**

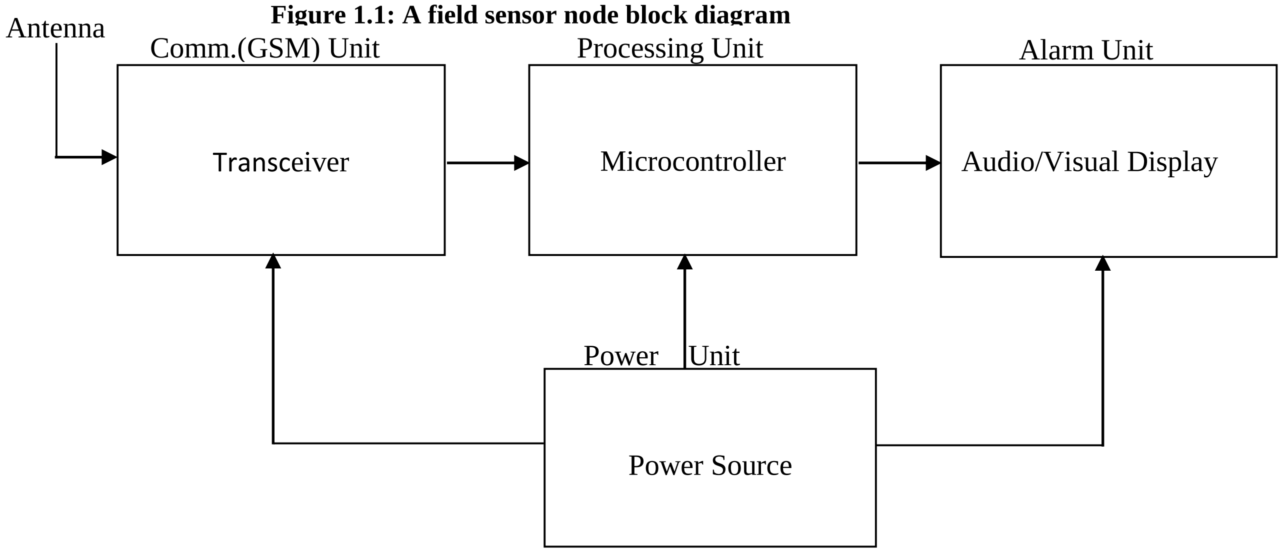



**Figure 1.2: A master sensor node block diagram**

The sensor is used for data acquisition from the physical environment, the microcontroller is for processing data acquired, and the transceiver is for communication between the field sensor nodes and the master sensor node(s). Sensor node(s) can transmit data or values wirelessly to one or several master or sink nodes (Singh, Woo, Raghavendra, and Pan, 2010). The battery is to power the node and this implies that the node is energy constrained (Asada, 1998). Clark and Culler (2004) posited that the microcontroller in a sensor node works with both sensor(s) and transceiver to form a resourceful system for relaying small amounts of important data with minimal power consumption. Okpare, Anyasi, and Ebegba (2019) citing Lochab (2011) stated that the design factors to be considered among others in the plan of a wireless sensor network include transmission media, environment, production costs of nodes, power consumption, sensor network topology, fault tolerance, scalability, hardware constraints, e.t.c. One of the advantages of wireless sensor networks in the detection and location of leaks has been highlighted as its ability to be used for continuous inspection and real time monitoring (Karray, F., Garcia-Ortiz, A., Jmal, M.W, Obeid, A.M, & Abid, M., 2016). It should be noted that wireless sensor networks also have shortcomings which include limitations in energy, sensing scope, and communication distance, susceptibility to electromagnetic interference, e.t.c. (Pang, C., Xu G., Shan, G., & Zhang, Y.,2020). AL-Kadi, T, AL-Tuwaijri, Z., and AL-Omran, A. (2013) presented a shortcoming of usage for only point evaluations where processed and sent information are compared with reference information (values). These shortcomings, however, could be mitigated through new designs and improvements.

Boaz, L., Kaijage, S., and Sinde, R. (2014) and Datta, S. and Sarkar, S. (2016) have reported numerous leak detection and localization techniques for Water Pipeline Monitoring (WPM) in their literatures. According to Karray, F. et al (2016), WPM systems depend on two main practical steps, and these are the sensors/equipment employed to collect useful data and the process of analyzing the collected data. Water monitoring in pipes using pressure variation to locate leaks in the pipes has attracted a lot of interest because of economic losses resulting from water wastages and damage to the environment.

