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An Automated Real Time Oil Leakage Detection without False Alarm

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Abstract- In the course of this project, real time oil leakage detection without false alarm has been designed and implemented to ensure that leakages are detected without any incidence of false alarm. Here, a mass flow rate difference between the two ends of the oil pipeline is used as the basis of the oil leakage detection. A pipeline that connects two flow stations A and B is used as a reference. Flow station A has a microcontroller as the central control unit with pressure pump and sound alarm as the output devices and mass flow meter and start button as the input devices. It also has a mobile phone that serves on as a modem. Equally flow station B has similar arrangement as the flow station A except that it has sound alarm as the output device. This project is based on the modification of continuity equation (Inlet Mass flow rate equals outlet Mass flow rate) to Inlet Mass flow rate equals Outlet mass flow rate plus Losses due to pipeline. At interval of time (t), the flow meter at flow station A measures the mass flow rate MA and sends its value to flow station B via the mobile phone that acts as the modem. Flow station B in return measures its mass flow rate MB and compares it with MA received flow station A. If the difference between MA and MB is less than or equal to the threshold acceptable loss for the given pipeline, the system continues to pump oil through the pipeline but if the difference becomes greater than the threshold loss of the pipeline, it means that leakage has occurred. Hence, flow station B sends short message service (SMS) to flow station A to alert it that leakage has occurred and equally alerts its workers using sound alarm. Once, flow station A receives a short message service (SMS) alert from flow station B that leakage has occurred, it stops the pump and alerts its workers of the leakage. This system is real time based and eliminates false alarm that is common with other methods of leakage detection based on flow rates, since the exact tolerable threshold loss ML due to the pipeline length, cross sectional area and density of fluid flowing through the pipeline over a given time was considered as the acceptable difference between mass flow rates at the inlet and outlet of the pipeline.

Index Terms- Microcontroller, Mass Flow Rates, Modem, Tolerable Threshold, Leakage, Alarm and Short Message Service (SMS)

I. INTRODUCTION

This project is designed with the intention to ensure timely oil leakage detection without incidence of false alarm. False alarm is a scenario which arises when a leakage detecting system produces an alarm that leakage has occurred whereas no leakage actually occurred in the pipeline. It is common with wireless sensor and flow rate detections [1 – 8].

This shortcoming of acoustic sensor has been largely responsible for the increase in the level of pollution in Nigeria and other developing countries due to failure to timely detect leakage and shutdown oil production. Here, there is a maximum threshold ML accepted for mass flow rate differences between the inlet and outlet mass flow rates across the pipeline. Unless the difference in flow rate exceeds this threshold, no leakage is reported by the system. Hence this project when implemented in the oil and gas industries in Nigeria and other developing countries as shown in Fig. 1, Fig. 2 and Fig. 3 , will go a long way to ensuring timely oil leakage detection without incidence of false alarm. It will equally eliminate the incidence of late oil leakage detection which is the main cause of pollution in oil producing areas as reported by United Nation Environment Programme (UNEP) 2021 report on

Ogoni (A small oil producing community in Rivers State, Nigeria [9 - 14].

