APPLICATION OF A DEVELOPED SOFTWARE FOR SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

BY

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EEE/96/8506

SCHOOL OF POSTGRADUATE STUDIES,
THE FEDERAL UNIVERSITY OF TECHNOLOGY,
AKURE – NIGERIA

OCTOBER 2003

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A THESIS SUBMITTED TO THE ELECTRICAL AND ELECTRONICS ENGINEERING DEPARTMENT OF THE FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE – NIGERIA

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF ENGINEERING DEGREE IN ELECTRICAL AND ELECTRONICS ENGINEERING (CONTROL ENGINEERING OPTION) OF THE FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE. ONDO STATE, NIGERIA

OCTOBER 2003

CERTIFICATION

This project has been read and approved as meeting the required standard of the Department of Electrical and Electronics Engineering, The Federal University of Technology Akure, for the award of Master of Engineering in Electrical and Electronics Engineering (Control Engineering option).

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DATE

DEDICATION

This project is dedicated to the blessed Trinity-God the Father, God the Son and God the Holy Spirit and to those whom God has used in one way or the other to touch my life.

ACKNOWLEDGEMENT

" WHERE THERE IS A WILL, THERE IS A WAY"

Glory, Honour, Majesty, Adoration and Praise be unto the only wise God and my redeemer, Jesus Christ by whose grace I have come thus far.

I am short of words to express my unfeigned appreciation and gratitude to the under mentioned who contributed in no small measure towards the successful completion of this course.First,my Project Supervisor, Engr. (Dr.) A.C.T Briggs whose wealth of experience and professional guidance gave me the needed tonic to carry out the project.
My gratitude goes to Engr. (Dr.) V.S.A.Adeloye the Head of department, Electrical and Electronics Engineering for his understanding, useful advise and fatherly care. My beloved Engr. I. O Megbowon, you are precious to me and I will always thank God for using you to encourage me to pursue this course. Your statement to me -"Where there is a WILL, there is a WAY" – at the commencement of the course was my anchor throughout the course. To Engr. J.O. Oni, Engr. Y.O.Olasoji and my other departmental lecturers and colleagues, I say a big thank you.

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I am also grateful to my district Pastor Rev. M. A Folarin and his wife for their prayers and support and Franca Obasi, Teddy Visor and Eunice Isiguzor who painfully and carefully typed the manuscripts.

My precious and darling wife Deaconess (Mrs.) Victoria Ogidi-Olu and our loving children, who shared this vision with me, I say, I love you all. Finally, to the king eternal, immortal, invisible, the only wise God be praise and glory forever and ever. Amen.

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ABSTRACT

This Project aims at providing a Technical, time and cost saving, more efficient and less hazardous technique of either preventing or reducing significantly, Pipeline Vandalisation in Nigeria using the Supervisory Control and Data Acquisition (SCADA) Monitoring System. Oil and Pipelines leaks are a major problem. It has been estimated that as much as 17% of available fuel for consumption in Nigeria is lost through pipeline vandalisation, and NNPC (PPMC) spends millions of naira each year finding and repairing oil line breaks. The project is considered critically necessary and one that should go a long way in helping to solve the lingering problem of pipeline vandalisation in Nigeria.

In carrying out this project, Warri-Benin pipeline was used as case study. Computer software was developed with associated program written in visual basic code with Microsoft Access. Necessary flow charts were also developed to enhance simulation. Passing emulsified water through some pipes simulated the Operational pipelines. Remote Terminal Units (RTUs) with appropriate sensors were installed along the routes at 50 km intervals.

Intentional pipeline agitations were carried out with the purpose of disrupting flow at different points between the installed RTUs. The nearest RTU to the point of agitation, transduced, processed and transmitted the intentional act to the monitoring station. The received signal was procedurally processed and displayed on the Visual Display Unit (VDU).

The information displayed revealed codes of the RTUs along the affected routes, quantities of products transmitted and received, any discrepancies between the two quantities and the two consecutive RTUs, one immediately before and the other immediately after the location of fault. Where there is any appreciable discrepancy the nearest NNPC (PPMC) location to the indicated RTU nearest to the fault is immediately contacted for necessary actions.

Thus SCADA has been used to monitor, locate, prevent or reduce pipeline vandalisation. Recommendation for further application has also been made.

DEFINITION OF TERMS AND ABBREVIATIONS

SCADA	Supervisory Control and Data Acquisition
RTU	Remote Terminal Unit
PPMC	Pipelines and Products Marketing Company
PMS	Premium Motor Spirit (Petrol).
DPK	Dual Purpose Kerosene
AGO	Automotive gas oil (also called diesel)
ROW	Right Of Way
DCS	Distributed Control System
ZOH	Zero Order Hold
MTBF	Mean Time Before Failure
MTTR	Mean Time To Repairs
MW	Microwave
UHF	Ultra High Frequency
VHF	Very High Frequency
CPU	Central Processing Unit
I/O	Input/Output
RF	Radio Frequency
TX	Transmitter
ADC	Analog To Digital Converter
DAC	Digital To Analog Converter
TF	Transfer Function
MT	Metric Tones

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Government policy is to:

Supply petroleum products to the domestic market at minimal operating costs; provide excellent customer service by efficiently transporting crude oil to the Refineries and moving petroleum products to the market. Market special products competitively in the domestic and international markets. The Nigerian National Petroleum Corporation is mandated to effect government policy.

The vision is for NNPC- PPMC to be the dominant supplier of refined petroleum products to the existing domestic and growing export markets within the West African sub-region.
It is a common knowledge that as at today about 90% of the nations annual revenue comes from petroleum. This is to say that the country's economy strongly relies on this sector. To protect this industry is to therefore, protect the nations source of revenue and the economy. Effective transportation of crude oil to the Refineries for processing, supply and distribution of the petroleum products to customers constitute very vital aspects of PPMC Operations Network. It is important that crude oil gets to the Refineries as at when required and equally important that the white products get to the consumers promptly.

All over the world, transportation of crude oil and all its derivatives is carried out either by coastal vessel, rail wagons, road tankers or through the pipeline. Apart from the inter-continental transportation where the construction and operation of pipeline is logically difficult and the cost is albatross, transportation of petroleum using the pipeline system is the cheapest, Okpidi, (2001). The ratio of the cost of using the pipeline with the next cheapest means, the coastal vessel is 1:4 while the ratio to the highest means, the road tankers is 1:15

In the Nigeria National Petroleum Corporation, (NNPC) the Pipelines and Products Marketing Company (PPMC) is directly responsible for the transportation of crude oil to the two Refinery and Petrochemical companies at Warri and Kaduna (WRPC and KRPC). PPMC is also responsible for the transportation of all the refined petroleum products from all the nations Refineries at Warri, Kaduna and Port Harcourt to the existing twenty-two (22) depots spread across the nation. These refined petroleum products are, Premium Motor Spirit (PMS) popularly known as Petrol, Automotive Gas Oil (AGO) also called diesel and the Dual Purpose Kerosene (DPK) or the House Hold Kerosene (HHK), Meteke, (2001).

PPMC's installations are spread throughout Nigeria and some of them are inter-linked by a Network of Pipelines.
Presently, there are twenty- two (22) liquid fuel depots, two (2) offshore terminals, twenty – one (21) Pump stations and two (2) offshore storage tankers. To promptly and efficiently carry out its operations with a view to meeting the mission and vision of the company, PPMC transports crude and white products to meet the domestic demand through a Network of over 4,435 kilometers of multi-product pipelines and over 660 kilometers of crude oil pipelines (Fig.1.4), PPMC, (2000).

1.2 STATEMENT OF THE PROBLEM

The key functions of the Pipeline and Products Marketing Company (PPMC) is to provide excellent customer service by efficiently transporting crude oil to the Refineries and moving the refined petroleum products to the market. These services are expected to be delivered at minimal operating costs, PPMC, (1999).

About 14,000,000 MT of crude oil is supplied to the four (4) nation's Refineries at Warri, Port-Harcourt and Kaduna through the pipeline annually. An average of 18,000,000 MT of different grades of refined petroleum products comprising mainly of PMS, DPK and AGO is also supplied to the consumers mainly through the pipeline network. Movement of petroleum products through the pipeline is generally considered as one of the fastest, safest and cheapest means of transportation in custody transfer.

To effectively and efficiently distribute petroleum products nationwide, PPMC has in place twenty-two (22) liquid fuel depots, which are inter-linked by over 4,435 km of multi-product pipelines, storage tanks at the various depots, some booster pump stations as well as loading facilities for dispensing refined petroleum products into road tankers.

In normal operating conditions, marketers are expected to lift refined petroleum products from the depots nearest to them. The products are then taken to the retail outlets – the filling stations – where they are sold to the public. This situation ensures a fast and smooth distribution of petroleum products, availability of the products at all times as well as guarantees consumer comfort. But when pipeline leaks occur mainly due to pipeline vandalisation and are not promptly detected then the supply of products to the depots is truncated. The resultant effects are:

- Untold hardship on the masses due to fuel scarcity
- The masses economic life becomes paralyzed
- Environmental pollution and degradation.
- High downtime and man-hour losses
- High risks and overhead costs of road tankers having to travel some hundreds of kilometers to lift products. For example, a road tanker going from Maiduguri to Warri or Port-Harcourt to bridge product will take days.
- Colossal loss of revenue.

