Sacrificial Anode Cathodic Protection Remote Monitoring And Control Using Labview And Micaz Motes

Prof. Dr. mohammed zeki Al–faiz
Department of Computer Engineering, **AL-Nahrain University Baghdad, Iraq**
Email: mzalfaiz12@gmail.com

Eng. Liqaa saadi mezher
Department of Computer and Software Engineering, **AL-Mustansiriya University, Baghdad, Iraq**
Email: liqaa14@gmail.com

Abstract :

The Cathodic Protection system (CP) is used for the monitoring system of oil pipeline via Wireless Sensor devices to prevent corrosion. In this paper the use of Sacrificial Anode Cathodic Protection (SACP) system was presented and how they can be developed to prevent the corrosion. The aim of developing a CP system is to provide control over oil pipelines and to reduce the incidence of corrosion. The proposed system integrates the technology of Wireless Sensor Network (WSN) in order to collect potential data and to realize remote data transmission. Three cases had been studied, the first case is a normal situation when there is not find any problem in oil pipeline, the second case is in the event of a malfunction in the values of voltage by a simple increase or decrease in this case possible controller by the observer in the remote control room. The third case is in the event of a serious defect in the pipe and be output either smuggling operation or malfunction in the anode. Each one of the three studies cases use nine Wireless Sensors (WS's), three Remot Terminal Units (RTU's) and one Base Station (BS). LabVIEW 2010 program was used as the tool to build the simulation environment. Two algorithms are proposed of WSN, the first algorithm apply of WS's side while the second algorithm apply of BS side. The simulation results of this technique with the proposed show that it has least time delay, high speed, low power, and the find corrected location of the WS determined.

Keywords: Sacrificial Cathodic Protection System, Corrosion, Wireless Sensor Network, MicaZ motes, MIB520, Remote Terminal Unit.

مراقبة والسيطرة عن بعد بأستخدام منظومة الحمايه الكاثودية و اجهزة MicaZ Motes وبرنامج لاب فيو

أ.د. محمد زكي الفائز
قسم هندسة الحاسوب ، جامعه النهرين
أيميل mzalfaiz12@gmail.com

المهندسة لقاء سعدي مزهر
قسم هندسة الحاسبات والبرمجيات ، جامعه المستنصرية
أيميل liqaa14@gmail.com

الخلاصة :

منظومة الحماية الكاثودية (CP) أستخدمت لمراقبة خطوط انابيب النفط عن طريق أجهزة المتحسسات اللاسلكية لمنع التآكل. في هذا البحث ،تم استخدام نوع منظومة الحماية الكاثودية الكلفانية (SACP) وتبيان كيف يمكن تطويرها لمنع التآكل. والهدف من تطوير نظام الحماية الكاثودية هو توفير السيطرة على خطوط أنابيب النفط والحد من حدوث التآكل. النظام المقترح هو دمج تكنولوجيا شبكة المتحسسات اللاسلكية (WSN) مع منظومة الحماية الكاثودية من أجل جمع البيانات المحتملة وتحقيق نقل البيانات عن بعد. درست ثلاث حالات، الحالة الأولى هو الوضع الطبيعي عندما لا يكون هناك أي مشكلة في خط أنابيب النفط، والحالة الثانية هي في حالة وجود خلل في قيم الجهد عن طريق زيادة أو نقصان بسيط، في هذه الحالة يمكن التحكم بواسطة المراقب في غرفة التحكم عن بعد. الحالة الثالثة هي في حالة وجود خلل خطير في أنابيب خطوط النفط ويكون الناتج إما عن عملية تهريب أو عطل في الأنود. في كل الدراسات الثلاثة تم استخدام تسعة أجهزة من المتحسسات اللاسلكية (WS) وثلاث وحدات للمحطة الطرفية (RTU) ومحطة رئيسية واحدة (BS). و تم استخدام محاكاة لاب فيو الاصدار 2010 بوصفها أداة لبناء بيئة المحاكاة. تم أقتراح خوارزميتان في WSN، الخوارزمية ألاولى تم تطبيقها في جانب WS والخوارزمية الثانية تم تطبيقها في جانب ال BS. وكانت نتائج المحاكاة لهذه التقنية مع الخوارزميات المقترحة بأن لديها أقل وقت تأخير، وسرعة عالية لايصال البيانات، وأقل طاقة، وتحديد الموقع الصحيح للجهاز اللاسلكي ومكان حدوث التأكل في الانبوب.

1. Introduction

Cathodic protection is an electrochemical repair technique that has increasingly been used for the repair of reinforced concrete structures in the UK and worldwide [1].

It is interesting that the first large scale application of CP by Davy was directed at protecting copper rather than steel. It is also a measure of Davy's grasp of the topic that he was able to consider the use of two techniques of CP, namely sacrificial anodes and impressed current, and two types of sacrificial anode, namely zinc and cast iron [2].

The principle of CP is to connect an external anode to the metal to be protected and to pass a positive DC current between them so that the metal becomes cathodic and does not corrode.

CP has become a standard procedure for many structures such as underground storage tanks, pipelines, water storage tanks, ship hulls and interiors [3].

Corrosion is an electrochemical process that involves the passage of electrical currents on a micro or macro scale.

The advantage of the SACP is esay to install, minimum of maintenance required, minimum of cathodic interferences problems, no regulation is required, nodes can be readily added, uniform distribution of current [4], independant of any source of electrical power, due to the fact that the protective current is generated by the electrochemical reaction between the metals [5].

The disadvantage of the SACP is small driving voltage available, the limited driving potential between the structure and the anode materials used, poorly coated structures may require many anodes, can be ineffective in high resistivity environments, installation can be expensive if installed after construction [4].

The field of WSN is gaining a rapid interest due to the application of low cost long battery life WS's. Usually WSN consists of the WS's as end devices, routers to choose the most appropriate path to an administrator host that is called RTU and BS to be monitor.