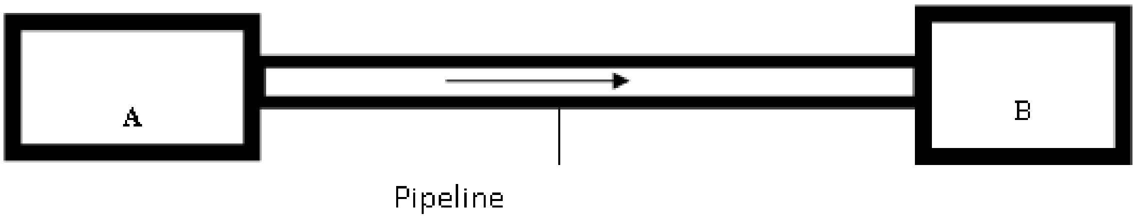

Fig. 1. Block diagram of oil flow from station A to station B

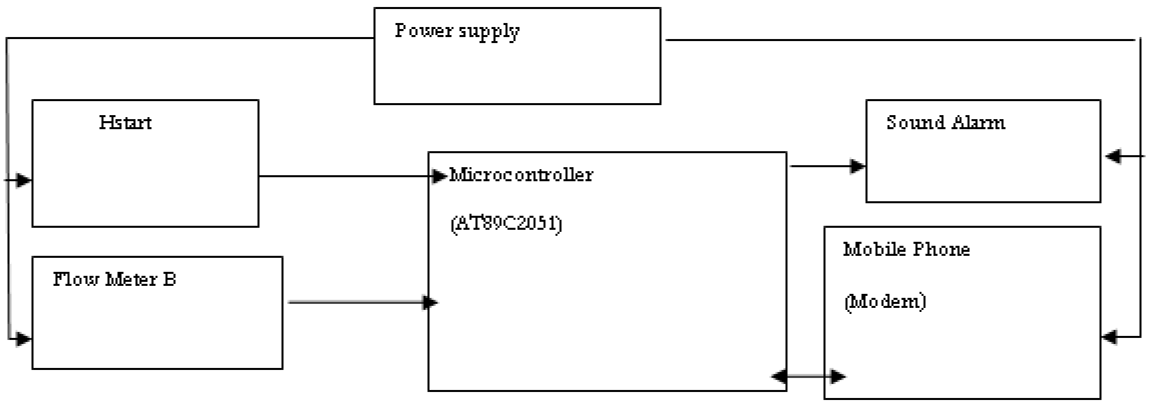

Fig. 2. Block diagram of flow station B.

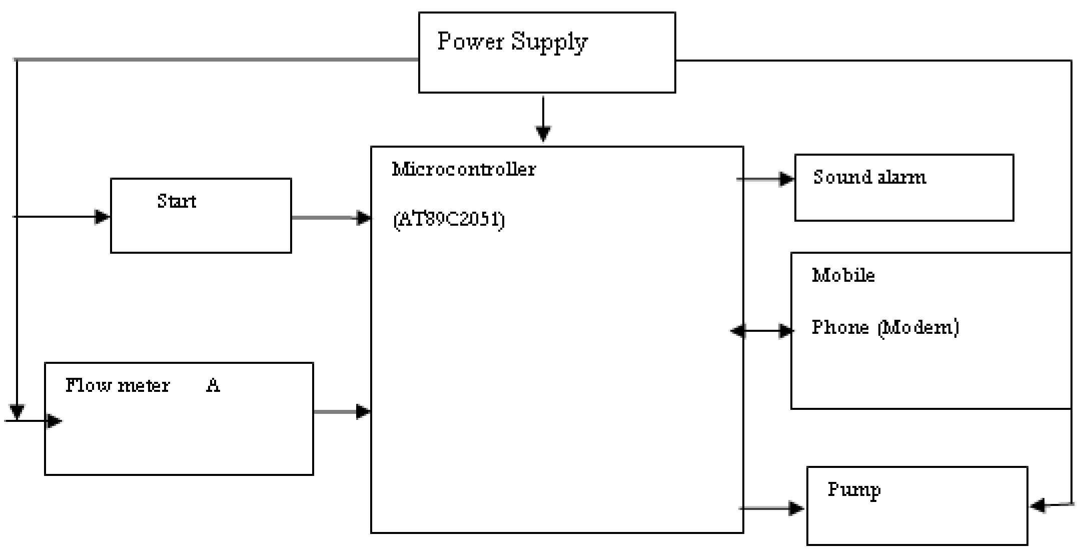

Fig. 3. Block diagram of flow station A

II. DESIGN

Here, top-down design shown in Fig. 4 is used. The whole system is broken down into three different smaller modules [15 - 20].

MODULE 1: Configuration of the microcontroller and its control software as shown in Fig. 5 and Fig. 6.

MODULE 2: Design of the data acquisition system. This comprises wiring and interconnecting the Flow meters, pump, Sound alarms, modems and relays to the microcontrollers at stations A and B. The circuit diagrams for both flow stations A and B as shown in Fig. 8 and Fig. 9 were drawn using PCB software for circuit design.

MODULE 3: Configuration of the microcontroller and its control software program for reporting of faults.

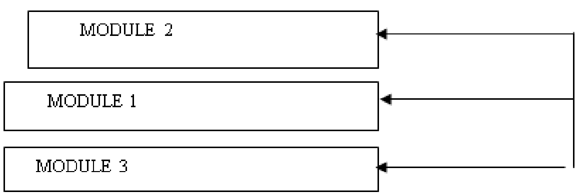

Fig. 4. A modularized approach of the project system design.