## 2. RELATED WORK

Sadeghion, Metje, Chapman, and Anthony (2014) presented a smart wireless sensor network for leak detection in water pipelines based on the measurement of relative indirect pressure changes in plastic pipes. A relative pressure sensing method based on Force Sensitive Resistors (FSRs) whose operation is based on the principle of a changing diameter of the pipe caused by an internal pressure change was used to take pressure measurements. Pressure profiles from pressure sensors were used to determine approximate location of leaks since the profile of the pressure drop caused by leaks is different from measurements before and after leaks.

Yuanwei and Ali (2008) developed a leak detection technique that made use of acoustic sensing devices like Lead Zirconate Titanate (PZT) acoustic sensors.

Nwalozie and Azubogu (2014) investigated the relationship between flow-induced vibration and pressure fluctuations along pipes. Acceleration sensors were used and experimental findings indicated that a sharp change in pressure is associated with a sharp change in pipe surface acceleration at corresponding locations along the length of the pipe. They inferred that water pressure monitoring can be transformed into acceleration monitoring of pipes surfaces.

Okpare (2019) amongst other things investigated the relationship between pressure variation and voltage variation over a time interval. Matlab graphs show that there is corresponding change in pressure and voltage over a given time interval. The research work also showed how pressure sensors in field sensor nodes of a wireless sensor network could be used to monitor oil pipeline against leaks. Information of pressure drop below a set pressure point is processed, transmitted, received, and used to drive an LCD and a buzzer. This information is used to localize leaks along the oil pipeline and hence monitor the oil pipeline.

Karray, F, Garcia-Ortiz, A, Jmal, M. W, Obeid, A. M., and Abid, M. (2016) designed and tested an in-node LPKF algorithm that was used for leak detection, data filtering, and data compression, which was employed for reliable water pipeline monitoring in an EARNPIPE prototype. The LPKF algorithm worked very well for its intended purpose and could be extended for leak location and size estimation.

AL-Kadi, T., AL-Tuwaijri, Z., and AL-Omran, A. (2013) basically surveyed four wireless sensor network technologies for detecting leaks and they are the magnetic induction based WSN for underground pipeline leakage detection and localization, ad-hoc wireless pressure monitoring system which uses mobile wireless network technology for leakage detection, underground to above ground radio propagation based WSN, and Wireless Signal Network (WSiN) systems for efficient leakage detection that also provides accurate and real time detection. They also presented some of their advantages and shortcomings and areas of applications.

Rest of the paper is organized as follows: Section 3 presents the methodology employed in the research which, include the experimentation carried out, results obtained, and discussion. Conclusion is given in section 4.

## 3. METHODOLOGY

A step by step modular method was employed in the development and implementation of the wireless sensor network used for monitoring the prototype water pipeline. The concepts behind the methodology used entail signal (energy) conversion, signal processing, signal transmission and reception which follow the modular approach where pressure parameter is monitored in the prototype water pipeline. Pressure sensors were installed at five selected points along the prototype water pipeline to measure pressure values at those points. When pressure values at those points fall below set points, the pressure data are converted into electrical (voltage) data by the pressure sensors and the voltage data are sent to the microcontrollers of the five field sensor nodes for processing. From the microcontrollers, the signals are sent to the GSM modules of each of the field sensor node where the signals are converted into radio waves and transmitted. The GSM module of the master sensor node receives the transmitted signals from the five field sensor nodes. Any signal received from a field sensor node is converted back to electrical signal and then used to drive both the LCD and the buzzer in the master sensor node.

The first valve before the first pressure sensor was used to simulate leak for experimentation purpose. A closed valve represents absence of leak while opened valve indicates presence of leak.