Many papers studied this problem [6,7], in these paper cathodic protection systems were discussed for water storage tanks, periodically tested, using voltmeter devices to measure the voltage between the poles.

Also studied this problem [8], used another method of CP is called Impressed cathodic Protection (ICCP) and also used voltmeter devices to measure the voltage value. While this paper proposed the wireless sensor device use instead of voltmeter device.

In this paper, a method was suggested handling the problem by CP for WSN and also used Labview simulator version 2010 for simulated this method.

2. Wireless Practical Implementation Specification

2.1 Hardware Specifications

Sensor network devices, called motes, are manufactured by companies such as Intel, Crossbow, Dust Networks, Millennial Net, Arch Rock, Ember, Sun Microsystems, and others. We had access to Crossbow MicaZ motes, including sensor boards and programming boards. The MicaZ, as shown in **Figure. (1)**, specifications are as follows [9]:

- IEEE 802.15.4, tiny, wireless measurement system.
- Designed specifically for deeply embedded sensor networks.
- 250 kbps, high data rate radio.
- Wireless communications with every node as router capability.
- Expansion connector for light, temperature, RH, barometric pressure, acceleration/seismic, acoustic, magnetic, and other Crossbow sensor boards.

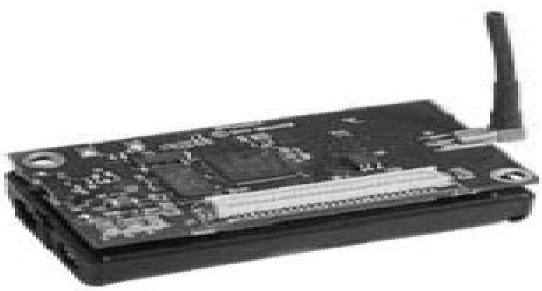


Fig . (1) MicaZ Mote

MIB520 Programming board specifications, as shown in **Figure. (2)**:

- Base station for wireless sensor networks via standard MICA2 processor radio board.
- USB serial port programming for all MICA hardware platforms.

Fig. (2) MIB520 Programming Board

The MIB520 offers two separate serial COM ports: one dedicated to ISP and a second for data communication over USB to the monitoring computer. The MIB520 is used for two main functions: a mote programming and as a gateway.

2.2 Xserve program

One important programs that are used to obtain the data from the devices via multiple channels, which this program receives data from the WS and displays the results.

2.3 LabVIEW Program

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphical programming language developed by National Instruments. LabVIEW integrates data acquisition, analysis and presentation in one system.

3. The Suggested SACP for Monitoring System

The network architecture design consists of a wireless sensor node, a gateway (RTU) and BS. Sensor side is responsible for monitoring the physical environment placed at the lowest level of the hierarchy. The gateway received the data packet and forwards them to the BS to be monitored, as shown in **Figure. (3)**.

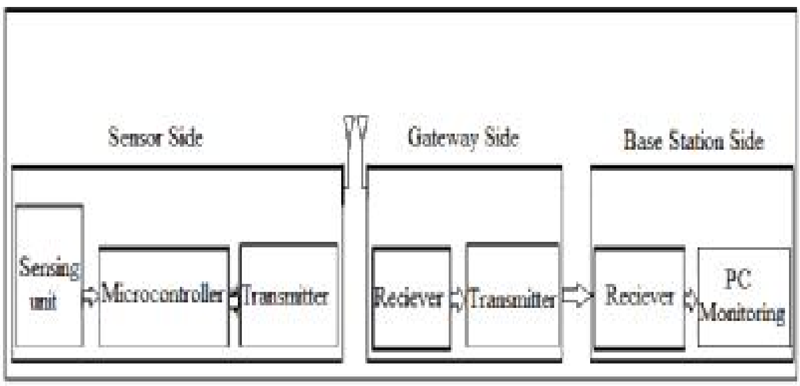


Fig.(3) Block Diagram of Proposel Network Architecture

In practical, the proposed network of the oil pipeline used length of 18 km and it consists of nine WS's devices, the distance between each two WS is 2 km. The WS was used instead of the voltmeter for CP, where connected these devices with the parties to the anode and cathode of cathodic protection, then installed these devices on the ground at a distance of one meter from the Oil pipeline, and the distance between two WS is 2km. The work of these devices is to collect data in the form of an analog signal and convert them into a digital signal, and sent it to the RTU. After gathering information from all wireless sensor devices, all the RTU stations send them to the base station to monitor and test data so it will give the result to the monitoring form. Each three WS's send their measured information to the one RTU and the later send the collected data to the BS. Each RTU contents three WS's devices, as shown in Figure. (4). The distance between the RTU and the WS is 50 km. When any problem occurs in RTU, the WS will search about near RTU which depends on distance (in which the WS sends data to WS in another RTU) after the RTU collected data from WS, then it forwards to BS. The distance between each RTU and the BS is 50 km, in which the total distance between the BS and WS devices is 100 km.