1.3 SYMPTONS OF THE PROBLEM

1.3.1 SCARCITY OF PRODUCTS

There is a set minimum product sufficiency level for each PPMC Operations zone in the country. This is to ensure adequate product supply to all areas. Any level below this limit will definitely result in scarcity of fuel. The Oil Movement department of PPMC ensures that the set limits are maintained on daily basis by setting out a well-articulated product supply programme. This programme becomes disrupted and disorganized whenever there is a line break caused by vandals because it becomes impossible to move products from areas of surplus (the Refining points) to areas of need (the depots) where the road Tankers can load and transport the products to filling stations where they are sold to the consumers-the public.

Pipeline Vandalisation is one of the major causes of scarcity of fuel and because there is no effective way presently put in place to monitor these pipelines, such dastardly and nefarious activities continue to escalate. This is a problem that needs to be solved.

1.3.2 HIGH LOSS OF PRODUCTS AND REVENUE

The colossal loss of products and revenue annually as a result of pipeline vandalisation is summarized in Table 1. An estimated cumulative total of about 420million litres of the different grades of products costing a whopping sum of about ₦11 billion was lost from about 870 No. of pipeline vandalisation recorded in just one year.

Table 2 also shows the breakdown of a staggering sum of ₦51, 225,000 expended on repairs of line breaks mostly caused by vandalisation (Figs.1.1&1.2). This is a colossal waste of resources. The serious effect that this ugly trend has on the nations economy and revenue generation cannot be over-emphasized (Table 3).

1.3.3 HIGH DOWN TIME / MAN-HOUR LOSSES

Pipeline vandalisation accounted for the highest number of downtime / Man-hour losses in PPMC Operations. From Table 4, it can be seen that a total of 18, 242 hours down time / Man hour losses recorded in a year was as a result of pipeline vandalisation (Fig.1.3). This abnormal situation has a negative effect on the operations of PPMC.

1.3.4 ENVIRONMENTAL POLLUTION AND DEGRADATION

When oil spillages occur, before the leakage is eventually detected and repairs carried out; the oil is absorbed into the surrounding soil, thereby saturating the soil. This results in serious pollution of the environment, the soil and the under ground water. The resultant effect is that the polluted soil becomes unfit for crop cultivation while the water also becomes unfit for drinking and fishing.

1.4 PROJECT OBJECTIVES

The effectiveness of a system is determined by the useful output produced, Okpidi, (2001). The inability to deliver crude oil to the Refineries promptly, and refined petroleum products to the consumers at minimal cost falls outside the vision and mission of PPMC. The efficiency and output of PPMC is therefore, measured by the availability of products and absence of queues at the filling stations.

The general objective of this project is to develop control software to detect faults along NNPC pipelines using the Supervisory Control and Data Acquisition (SCADA) System.

The specific objectives are to: -

- Develop control software.
- Use the software to detect faults along NNPC pipelines.

1.5 SCOPE OF STUDY.

This study is limited to the Pipeline and Products Marketing Company pipeline operations network in Nigeria.

1.6 EXPECTED CONTRIBUTION TO KNOWLEDGE

The developed software applied with SCADA will provide a technique that is time and cost saving, highly efficient and less hazardous than the existing ones used for monitoring pipelines.

1.7 METHODOLOGY

In carrying out this research, the Warri-Benin pipeline was used as case study. Computer software was developed with associated control program written in Visual Basic code (Version 6 - Enterprise edition) operating on the Microsoft Access 2000 platform. Necessary flowchart that will enhance simulation was developed.

Passing emulsified water through some pipes simulated the operational pipelines. Remote Terminal Units (RTUs) with appropriate sensors were installed along the routes at 50km intervals. Intentional pipeline agitations were carried out with the purpose of disrupting flow at different points between the installed RTUs. The nearest RTU to the point of agitation, transduced, processed and transmitted the intentional act to the monitoring station. The received signal was procedurally processed and displayed on the Visual Display Unit (VDU). The information displayed revealed codes of the RTUs along the affected routes; quantities of products transmitted and received, any discrepancies between the two quantities and the two consecutive RTUs before and after the location of fault. Where there is any appreciable discrepancy, the nearest NNPC-PPMC station to the location of fault is immediately contacted for necessary actions.

1.8 ORGANISATION OF THE WORK

For easy reference, this write up has been divided into five sections. In the introduction chapter, a brief description of the problem is given as well as the objectives of the work and the method employed. Description of the SCADA system and the component parts is given in chapter two. Modeling the SCADA system with the system flowchart was dealt with in chapter three. Chapter four deals with the system development, application and test results. And finally, conclusion and recommendation is in chapter five.

Table 1 Comparative Analysis Of Product / Financial Losses As A Result Of Pipeline Vandalization. (Source: PPMC Annual Reports)

S/N	Location	Total No. Of Pipeline Breaks	Quantity Of Product Loss	Value ₦	Total No. Of Pipeline Vandalisation	Quantity Of Product Loss Litres	Value ₦
1	MOSIMI AREA	14			32	1,500,000	65,000,000
2	KADUNA AREA	1	16,321 BBL	57.5M	2	3,666,814	95,337,164
3	P/H AREA	72			661	314,092,000	8,166,392,000
4	WARRI AREA	20			175	100,000,000	2,600,000,000
5	GOMBE AREA	1	10,000 litres	260,000	Nil	10,000 Lit	260,000
6	**TOTAL**	108			870	419,268,814	**11,080,597,164**

Table 2 Records Of Pipeline Leaks Due To Natural Failure And Vandalisation In PPMC Pipeline Network With The Cost Of Repairs In One Year. (Source: PPMC Year 2000 Operations Report)

S/N	Location	Line breaks due to pipeline failure	Line breaks due to vandalisation	Total line breaks	Estimated cost of repairs (₦)
1	Mosimi Area	14	32	46	12,955,000
2	Kaduna Area	1	2	3	7,480,000
3	P/H Area	72	661	733	21,990,000
4	Warri Area	20	175	195	7,800,000
5	Gombe Area	1	NIL	1	1,000,000
6	TOTAL	108	870	978	51,225,000

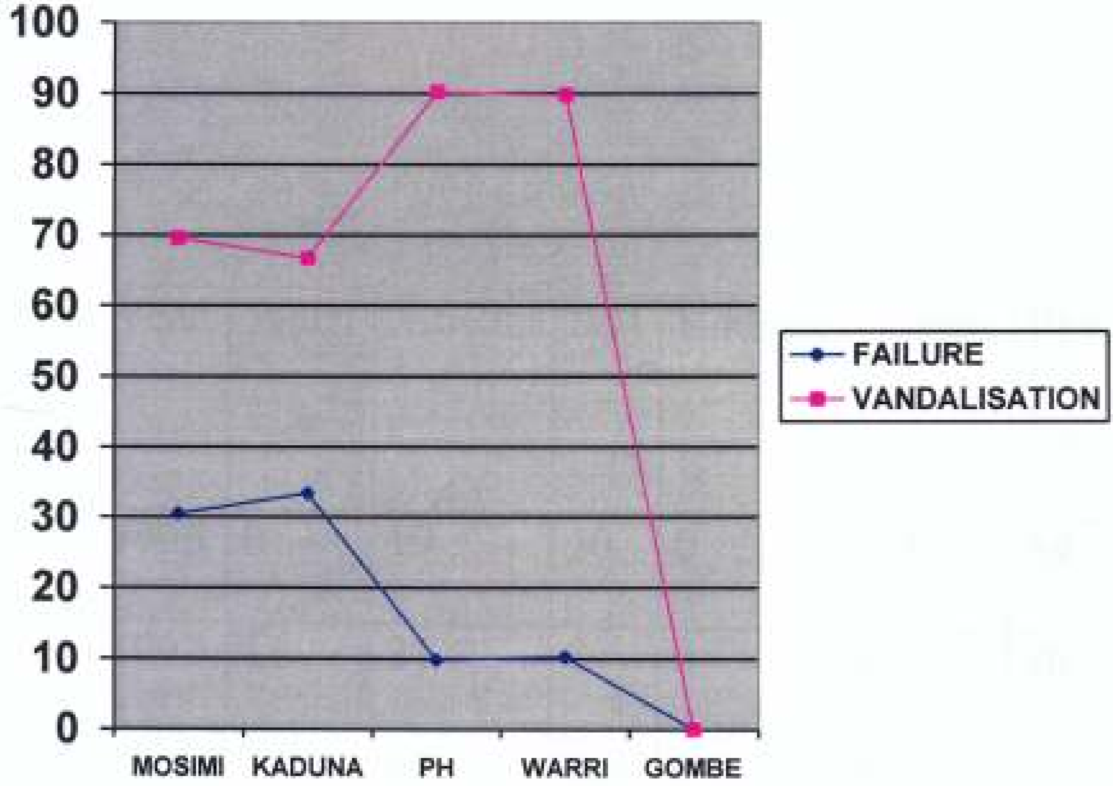


Fig. 1.1 Comparison Of Pipeline Leaks Due To Natural Failure And Vandalisation In PPMC Pipeline Network As Shown In Table2 (Source: PPMC Operations Report 2000)