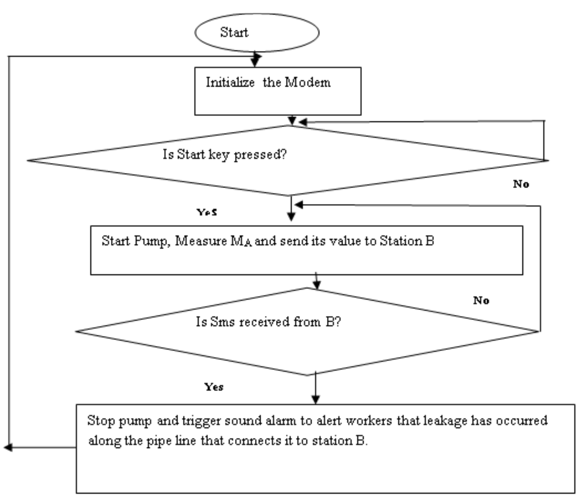

Fig. 5. Flow control chart at Flow station A

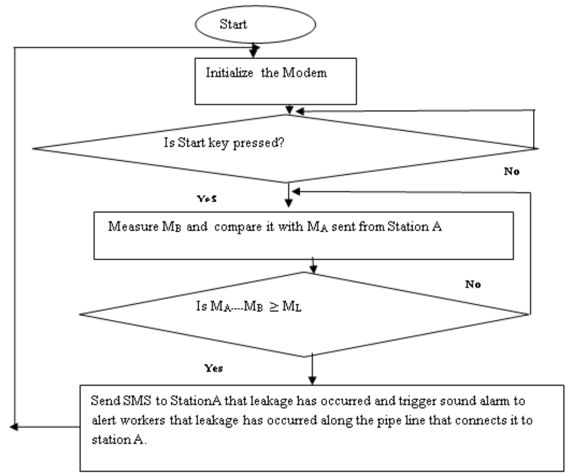

Fig. 6. Flow control at Flow station B.

III. METHODOLOGY

Having successfully completed the design as shown above, the actual implementation is to be done here. It involves the integration of the different components (modules) of the system to achieve the complete working system [21-27, 28, 29, 30 - 41].

Using the structure in Fig. 7 and equations 3.1 to 3.4, the model for the leakage detection was developed.

$$Mi = Mo + Ml \qquad \text{Eq. 3.1}$$

Where, Mi = Inlet mass flow rate

Mo = Outlet mass flow rate

Ml = Mass flow rate loss due to the pipeline Length (L), Cross Sectional Area (A), Density of the fluid flowing through the pipeline (ρ) at a given time (t).

$$Ml = \frac{LA\rho}{t}. \qquad \text{Eq. 3.2.}$$

$$Mi = Mo + LA\rho/t \qquad \text{Eq. 3.3}$$

$$Mi - Mo = LA\rho/t \qquad \text{Eq. 3.4}$$

Hence, for $Mi - Mo \leq LA\rho/t$, it is a normal condition.

For the experiments carried out at the implementation stage of this work, the under listed results were obtained for the mass flow rates at flow stations A and B with time interval of 10 minutes at L=1m

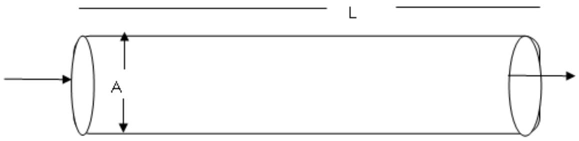

Fig. 7. Pipeline Model for Leakage detection

NB: For pipeline lengths below 1KM, Mi-Mo is very negligible and is assumed to be zero (Continuity equation). Two experiments were performed with different lengths of pipelines with the same cross-sectional area and dual-purpose kerosene (DPK) flowing through the plastic pipes as shown in table 3. However, Mi-Mo>LAρ/t means that leakage has occurred.

Table 1: Experiments with pipeline lengths of 1m and 1000m with Dual purpose Kerosine (DPK) as the fluid.

Tests	Length(m)	Area(m^2)	Tolerable Threshold M_L(kg/s)
1	1	0.00196	0.0027
2	1000	0.00196	2.7