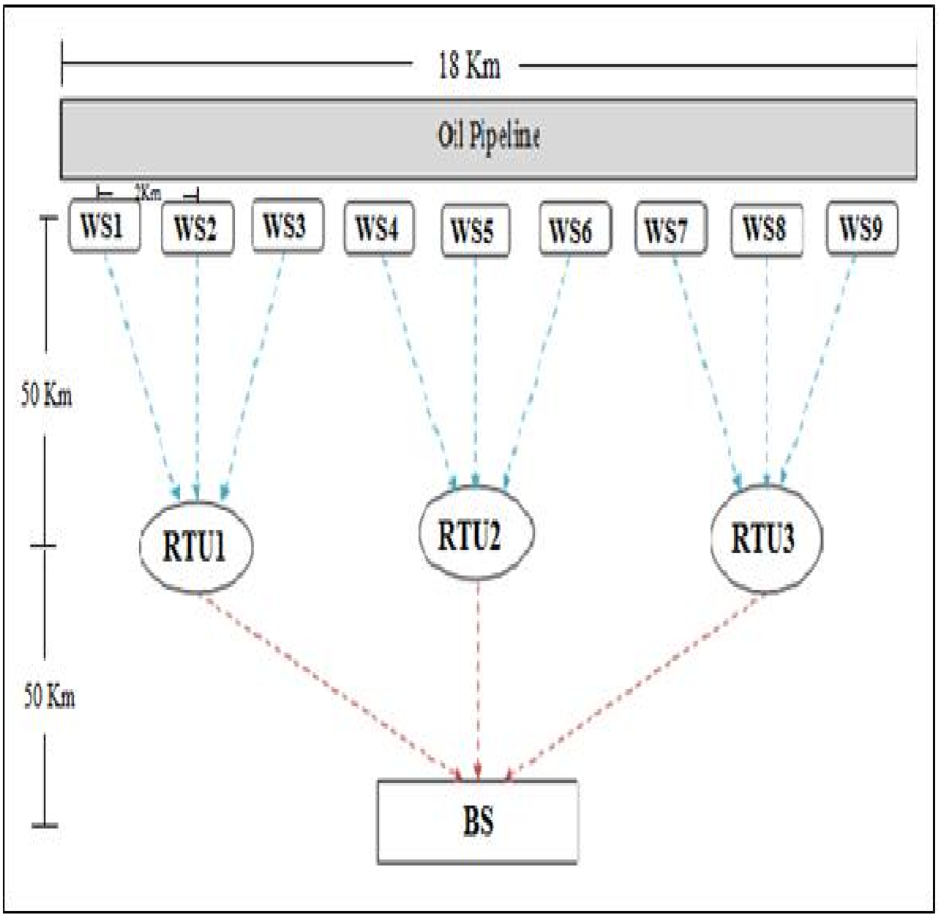


Fig. (4) Block Diagram of The Proposed Network Architecture Designed for Data Acquisition

4. Case Study

The WS used type MDA100CB mote with IRIS mote and used the gateway type MIB 520 mote with IRIS mode and BS represent by PC for monitoring. In all cases depends on Saturated Calomel Electrode (SCE), the SCE is standard rules of CP, as shown in **Figure. (11).** In SCE the range of normal case between (-1.7,-0.85) V, the range of warning case between (-0.85,-0.25) V and the range of alarm case is greater than (-0.25) V or is least than (-1.7) V. This WS collected data from the physical environment and sends it to RTU's and then the RTU's forwards data to the BS in order to conduct testing and monitoring them by using the Lab VIEW simulation program version 2010,as shown in **Figure. (10).**

5. Simulation & Result

In LabVIEW applied many cases. It is assumed to analyze the sending measurement reading for the while network to identify the pipeline status. Each case use nine WS's, three RTU's and a BS to be monitored.

5.1 Result for Xserve Program

BS receives the data from RTU's via USB port (MIB520), this port contents many channel explained before. Read the value of data from the channel of this port by Xserve program, as shown in the **Table (1).**

Table (1) Base Station Data from all Wireless Sensor Network with update (Voltage in V)

Time	RTU1			RTU2			RTU3		
	WS1	WS2	WS3	WS4	WS5	WS6	WS7	WS8	WS9
12:00AM	-0.91	-0.89	-0.9	-0.92	-0.9	-0.89	-0.88	-0.89	-0.88
1:00AM	-0.93	-0.92	-0.89	-0.91	-0.92	-0.91	-0.91	-0.89	-0.89
2:00AM	-0.91	-0.89	-0.92	-0.93	-0.91	-0.94	-0.93	-0.92	-0.91
3:00AM	-1.02	-0.78	-0.97	-0.91	-0.9	-0.89	-0.9	-0.89	-0.87
4:00AM	-0.99	-0.78	-0.93	-0.89	-0.88	-0.88	-0.89	-0.88	-0.88
5:00AM	-0.98	-0.78	-0.92	-0.88	-0.89	-0.89	-0.88	-0.87	-0.86
6:00AM	-0.93	-0.89	-0.89	-0.63	-0.9	-0.88	-0.89	-0.88	-0.87
7:00AM	-0.89	-0.91	-0.88	-0.63	-0.89	-0.88	-0.87	-0.87	-0.86
8:00AM	-0.95	-0.93	-0.89	-0.63	-0.92	-0.91	-0.9	-0.88	-0.87
9:00AM	-0.93	-0.97	-0.93	-0.92	-0.91	-0.9	-0.92	-0.91	-0.9
10:00AM	-0.96	-0.95	-0.92	-0.91	-0.9	-0.89	-0.89	-0.88	-0.87
11:00AM	-0.95	-0.94	-0.91	-0.9	-0.89	-0.88	-0.9	-0.89	-0.88
12:00PM	-0.93	-0.89	-0.89	-0.88	-0.89	-0.88	-0.87	-0.87	-0.86
1:00PM	-0.9	-0.88	-0.87	-0.87	-0.86	-0.36	-0.89	-0.89	-0.88
2:00PM	-0.89	-0.87	-0.86	-0.87	-0.86	-0.36	-0.87	-0.86	-0.86
3:00PM	-0.9	-0.89	-0.88	-0.87	-0.87	-0.36	-0.89	-0.88	-0.87
4:00PM	-0.89	-0.9	-0.89	-0.88	-0.88	-0.87	-0.88	-0.89	-0.88
5:00PM	-0.88	-0.89	-0.91	-0.88	-0.87	-0.88	-0.87	-0.87	-0.86
6:00PM	-1.8	-0.89	-0.89	-0.89	-0.88	-0.87	-0.88	-0.88	-0.87
7:00PM	-1.8	-0.91	-0.9	-0.88	-0.89	-0.89	-0.9	-0.89	-0.88
8:00PM	-1.8	-0.94	-0.92	-0.9	-0.88	-0.87	-0.88	-0.86	-0.86
9:00PM	-0.96	-0.95	-0.94	-0.92	-0.91	-0.88	-0.87	-0.87	-0.87
10:00PM	-0.95	-0.94	-0.93	-0.91	-0.9	-0.89	-0.88	-0.88	-0.86
11:00PM	-0.94	-0.92	-0.91	-0.9	-0.9	-0.89	-0.89	-0.88	-0.88
12:00AM	-0.93	-0.92	-0.91	-0.9	-0.89	-0.89	-0.88	-0.87	-0.86

5.2 LabVIEW Resualt

1. Normal Case

The BS reads the measured information from file and testing , if the value obtained from the WS is between the range (-1.70 to -0.85) V, as shown in Fig. (5) this means that no problem in the oil pipeline and any WS's, which the oil pipe line is coated, protected and activated, it is called normal case.