Table 3 Occurrence Of Pipeline Vandalisation In PPMC For 5Years
(Source: PPMC Annual Reports)

S/N	Year	Warri	Mosimi	P/H	Kaduna	Gombe	**PPMC Total**
1.	1996	0	19	10	0	0	**29**
2.	1997	11	21	8	0	0	**40**
3.	1998	7	35	165	0	0	**207**
4.	1999	51	49	312	7	3	**422**
5.	2000	175	32	661	2	0	**870**

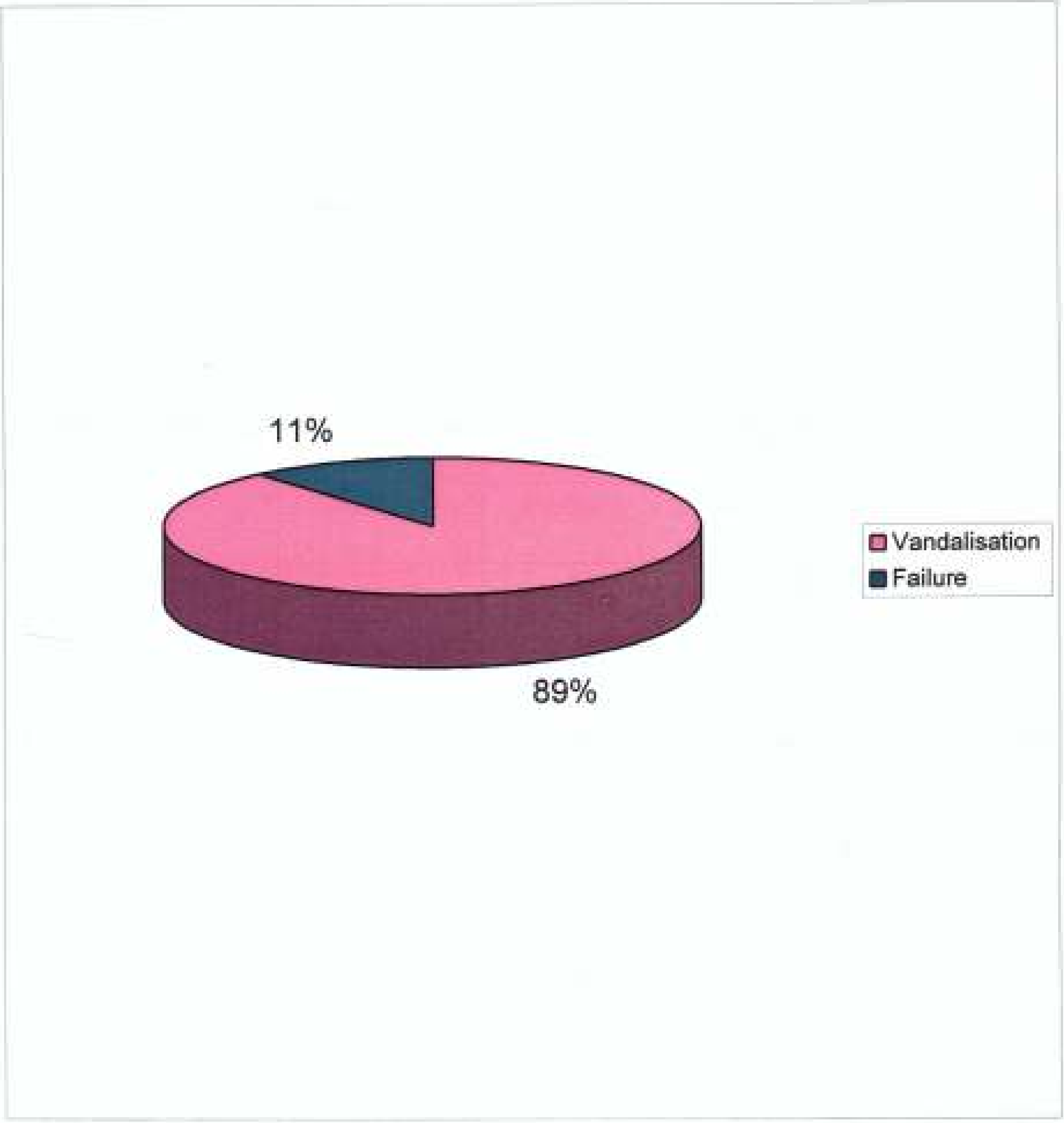


Fig. 1.2 Pipeline Leaks Due To Natural Failure And Vandalisation In PPMC (As Shown In Table 2)

Table 4   Analysis Of Annual Down Time / Man-Hour Losses In PPMC. (Source: PPMC Maintenance Reports)

S/N	Location	Equipment Failure	Power Failure	Pipeline Vandalisation	TOTAL (HRS)
1	Mosimi Area	1650	570	4380	6600
2	Kaduna Area	750	300	240	1290
3	P/H Area	2,350	777	7400	10,527
4	Warri Area	319	141	6212	6672
5	Gombe Area	215	100	10	325
6	**TOTAL**	5,284	1888	**18,242**	25,414

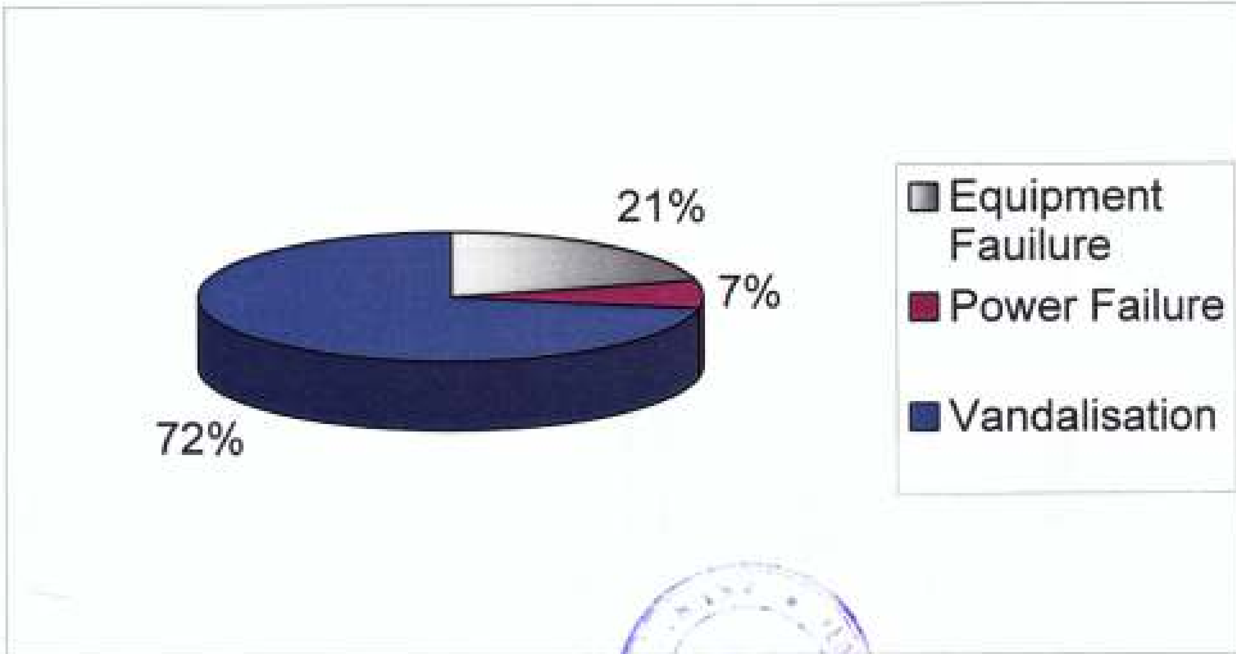


Fig. 1.3 Annual Down Time / Man Hour Losses In PPMC (As Shown In Table 4)