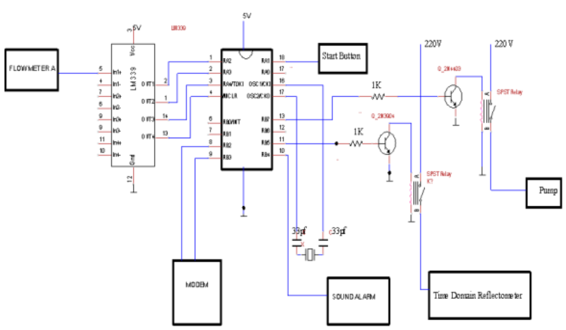

Fig. 8. Circuit diagram of Flow station A

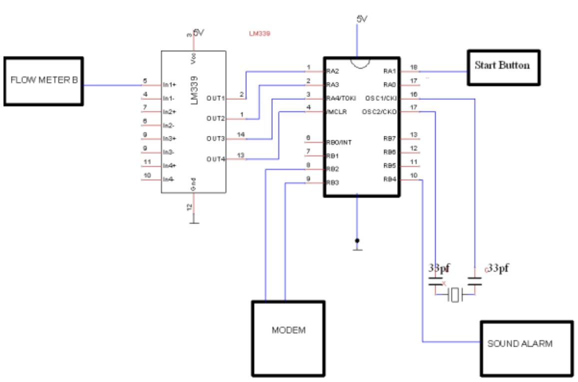

Fig. 9. Circuit diagram of flow station B

IV. RESULTS AND DISCUSSIONS

For the first experiment, a cut is made on the pipeline to introduce a leak between the 6th and 7th interval, hence, flow station B alerts Flow station A and the later turns off the pump. It took extra 30 minutes for the pipeline content to be emptied as shown in Table 1.

Table. 1. Mass Flow rates at Flow stations A and B over a given time interval for L = 1m.

Mass Flow Rate at Flow Station A (M_A) kg/s	Mass Flow Rate at Flow Station B(MB) kg/s	Time Interval (Minutes)
10	10	10
10	10	20
10	10	30
10	10	40
10	10	50
10	10	60
10	8	70
6	6	80
4	4	90
0	0	100

Table. 2. Mass Flow Rates at Flow Stations A and B over a given time interval for L = 1000m

Mass Flow Rate at Flow Station A (M_A) kg/s	Mass Flow Rate at Flow Station B (M_B) kg/s	Time interval (Minutes)
10	9	10
10	8.5	20
10	8.5	30
10	8	40
10	8	50
10	7.5	60
10	7	70
6	6	80
4	2	90
0	0	100

From Table.2 above, the first reading at flow station B experienced a difference of 1kg/s from the corresponding value at flow station A and subsequent readings had such experience but the leakage alarm was not activated until the difference between them becomes higher than the tolerable threshold $M_L = 2.7$. Hence, a change between M_A and M_B cannot be considered as a leakage until the change becomes higher than the M_L. A leak was introduced between the 6th and 7th interval by giving a cut to the pipeline and the mass flow rate at flow station B became 7kg/s and using $M_L = 2.7$kg/s, the change between M_A and M_B = 3kg/s which is greater than the M_L. Hence, the flow station B sends an short message services (Sms) to flow station A that leakage has occurred and the later turned off the pump. Both M_A and M_B decrease steadily to zero. Both flow stations also alerted their workers of leakage using sound alarm. Figures 10, 11, 12, 13, 14, 15 and 16 showed the different conditions of the flow rates at stations A and B under normal and leakage conditions.

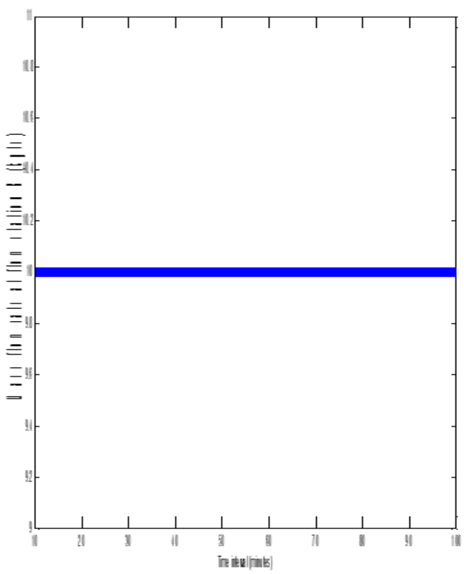

Fig. 10. Mass flow rate at flow station A over a given time interval under normal condition

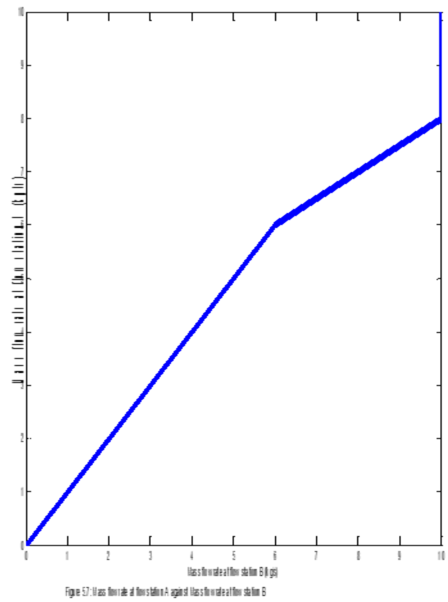

Fig. 11. Starting pump at station A until the pumps full capacity reaches station B