### 3.1 Components Used

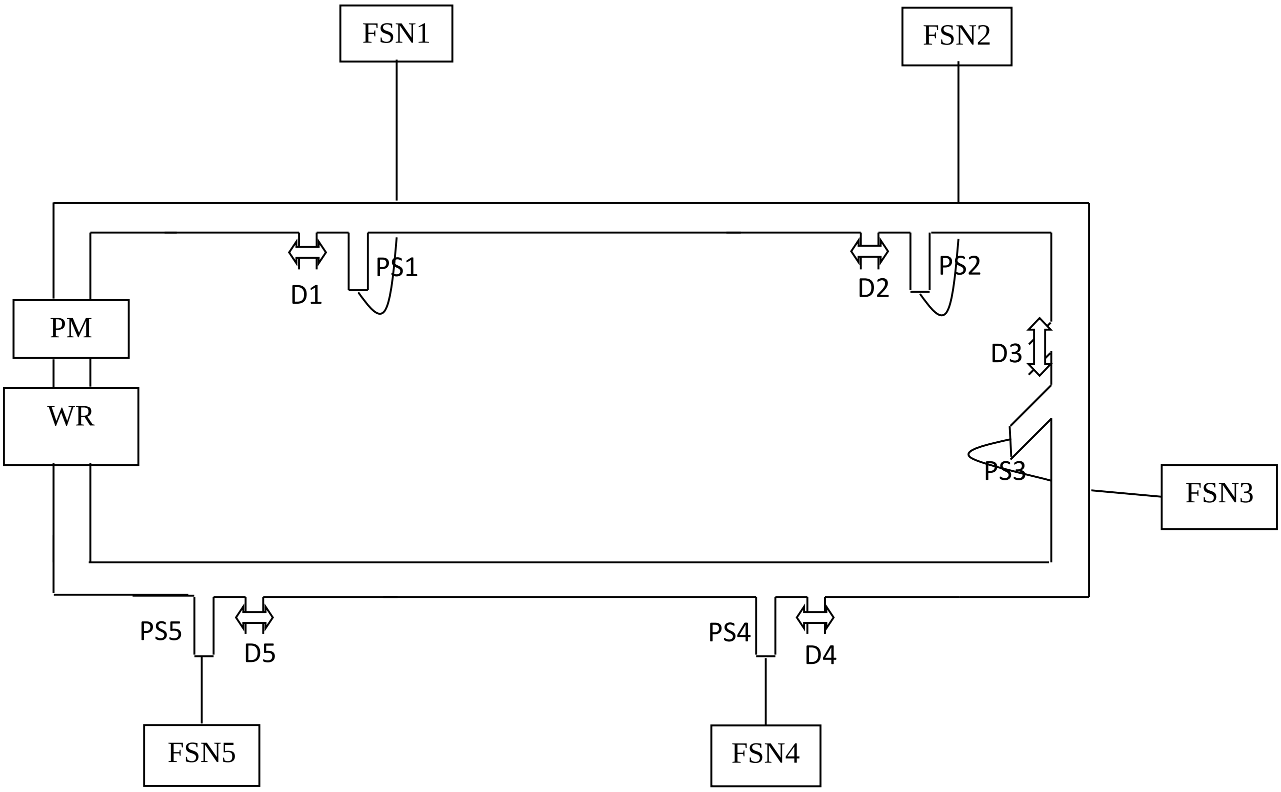
This sub section presents the components used for one field sensor node in the study and they are the pressure sensor (HK1100C pressure transmitter), Arduino Uno board containing an 8-bit AT mega328P microcontroller, a SIM800L GSM module, a JHD162A LCD module, audio alarm buzzer, and a 9V battery for power supply. The components were carefully selected putting material properties, processing, and environmental factors in mind.

### 3.2 Experimental results and discussion

Figure 3.1 presents the architecture of the prototype pipeline system used as an experimental set up in the study of leak detection. Plumbing materials such as pvc pipes, valves, pumps, e.t.c. were used. Pressure and equivalent voltage data were obtained and recorded using data log software and memory card module at field node 1 in the course of the experimentation. The experimentation was carried out in two stages representing absence of leak and presence of leak.

Closed valve represents absence of leak and high pressure while opened valve indicates presence of leak and low pressure. The drain valve was manually adjusted to these two states.

Measured and recorded pressure and equivalent voltage values were taken from 0 second to 3684 second. Drain valve was closed from 0 second to 1800 second and then opened between 1801second and 3684 second.