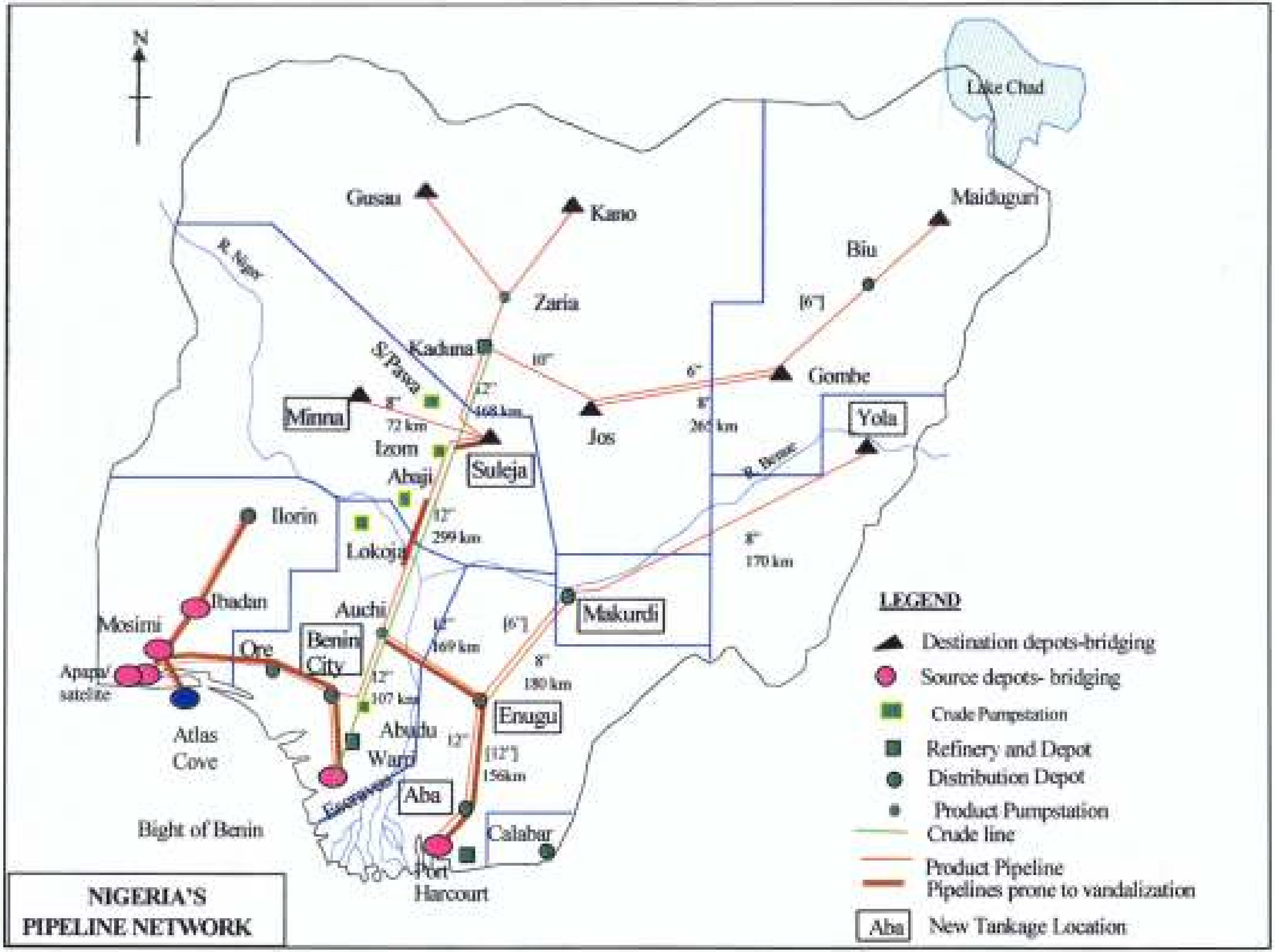


Fig. 1.4 PPMC Crude Oil And Petroleum Products Pipeline Network, Refineries, Depots And Pump stations (Source: PPMC Business And Investment Guide)

CHAPTER TWO

LITERATURE REVIEW

2.1 THE SCADA SYSTEM

SCADA = Supervisory Control and Data Acquisition- is a closed-loop system in which, from a master station, activities at another remote location can be identified, monitored and controlled.
The key elements of a SCADA system are:

- The primary sensors)
- The Remote Terminal Units (RTU)
- Communication link
- Master station
- Power supply and
- Software package

All these can be grouped into two: -

- The SCADA hardware and
- The SCADA software packages

Data monitored at the process points are sent via the RTU to the master station, which is usually the main control center or the supervisory control center, Chay, (2000). This will usually consist of *Pentium III class PCs, running on chosen SCADA software.* The chosen software should offer a totally non-proprietary set of open and scalable automation tools that provide the ultimate freedom of choice. It should also be ideally suited for Visualization, Supervisory Control, Data Acquisition, Advanced Alarming, Report and Recipe Management.

The system will usually run on Windows NT, Windows 98 or Windows 2000 and should be able to receive data from the outstations and field points. The system will also be configured to provide various displays of Pipeline Network from Global views to individual tag levels. These operating systems are available off the shelf, from vendors locally.

2.2 PRIMARY SENSORS – INSTRUMENTATION

The primary sensors provide the signal input to the RTU that is usually a PC based system. There are varieties of leak sensors that can be used in this application. Both vibration and acoustic sensors can be used to measure leak signals in the pipes. For vibration measurement, piezoelectric accelerometers having at least a sensitivity of 1 volt/g is used while for sound measurement, hydrophones having sensitivity of at least 0.447volts/kPa (44.7volts/bar) or a non-contacting Doppler flow meter can be used, Iloenyosi, (2000).

Electronic leak noise correlators are also widely used to locate leaks. In essence, a correlator consists of two transducers and a signal-processing unit. The transducers are specialized microphones or accelerometers, which are attached to access points bridging the suspected leak on the oil line. The transducer outputs are then fed into the signal-processing unit where they are digitized and cross-correlated. The cross-correlation operation produces an output that indicates how similar the two signals are as they are shifted in time with respect to one another. If there is a leak at the mid point between the transducers, the sound it makes will reach the transducers at the same time, and the cross-correlation will have a single central maximum. More usually, the leak will be offset from the mid-point, and the sound will reach the transducers at slightly different times. The correlation maximum will be offset from the center by this time difference, Desi, (2000).

Given the velocity of sound in the pipe and the location of the mid-point between the transducers, this time delay can then be used to calculate the distance of the leak from the mid-point. In practice, although certainly useful, correlators have not quite lived up to their promise. The main problem with existing correlators is the relatively poor signal-to-noise ratio. Here 'noise' can be considered as two unpredictable forms: 'random noise' and 'clutter'. Random noise is unpredictable on a short time scale, but has a zero mean. It can therefore, be removed by averaging over sufficiently long time periods. Clutter is a 'real' part of the detected signal, i.e. it has a reproducible cross-correlation that cannot be removed by averaging. Examples include echoes and resonance, Desi, (2000).

The DFM-IV Doppler flow meter is an ideal flow meter that works best in applications that would defeat regular contacting flow meters. Because the sensor is mounted on the outside of the pipe, it is unaffected by abrasives or harsh chemicals. There is no obstruction to flow and no pressure drop. The DFM-IV flow meter is capable of measuring flow in most common pipe materials like PVC, carbon steel, stainless steel, cast iron, fiberglass, and lined pipes or any pipe material that conducts ultrasound. Doppler signals cannot be transmitted through pipes walls which contain air pockets (materials like concrete and wood), or loose insertion liners (with an air gap between the liner and pipe wall), Golby and Woodward, (1999).
The DFM-IV is considered in this project because of the immense benefit which include among others the following: No contact means no maintenance, no sensor fouling, no obstruction to flow, no pressure drop, no corrosion and no pipe cutting or drilling for installation. Fig. 2.1 shows the schematic diagram of an installed DFM-IV Doppler flow meter.

The DFM ultrasonic, clamp-on flow meters measure flow velocity by detecting the change of frequency of ultrasonic echoes returned to the sensor (Fig 2.1a). The advanced DFM sensor contains two piezoelectric crystals in a stainless steel housing. One crystal transmits ultrasonic gases at a precise frequency which are reflected back to the receive signals from gases or solids in the liquid. Because the fluid is in motion the returned echo arrives back at the sensor at altered frequency (called the Doppler effect). The instrument's electronics monitor and convert this frequency range into velocity flow readings.
The DFM meters are rated to maximum flow velocity of 12.2m/sec. The measured fluid must contain solids or gas bubbles in concentration of 75micron or greater with a minimum size of 100 microns and flow at velocity greater than 0.08m/sec. The transducer can be attached semi permanently to the pipe with silicone coupling compound.

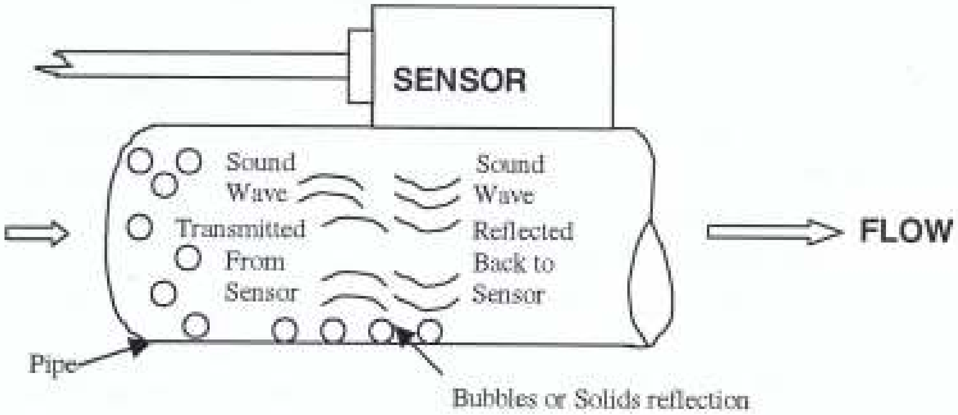


Fig. 2.1(a) DFM-IV Sensor Installed On A Pipeline.