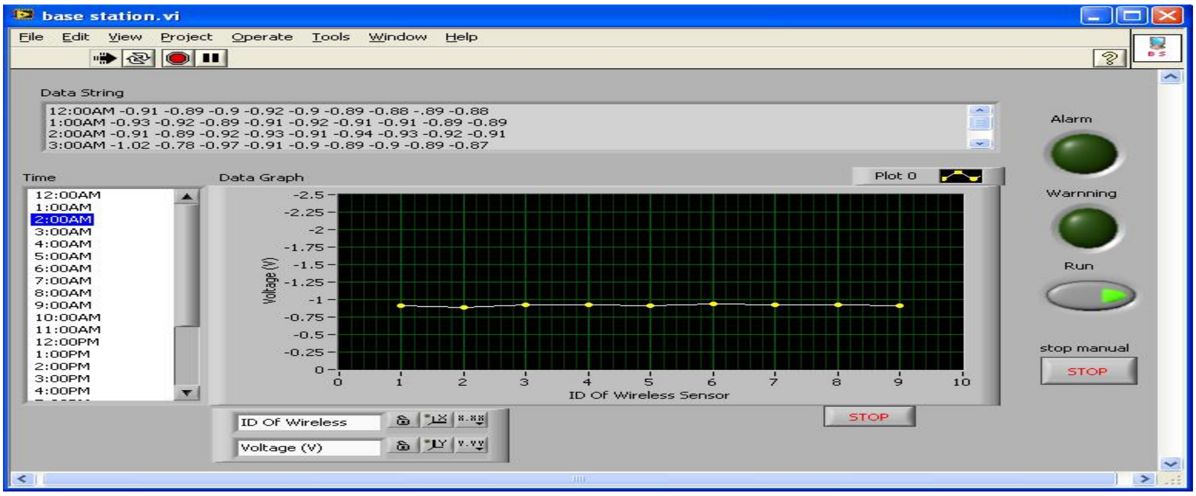


Fig. (5) Normal case study in the BS Front Panel

2. Warning Case

The second case when the value of WS is between the range (-0.85 and -0.25). The first condition of warning when the value obtained from the WS is the range (-0.85 to -0.65) V. In this condition, it found from the time 3:00 AM to 5:00 AM of WS2, this means that the value repeated in three loops continues in the same WS2, then the program stop reading and display message presents the case, as shown in **Figure. (6).** The message display is "the pipe line is coated, unprotected and it is liable to corrosion". When the user read this message can be this problem solved by increases the voltage value. After corrected the value the program return read another value from WS.

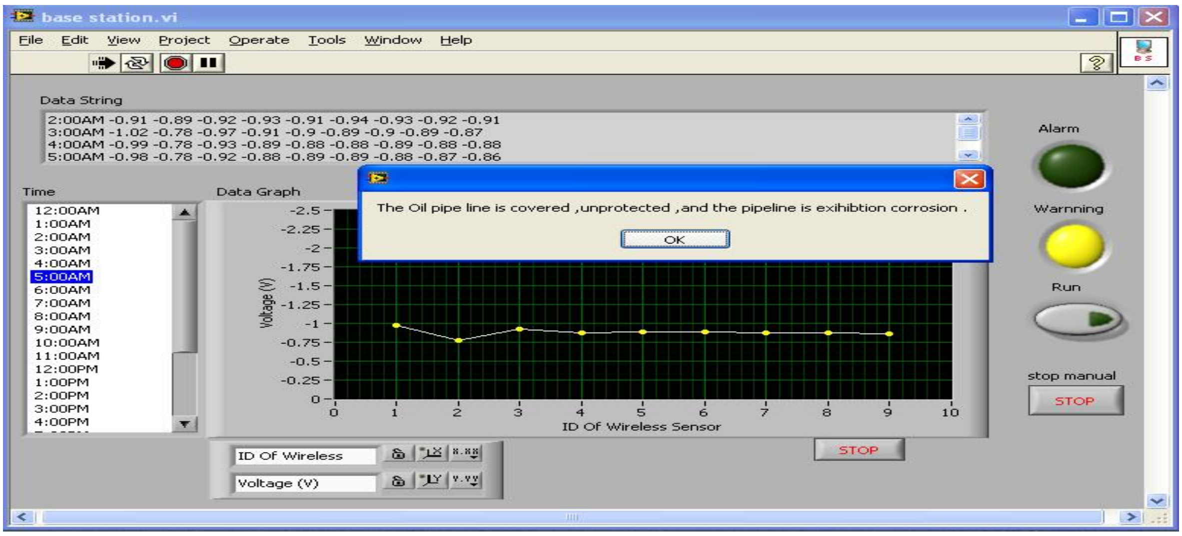


Fig. (6) Warning case study 1 in the BS Front Panel

The second condition of the same second case, if the value obtained from the WS is between the range (-0.65 and -0.45) V. This value found, from time 6:00 AM to 8:00 AM of

WS4. Also checking if the value repeated in three loops continues, then the program stop reading and display message presents the case. After corrected the value the program return to read another value from WS, as shown in **Figure. (7)**. This means that the pipe line is simple coated, unprotected and it is liable to corrosion.