KEY:

WR – Water Reserviour  PM – Pumping Machine

FSN1 – Field Sensor Node 1  FSN2 – Fie;d Sensor Node 2

FSN3 – Field Sensor Node 3  FSN4 – Field Sensor

FSN5 – Field Sensor Node

D1 – Drain 1  D2 – Drain 2  D3 – Drain 3  D4 – Drain 4  D5 – Drain

PS1 – Pressure Sensor 1  PS2 – Pressure Sensor 2  PS3 – Pressure Sensor 3

PS4 – Pressure Sensor 4  PS5 – Pressure Sensor 5

**Figure 3.1: Prototype Architecture**

**3.2.1 Results**

Obtained and recorded pressure and voltage values for every second were analyzed using Microsoft excel and the consequent graphs of figures 3.2, 3.3, and 3.4 were produced.

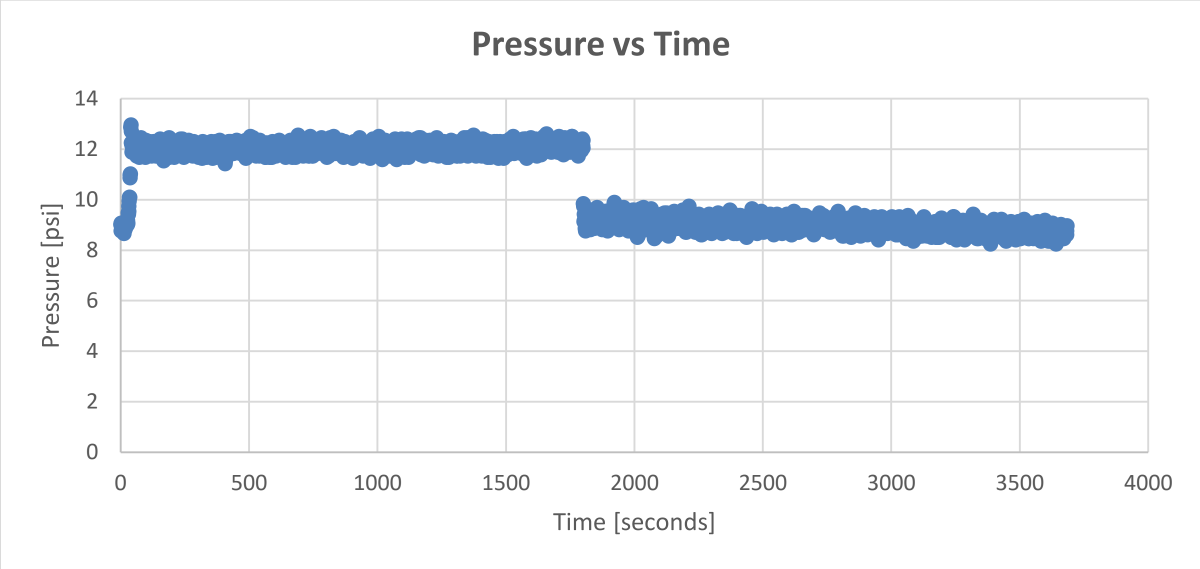



**Figure 3.2: Pressure against time graph**

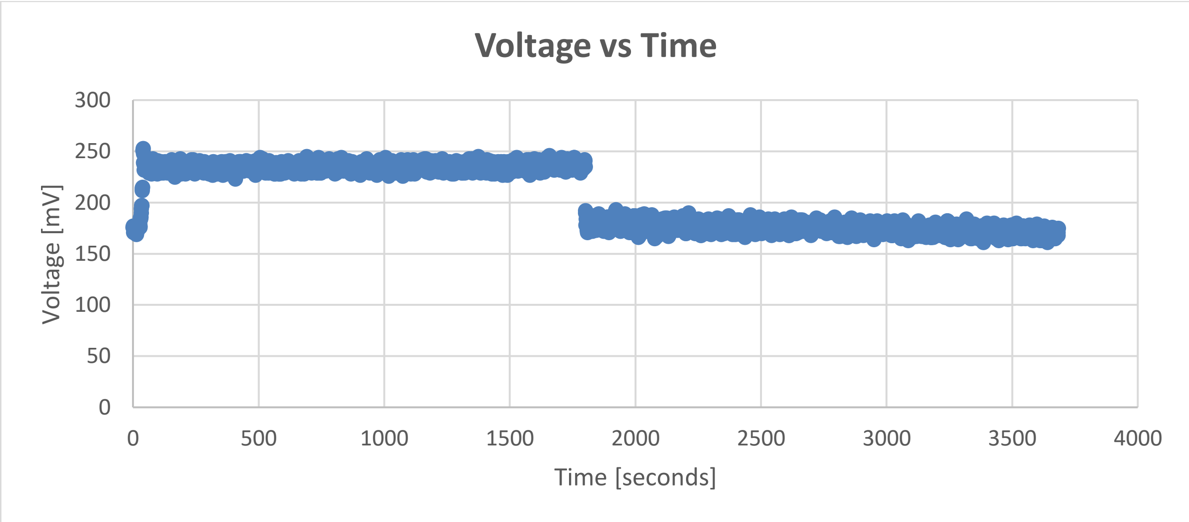



**Figure 3.3: Voltage against time graph**

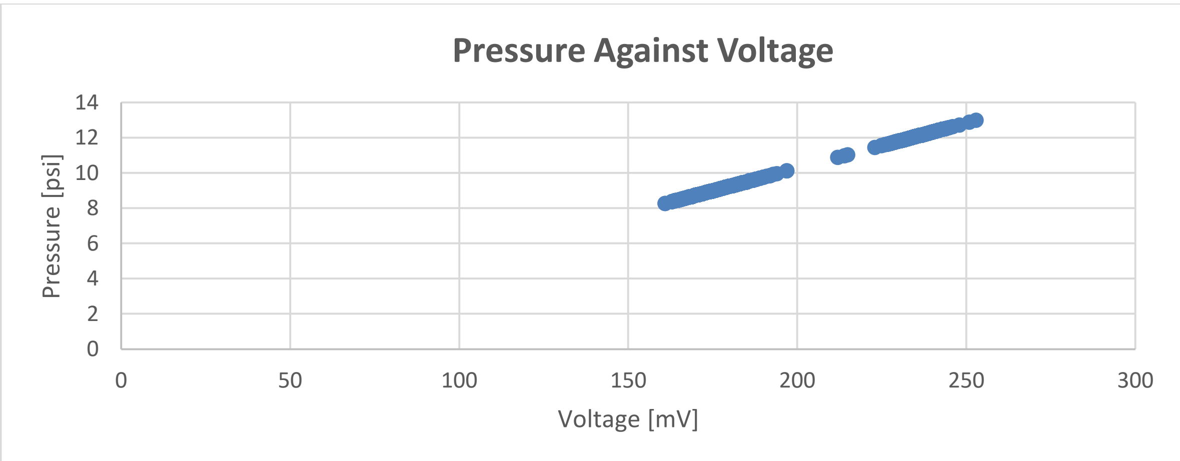



**Figure 3.4: Pressure against voltage graph**

**3.2.2 Discussion**

We evaluated the pressure and voltage profiles for absence of leak state (closed valve) and presence of leak state (opened valve) for time intervals of 0 second to 1800 second and 1801 second and 3684 second respectively. It can be seen from figure 3.1 that the pressure profile for absence of leak started from about 8.5psi and then fluctuated between 11.5psi and 12.5psi. This fluctuation is as a result of ac voltage fluctuations in the ac voltage supplied to the electric pumping machine. This consequently led to the fluctuations in the speed of the electric pumping machine. It can be seen that the pressure profile for presence of leak is also fluctuating around about 9psi. From figures 3.1 and 3.2, it can be seen that once the valve was opened to simulate leak, there was an sharp and instant fall in the both pressure and voltage profiles and this indicated the presence of leak.

The pressure profile and voltage profile are exactly the same showing linear relationship or direct proportionality. This direct proportionality is also evident in the plot of pressure against voltage, which is a straight line graph.

It was also observed in the course of the experimentation, that the wider the size of the leak, simulated by opening the drain valve, the more the pressure drops. And this shows the extent of leak detected.

## 4. CONCLUSION

In this research work, a wireless sensor network comprising five field sensor nodes and one master sensor node has been developed and implemented to monitor a prototype water pipeline against leak using pressure variation. Test operations and experimentations carried out showed that pressure variations or drops can be used to localize leaks and the wider the leak size, the more the pressure drops. Leaks location accuracy can be increased by using more field sensors. Further works on the use of both pressure sensor and impact sensor will be carried out to cater for both reactive and proactive actions.

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