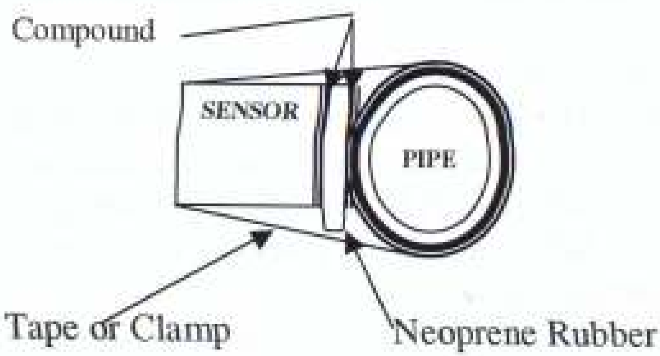


Fig. 2.1(b) DFM Sensor Coupling

2.2.1 SENSOR POSITIONING

The sensor must be positioned or mounted away from velocity increasing devices such as pumps, controlling valves, orifice plates, venturies, or pipe inlets and discharges. These devices cause release of gas bubbles in the fluid and readings nearby will indicate higher velocity. Normally flow will be evenly distributed 30 to 40 pipe diameter away from the velocity-increasing device, Okpidi, (2001). An appropriate up or downstream sensor mounting location can be determined by on site experimentation. Locate the sensor at least 30 pipe diameters up or downstream from velocity increasing devices (Fig.2.2a).

Elbows, flanged connections and tees introduce desirable conditions of an evenly distributed flow profile with some air or gasses entrained in the flow. Sensor mounting 6 to 10 pipe diameters up or downstream from these disturbances is generally optimum. (Fig 2.2b)

2.2.2 THE MICROPHONE FLOW SWITCH (MFS100)

THE DFM – MICROPHONE FLOW SWITCH (MFS 100) is the primary sensor in this application. The microphone flow switch is an acoustic flow detector directly coupled to a set-point relay. It consists of a sensitive - microphone sensor for attachment to the outside of a pipe, an amplifier, sensitivity control, and a relay.

The movement of fluid (solids) in a pipe generates a broadband of shear noise in the 1 H_Z to 100KH_Z range. Although pumps and machinery generate noise, it is usually at the low end of the sound frequency spectrum (1-5KH_Z). Higher frequency sound at 5-50KH_Z (ultrasonic) provides a suitable – indication of flow rate. The MFS 100 electronic circuits discriminate against low frequencies, monitor high frequencies, and control the relay. The MFS 100 Microphone switch is best suited to noisy or turbulent flow, which is generally found close to, elbows, valves, couplings etc. Laminar flow, as found in long horizontal pipe runs does not give good results. As a general guideline the MFS 100 requires flow with a Reynolds number of 4000 or greater for reliable operation?

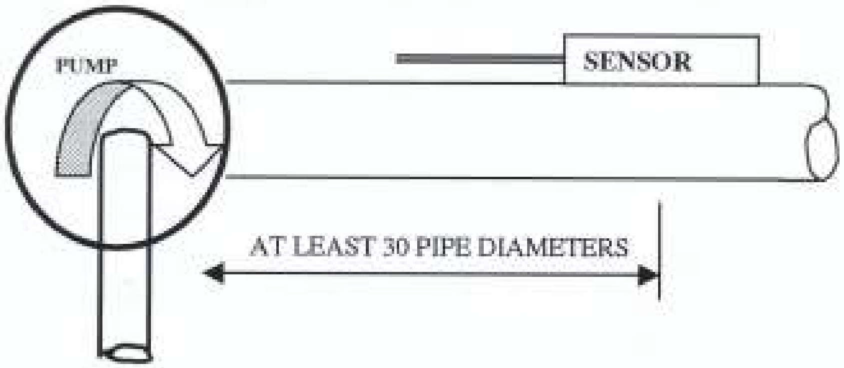


Fig 2.2(a) Positioning The Sensor

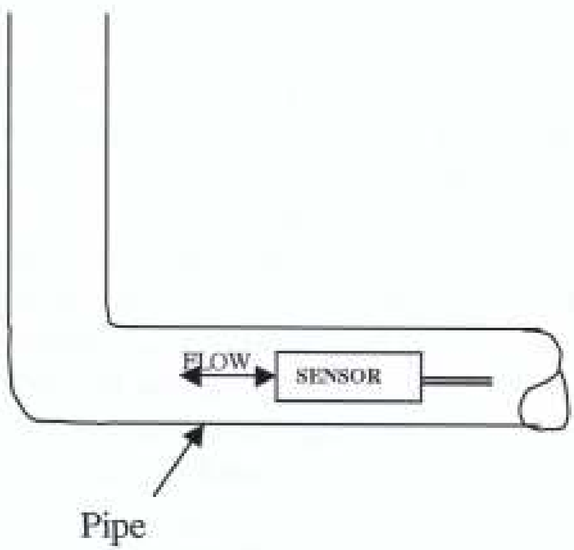


Fig 2.2(b) Positioning The Sensor On An Elbow Pipeline

2.2.2 PIPE MATERIAL AND PIPE DIAMETER

Sound conductivity varies according to the density of the pipe wall materials. Porous materials such as concrete or wood cause sound attenuation and Doppler performance may be erratic. Steel, PVC, Cast iron, Copper, Aluminum, Fiberglass and other plastic and metal pipes are generally ideal, with minimal sound attenuation. Pipe with loose insertion liners where sound transmission may be broken by air gaps should be avoided. Sound refraction may occur with some liner materials such as cement or coal tar as the Doppler signal travels through different densities of the liner and the pipe wall. The resulting error will be constant and can normally be corrected by calibration adjustment in situ, Okpidi, (2001).

The DFM Doppler sensors are designed to mount on pipes ½ inch (2.5mm) diameter or larger. Accuracy of the instrument may be affected by the flow profile. In liquids with a high concentration of solids the Doppler signal may not penetrate very deeply into the flow stream before being reflected back to the sensor. Because fluids tend to move more slowly at the pipe wall than in the center, accuracy may be reduced, particularly if measured on a long horizontal pipe run. For best performance, locate the sensor 6 or 10 pipe diameters downstream from an elbow where the flow is evenly distributed (Fig.2.2b). On horizontal pipes, the sensor should be mounted at the 3 0r 9 o'clock position to avoid concentrations where minimal gas bubbles are present, the sensor should be mounted at the 12 o'clock position on horizontal pipes (Fig2.3a).

Scale or sediment deposits reduce the pipe cross-section resulting in high flow volume readings. Deposits can also cause sound attenuation and reduce Doppler signal strength (Fig 2.3b). Doppler accuracy and signal strength is reduced at very slow velocities (0.3m/sec or less). Engineers usually design piping systems for velocity in the 0.6 – 3m /sec range which is ideal for Doppler instruments. Accuracy is also not affected within the sensor's rated temperature tolerance of 40 to 93°C(optional high temperature models –40 to 150°C) more than 0.3%. Higher or lower temperatures may damage the sensor. The sensor is designed to lock on to the strong Doppler return signal and to ignore most broadband noise. Using the built-in signal strength indication one can adjust the instrument's sensitivity to help lock out readings from noise in difficult applications. High voltage sources, variable speed drive inverters or DC motors in close proximity to the sensor, cable or electronics can interfere with the Doppler signal.

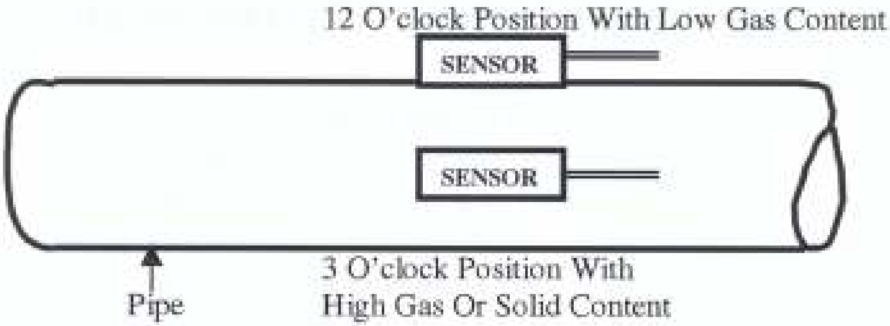


Fig 2.3(a) Sensor Mounting On Horizontal Pipeline

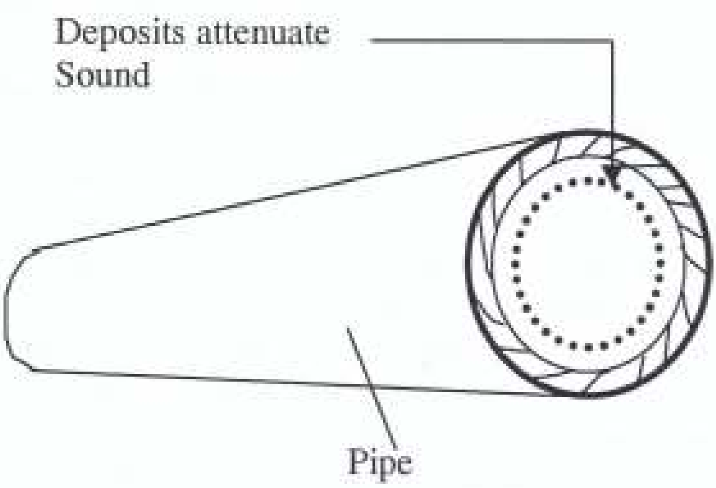


Fig 2.3(b) Pipe Inner Diameter Coated With Sludge

2.3 THE REMOTE TERMINAL UNIT (RTU)

The Remote Terminal Unit (RTU) is the field monitoring point which should usually be computer based (intelligent RTU). The RTU inputs/outputs can monitor level, flow, pressure, temperature, security, power etc from switches, sensors or transducers. A Standard Remote Terminal Unit (RTU) will consist of: -

- The Sensor(s)
- The field point data acquisition modules
- The communication unit
- The intelligence unit
- The power supply
- Secured enclosure

The intelligent RTUs are individually rated with an extended temperature range of + 70°C. They also provide local historical data storage and alarming with time stamp to ensure the integrity of all data in the event of a network communication failure. There are numerous types of Remote Terminal Unit systems available in the market for use. In this write up mention will be made of only three types of RTUs.