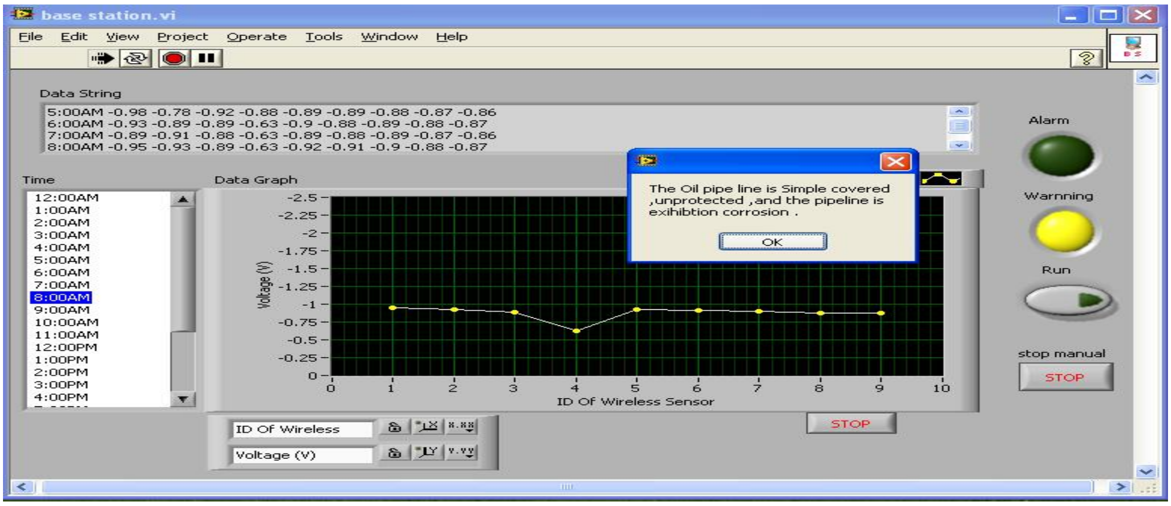


Fig. (7) Warning case study 2 in the BS Front Panel

The Third condition when the value obtained from the WS is between the range (-0.45 and -0.25) V. In this example, the value found from time 1:00 PM to 3:00 PM of WS6, this means that the oil pipe line is uncoated, unprotected (a reason for this either that the anode exhibit a corrosion or is disconnected) and it is liable to corrosion, as shown in **Figure. (8).**

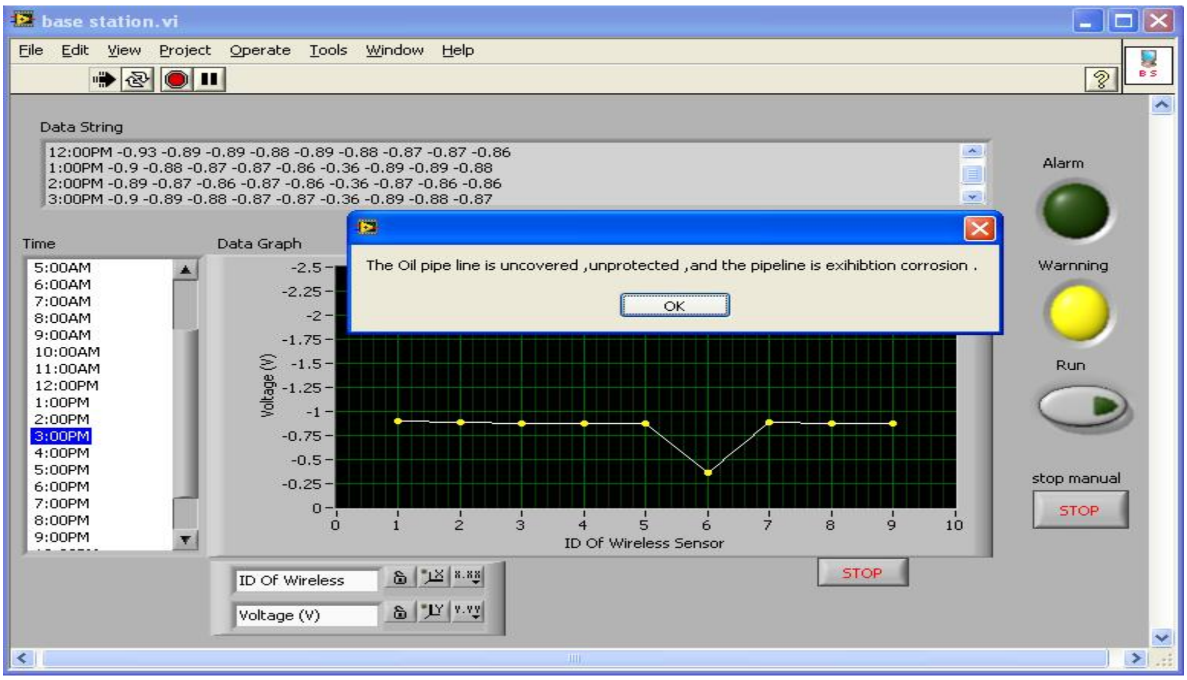


Fig. (8) Warning case study 3 in the BS Front Panel

a. Alarm Case

This case occurs when the value obtained from the WS is greater than -0.25V or is least than -1.7V. When the program read the value and it found this case, starting check if the value repeated in three loops continues, then the program stop reading and display the message. After correcting the value the program return read another value this means that the pipe line is uncoated, unprotected and it is corrosive, as shown in **Figure. (9)**.