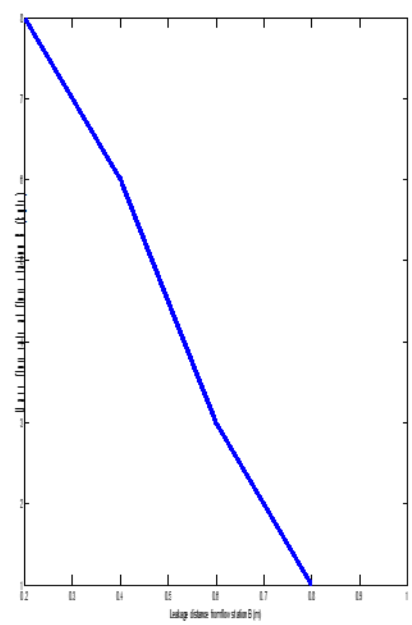

Fig. 12. Relationship between mass flow rate at flow station B and leakage distance from flow station B

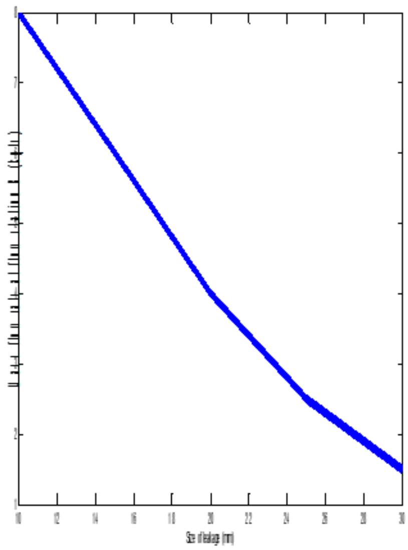

Fig. 13. Relationship between mass flow rate at flow station B and the size of leakage

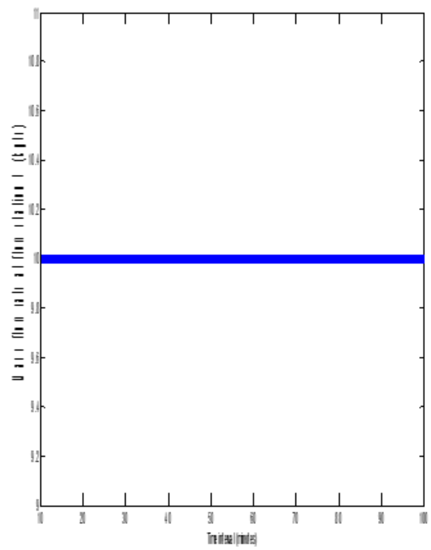

Fig. 15. Steady mass flow rate within tolerable threshold between stations A and B.

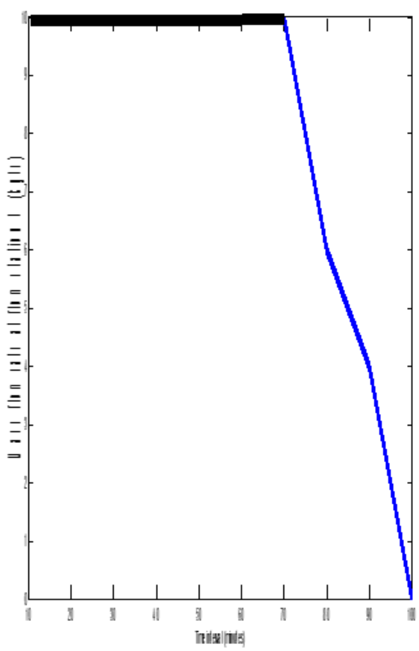

Fig. 14. Leakage recorded at the 60th minute by station B with L=1m

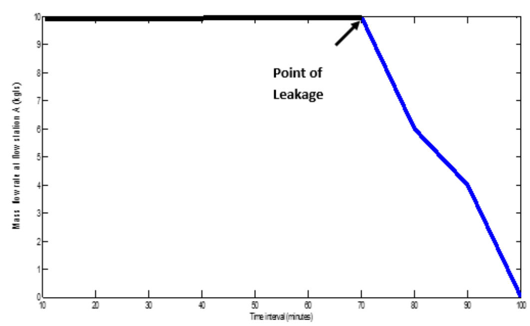

Fig. 16. Leakage recorded between the 60th and 70th minutes by station B with L= 100m

CONCLUSION

The above two results have shown that the modified continuity equation with tolerable threshold M_L as a model when employed in the oil and gas industry will not give a false alarm of leakage simply because of the difference between mass flow rates at flow stations A and B unless the difference is greater than tolerable threshold for the given length of pipeline. This will eliminate the incidence of false alarm in oil leakage detection. Hence, this project will ensure timely and real time based oil leakage detection without false alarm.

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