(i) THE ULTRACD SYSTEM

This system offers practical, economical wireless monitoring and control of 1000 plus remote sites. The RTU can monitor level, pressure, temperature, security, power etc from switches, sensors or transducers. The system features modular components mounted on a metal back plane and installed in a small metal housing of NEMA industrial enclosure. Modular functional boards include: power supply, CPU, radio, phones, digital I/O, analog out, analog in, and relay. The system is expandable to 32 modules with up to 16 of any one type allowed. This configuration allows up to 445 digital inputs or outputs with 16 digital I/O per module, up to 176 analog input with 11 analog inputs per module, up to 64 analog outputs with 4 analog outputs per module, and up to 96 relays with 6 relays per module.
Some of the features of this RTU are: Report by exception and polling, windows based control software, user programmable RTU logic, 12 bit A/D resolution, store and forward, communicate via cell phone, RS 485 dial and leased line modem, radio or wire line, satellite such as VSAT etc; Hunaidi and Chu, (1999).

Some areas of applications include among others the following: Pump stations, Tank monitoring, Pipeline vandalisation alarm, Temperature monitoring control, Pipeline compressors control, Hydro stations, Fish hatcheries, Electrical sub-stations, Pipeline leak detection etc; Okpidi, (2001).

(ii) SRM 6000 MODEM

The SRM 6000 is wired to a radio modem for transmission to the Supervisory Control Centre. Field Point I/O modules – include: Analog input, Analog output, Counter/Timers, Discrete digital input and outputs. They are hot plug gable; as such maintenance and replacement of a module do not require the shutting down of the station. Units are mounted in industrial enclosure for protection from harsh and dirty environments. The enclosure features a hinged cover with a 10degree door opening, removable hinge pins, and a quarter-turn latch system. The enclosure is constructed with a durable 16-guage steel. The enclosure with a solid metal cover is rated to NEMA 4, 12, and IP66, while the polycarbonate windowed enclosure is rated to NEMA 12 and IP55. The enclosure can house one network module and up to four field point I/O modules, which mount on a DIN rail in the rear of the enclosure. The dimensions of the enclosure are 20 by 60 by 15cm.
Since the many field monitoring points will be stand alone unattended units the basic Data Acquisition system comprising the field point modules will be powered by a combination of solar panel and Lithium – Nickel battery. The solar panel provides current for charging the batteries during daylight, while the batteries power the system. The Batteries are capable of providing power uncharged for up to 14 days, as the power consumption of the modules is minimal, while the spread spectrum radio modem will transmit in short bursts to reduce power consumption. Remote units (RTU) will be enclosed in protective casing up to 4 meters in height with the solar panel at the top and the Radio antenna protruding, Desi, (2000) (Fig. 2.4). The system is protected by a combination of a proximity sensor and a miniature camera with wide-angle lens. If the proximity sensor detects an intruder, it sends the signal to the supervisory control center, it can also automatically activate the camera to start capturing the image of the intruder and transmit the image to the supervisory control center. Camera lighting can include infrared source to illuminate the area at night and at low visibility levels.

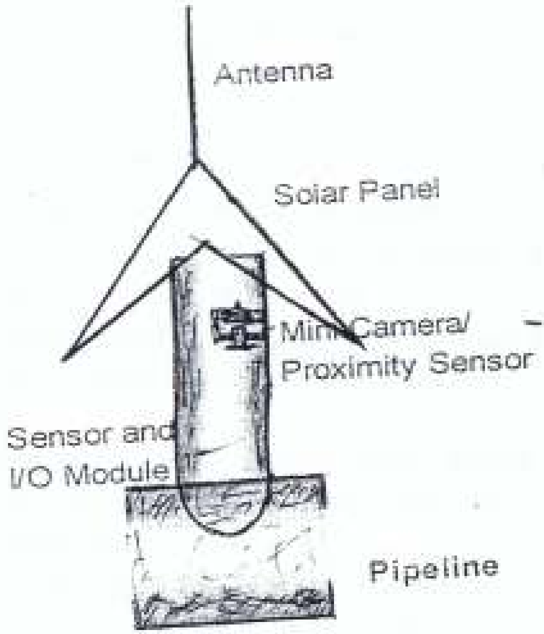


Fig 2.4 Field Data Acquisition Module

(iii) MOSCAD

The MOSCAD is an intelligent RTU manufactured by Motorola Company. It is a powerful combination of two functions: Advanced Programmable Logic Controller (PLC) and State-of-the Art Communication Modem. This gives the RTU an edge over those previously mentioned. The MOSCAD RTU is Modular and Expandable. The Plug-in modules include: CPU module, Digital I/O modules, Analog I/O modules and modules for special applications, Chay, (2000). The most exclusive feature of the MOSCAD is the built in two- way (VHF/UHF) conventional radio (Fig 2.5). The benefit of this built-in two way conventional radio among others are: -

- Easy system expansion to new sites with no need for MW or other infrastructure.
- Reliable and instant communication to and from the sites.
- No need to use the existing microwave or other infrastructure in the sites.
- Simple and fast installation and operation
- Very short time for repair (MTBF is high and MTTR is low)
- Not affected by storms, rains, floods and fogs.
- Very low cost communication infrastructure.
- Application program can be easily changed and downloaded to RTUs in the field.
- Permits maintenance staff to identify and correct problems at the RTUs from any site in the system.
- Guarantees employee safety.

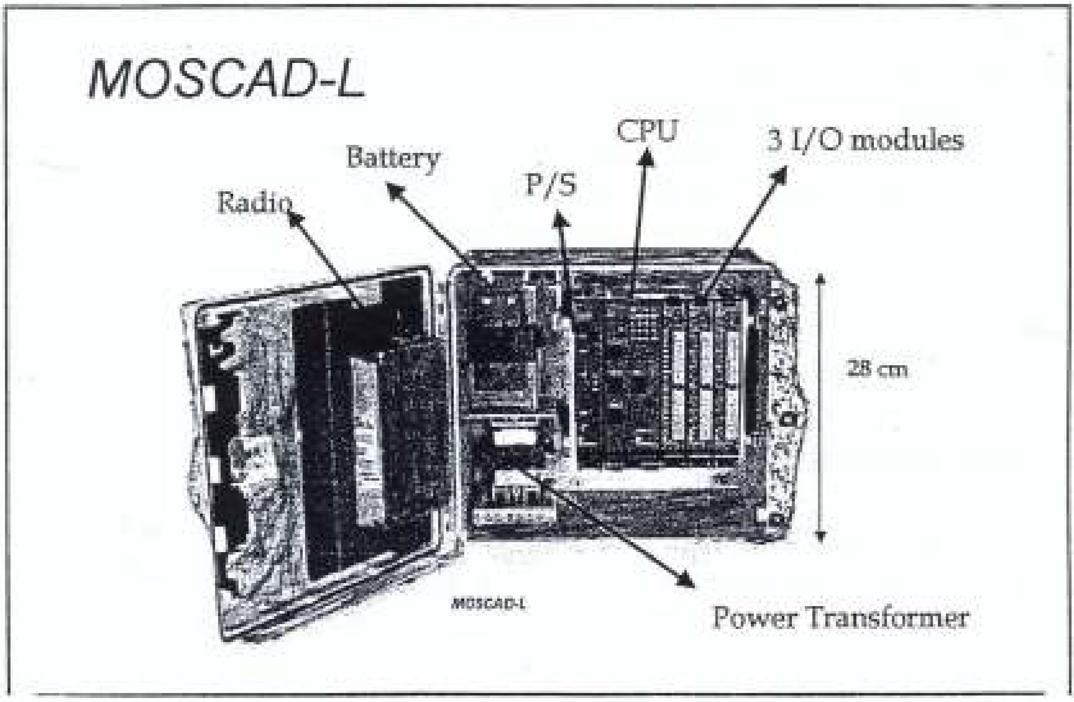


Fig. 2.5 MOSCAD RTU

2.4 COMMUNICATION MEDIUM

One of the major problems with a SCADA of this nature is the high cost of implementing the Telecommunication elements, as well as the reliability or lack of it. Monitoring and controlling multiple and remote locations is not always possible or feasible using wire. In this system the applied technology is TELEMETRY. Telemetry is defined as the sensing and measuring of information at some remote location and then transmitting that information to a central or host location. There, it can be monitored and used to control a process at the remote site, Desi, (2000). The basic concept of telemetry has been in existence for centuries (Fig.2.6). Telemetry using radio waves or wireless offers several distinct advantages over other transmission methods. Some of these advantages are:

- No transmission lines to be vandalized
- It has faster response time
- The cost is lower compared to leased lines.
- Ease of use in remote areas where it is not practical or possible to use wire or coaxial cables.
- Easy relocation.
- Functional over a wide range of operating conditions.