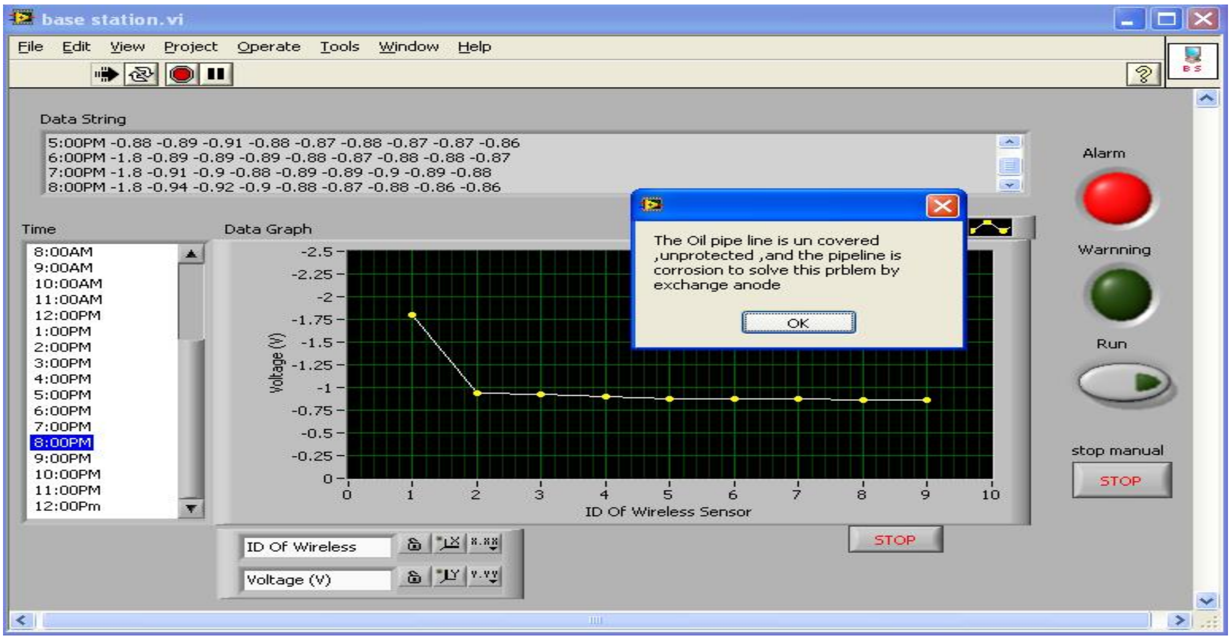


Fig. (9) Alarm case study in the BS Front Panel

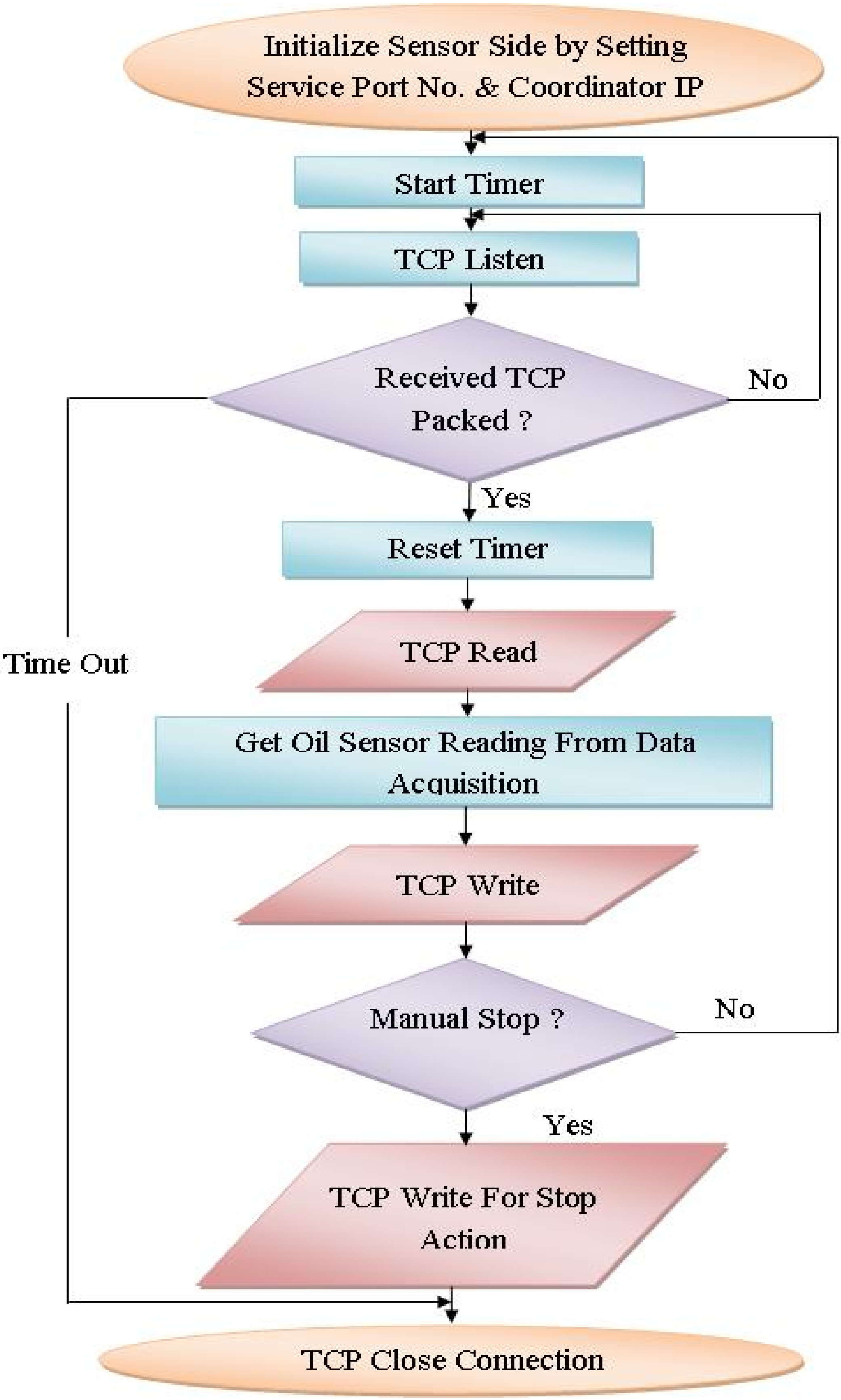
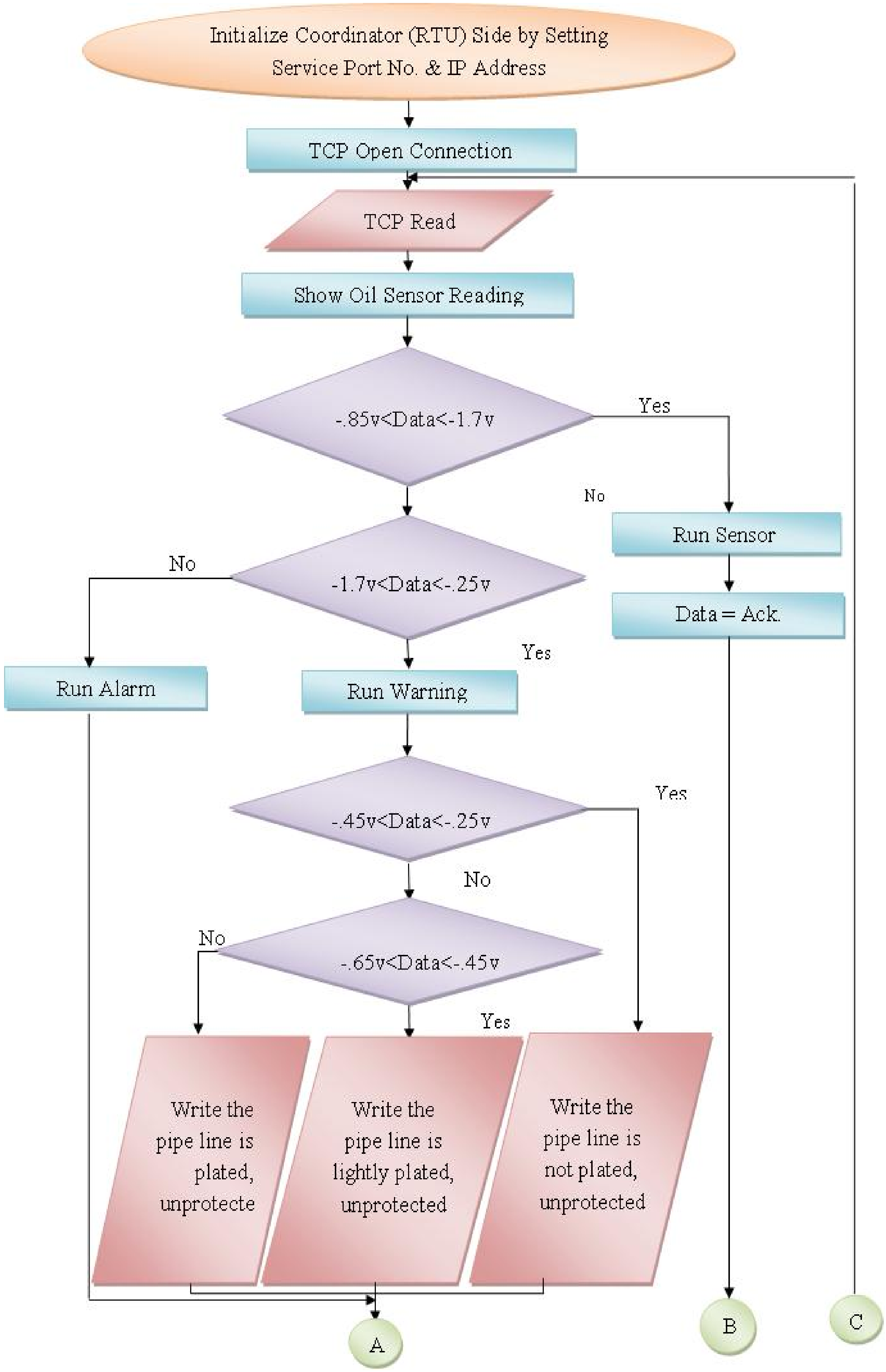


Fig. (10) Flow Chart of The Wireless Sensor Side



Initialize Coordinator (RTU) Side by Setting Service Port No. & IP Address
TCP Open Connection
TCP Read
Show Oil Sensor Reading
-.85v<Data<-1.7v
Yes
No
Run Sensor
Data = Ack.
No
-1.7v<Data<-.25v
Yes
Run Alarm
Run Warning
Yes
-.45v<Data<-.25v
No
No
-.65v<Data<-.45v
Yes
Write the pipe line is plated, unprotecte
Write the pipe line is lightly plated, unprotected
Write the pipe line is not plated, unprotected
A
B
C