Properly designed radio link can provide low cost, effective and flexible data gathering system that operate for many years with very little maintenance.

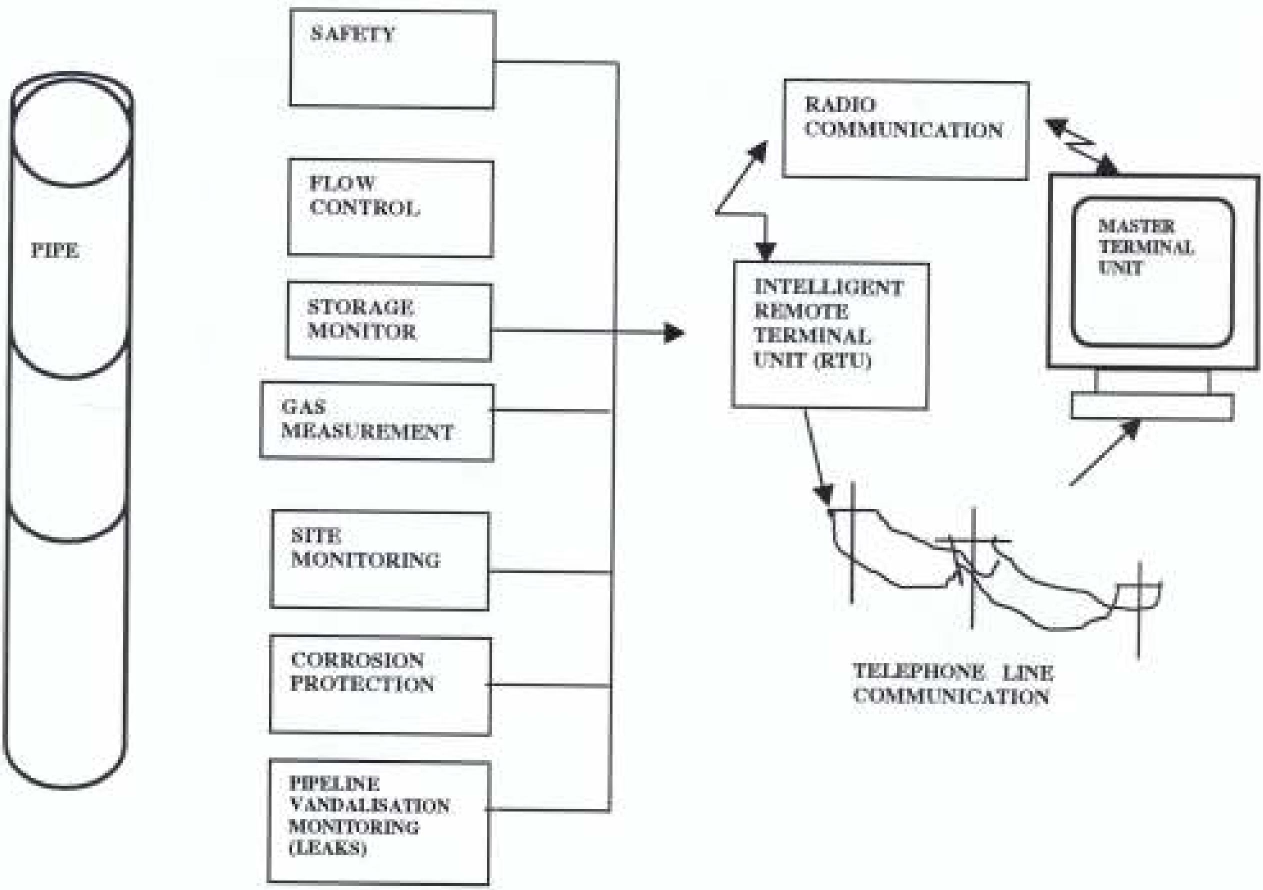


Fig.2.6 Pipeline Real-Time Telemetry System
[Source – National Gas Supply Association (NGSA)]

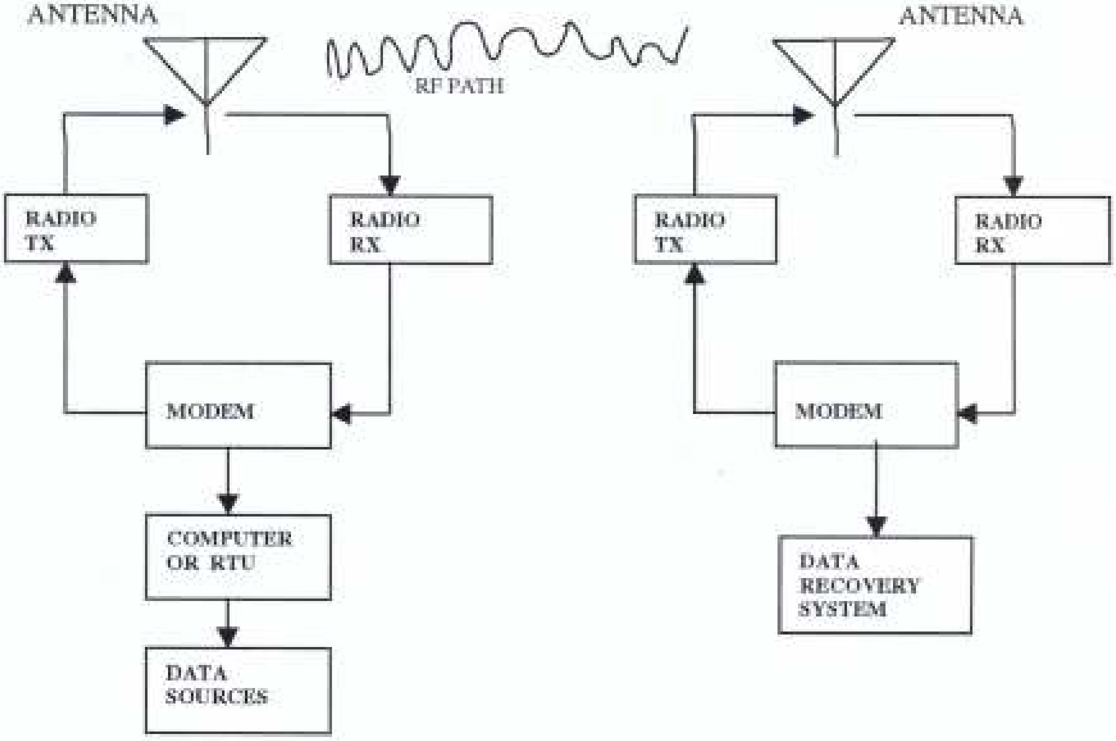


Fig. 2.7 Communication Network

At the remote site, a sensor or sensors are typically data source. The *output of the sensor(s) is converted to digital data by a small computer device or Remote Terminal Unit (RTU). The RTU is interfaced to a* modem device that converts the digital data into an analog signal that can be transmitted over the air. The radio transmitter then transmits the signal to the host site radio receiver. Now the process is reversed. The modem takes the analog signal received and converts it back to a digital form that can be processed by the data recovery equipment (Fig 2.7).

In a typical application, the base or host site requests data from the remote site(s). The base transmits a request to the remote unit telling it to send its data. The base reverts to a mode and awaits the transmission from the remote site. After the remote sends its data, it goes back to a receive mode waiting for further instructions to come from the base. Once the base receives the remote site information, it may request additional instructions to that site or continue on to request data from the next remote site. *This polling process continues* until all the remotes in the system have sent their data. Some key factors taken into consideration in SCADA Communication will be mentioned briefly here.

1. RF SIGNAL PROPAGATION

Propagation characteristics of radio waves are subject to many variables that affect the range and performance of a radio system. The main consideration is the loss in the transmission path between the transmitter and receiver. Factors affecting this loss are vegetation, *building, hills, mountains, and other natural or man-made* obstacles which all contribute to signal strength loss, Ogidi-Olu, (1998).

2. SENDING DATA THROUGH THE AIR

Radio waves are propagated when the electrical energy produced by the radio transmitter is converted into magnetic energy by the antenna. Magnetic waves can then travel through space. The receiving antenna intercepts a very small amount of this magnetic energy and converts it back into electrical energy that is amplified by the radio receiver.