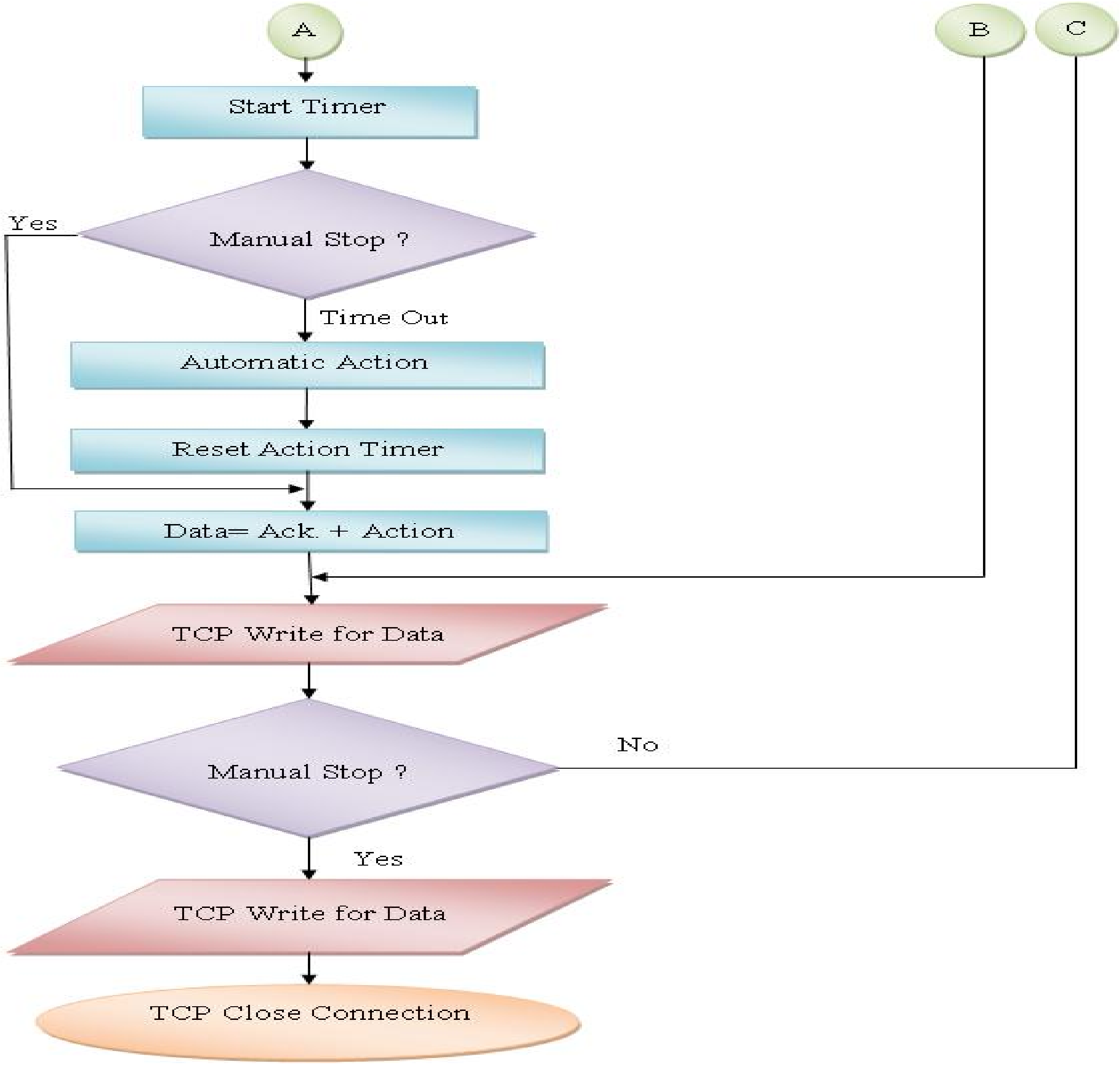


Fig. (11) Flow Chart of The Gateway Side

6. Conclusion

The conclusions are summarized as follows:

- The Cathodic Protection for monitoring system of oil pipeline was implemented for Sacrificial Anode type to prevent corrosion.
- Three cases had been studied, the first case called is normal case, when the data is between the range (-1.7 to -0.85)V. The second case is called warning case, when the data is between the between (-0.85 and -0.25)V. In this case can be corrected this problem by increases the voltage value by administrator monitoring in BS. The third case is called Alarm case, which is greater than (-0.25)V or is least than (-1.7)V. In this case when the message display in BS, we can sent administrator group to pipeline location.

- Apply Tree - Based method, gives maximum range and exactly location via using many WS’s (MicaZ motes devices (MDA100CB with IRIS motes) of WS’s) and gateways (MIB520 with IRIS motes) of RTU's. This method can be determined the corrected location of WS and RTU. Also can be determining the corrected location between RTU and BS.
- The data is forwarded through the shortest path length between the base station and the other nodes depended on this algorithm and the Member Forward List (MFL) algorithm.
- The Member Forward List (MFL) algorithm, gives high speed to find the suitable node for data forwarding. This property prevents the algorithm from repeating to find the forwarder node because always there are some nodes with different priority listed in the MFL.
- The WS’s use sleep mode, gives low power.

References

1. **K. Wilson, M. Jawed and V. Ngala, "The selection and Use of Cathodic Protection Systems for The repair of Reinforced Concrete Structures", Journal of Construction and Building Materials, pp. 19–25, 2013.**
2. **V. Ashworth, "Principles of Cathodic Protection", Elsevier B.V., Third Edition article 10.1, Vol. 2, pp. 10:3 – 10:28, 2010.**
3. **M. Z. AL-Faiz and L. S. Mezher, "Cathodic Protection Remote Monitoring Based on Wireless Sensor Network", Journal of scientific research - Wireless Sensor Network,Baghdad-Iraq, AL-Nahrain University, Vol. 9, No. 5, pp. 226-233, 2012.**
4. **M. Hafiz,” Modeling Of Pipeline Corrosion Control By Cathodic Protection”, Ph.D. Thesis, AL-Technology university, Baghdad, Iraq, September, 2006.**
5. **R. Johnsen, "Cathodic Protection", Inst. of Engineering Design and Materials, Trondheim, October, 2006.**
6. **J. Bushman,” Corrosion and Cathodic Protection Theory “, Bushman & Associates, Inc Medina, Ohio USA, 2010.**
7. **A. Kumar and L. D. Stephenson, “Comparison of Wireless Technologies for Remote Monitoring of Cathodic Protection Systems”, U.S. Army Corps of Engineers, Engineer Research and Development Center Construction Engineering Research Laboratory, P. O. Box 9005, Champaign, IL 61826-9005, 2007.**
8. **J. T. Al-Haidary, M. H. Hafiz and Y. M. Abdu Al-Sahib, “Galvanic Cathodic Protection Evaluation of a Steel Pipe in Iraqi Soil”, Eng. & Tech. Journal, Vol.29, No.9, 2011.**
9. **MICAz Datasheet, www.crossbow.com.**