Electric __ Energy Radio TX	Magnetic ___ Energy Antenna	Radio wave __ by propagation	Magnetic wave travels in space

But how far can data be transmitted?
Propagation characteristics of radio waves are subject to many variables that affect the range and performance of a radio system. The main consideration is the loss in the transmission path between the transmitter and the receiver. Factors affecting this loss are obstacles and power loss, Ogidi-Olu, (1998).

The most reliable system will employ a "line-of-sight" design where the radio wave travels directly from the transmitting antenna to the receiving antenna without obstructions as shown in Fig.2.8a. However, the curvature of the earth limits the line-of-sight distance. If the transmitting and receiving antennas are too far apart, the earth will block the radio wave. The maximum line-of-sight transmission distance is determined by antenna height and may be limited by other obstacles as shown in Fig. 2.8b.

Once the transmission path is determined, signal power comes into play. In general, signal power decreases in proportion to the square of the distance. For example, if the distance doubles, power decreases by four times. However, in actual practice, power drops off much faster because obstructions, trees, foliage, and other factors cause attenuation.
Predictions of radio range can be made using a free isotropic non-directive antenna model where the path loss is 22dB for one wavelength of separation between antennas and increases 6dB every time the distance is doubled. However, this model holds true only in free space. Under actual conditions, other factors must be considered, Hunaidi and Chu, (1999).

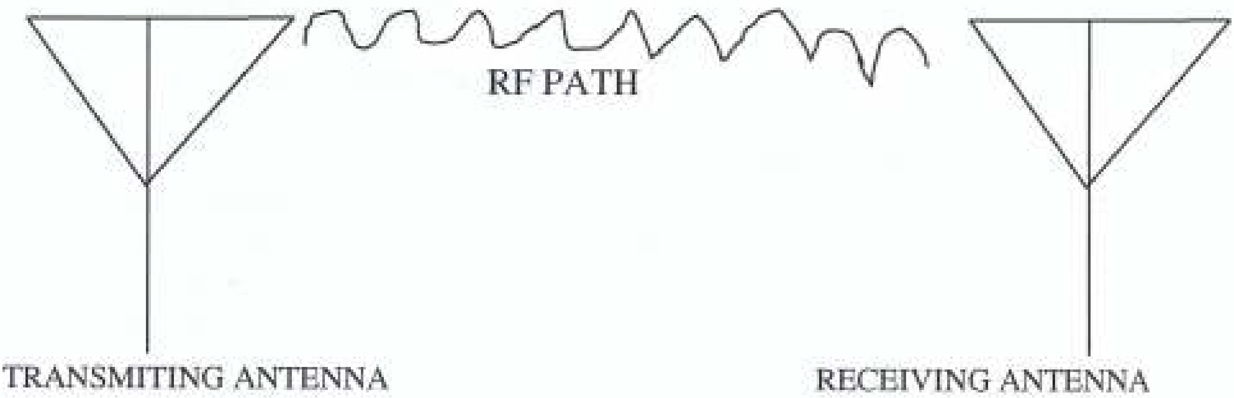


Fig 2.8(a) Line-Of-Sight Transmission

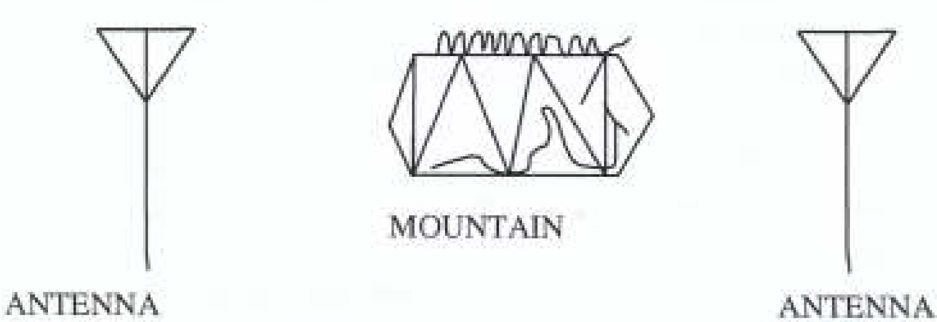


Fig 2.8(b) Line-Of-Sight Obstacle

3. FREQUENCY RANGE

(i) VHF BAND (150-174 MH_Z)

Man-made noise such as that from automobiles and power lines and skip interference caused by radio waves reflecting off the ionosphere back to earth, are much less of a problem at the VHF frequencies.
Under certain atmospheric conditions, long-range transmission can occur and cause interference. Normally, the dielectric constant of the atmosphere decreases with increase in altitude. However, with some weather conditions, the opposite occurs. This causes the radio wave to be trapped between the earth and the maximum height of the radio wave to travel much further than line-of-sight. This ducting occurs infrequently and may cause interference with direct wave signals, Desi, (2000).

(ii) UHF BAND (450-470 MH_Z)

This band is the one often used in recent years because of the number of channels available. Range is not quite as good as at VHF, but this band is free of most man-made noise, skip interference and ducting effects. Absorption by trees and foliage causes a greater path loss, but penetration into buildings is better because the short wavelength signal has the ability to reflect off conducting objects.

(iii) 900MH_Z BAND (928-960 MH_Z)

Skip interferences and ducting are insignificant in this band. However, foliage absorption of the short wavelength is greater which reduces range. In addition, moving objects in the communication path can cause fading due to multipath reception. Multipath reception occurs when the direct wave and a reflected wave arrive at the antenna at different phase angle. This phase difference occurs because the reflected wave has to travel further than the direct wave. This causes canceling, which weakens the received signal, Ogidi-Olu, (1998).
Multipath reception can also occur at the lower frequencies, but is more a problem at the higher frequencies because the ability to reflect off objects increases with frequency. This problem is most common with communication between two moving vehicles or one moving vehicle and fixed station. However it can also occur when two fixed stations are communicating, if there are moving vehicles or other types of moving reflective objects in the communication path. These are some of the problems encountered in the various bands when radio waves are used to establish a telemetry link, Desi, (2000).

4. THE SYSTEM ANTENNA

The design of transmit and receive antenna system is important because it determines how well energy is transferred from one antenna to the other. Some of these factors are gain, directivity, polarization and height above the ground. Antenna height is simply a matter of the higher the better. Increasing the height extends the line-of-sight distance and reduces the effects of objects on the ground. The distance to the horizon is dependent on the height above the surface of the earth. It can be seen that because of the curvature of the earth the distance to the horizon is longer when viewed from an elevated position, Breeds, (1994).

Radio waves are somewhat like light waves in that they tend to travel in a straight line. However, radio waves also tend to refract or bend as they follow the curvature of the earth. This extends the radio horizon beyond the optical horizon. This bending is caused by the tendency of a radio wave to travel slower as the density of the air increases. Since part of the radio wave travels near the earth where the air is denser, this bending occurs. When studying the behaviors of radio wave in space, it is more convenient to use a path that is a straight line instead of a curve. This requires that the radius of the earth – curvature be simultaneously readjusted to preserve the correct relationship. For the standard atmosphere, the equivalent radius is 1.3 times that of actual radius of the earth as shown by experience. As previously stated, the optical and radio wave path differ. The distance in miles from antenna to the optical and radio wave horizon is determined as follows:

Optical Horizon Distance = Square Root of 2h
Radio Horizon Distance = 1.33 x Square Root of 2h
Where "h" is height in feet.

The maximum possible distance at which direct wave transmission is possible between transmitting and receiving antennas at given heights (the line-of-sight distance) is equal to the sum of the horizon distance calculated separately from the individual antenna heights. When the distance involved is less than line-of-sight, the path is sometimes referred to as the optical path, Iloenyosi, (2000)

As the distance between the transmitting and receiving antennas increases, the energy concentration for a given area decreases. Therefore, the distance from the transmitting antenna also determines how much energy an antenna intercepts. This loss of signal strength due to increased distance is known as path attenuation and is expressed in decibels or dB. The amount of power available at the receiving antenna is dependent on the amount of energy it intercepts.

An electrically large antenna will intercept more energy than an electrically small antenna. The actual dimensions of an antenna are related to wavelength. The higher the frequency, the smaller the antenna for a given wavelength, Ballanis, (1982). Because a smaller antenna intercepts less energy, there is a decrease in usable range as frequency increases. It is possible to increase the size (in terms of wavelength) of higher frequency antennas so that they intercept more power. These antennas are referred to as "gain". If the radio link consists of two fixed stations communicating only with each other, the use of directional (gain) antenna can offer an advantage. A directional antenna normally provides several dB of gain by concentrating the RF energy in only one direction. This minimizes potential interference with other stations on other azimuths, Ogidi-Olu, (1998). If communication is required with stations on different azimuths, an omni-directional antenna is probably required. Some gain can also be built into that type of antenna. There are several ways of adding gain to antenna such as using $^5/_8$ wavelength, yagi, corner reflector, or collinear design. At VHF frequencies, gain antennas are rather large and cumbersome. However, at higher frequencies, they become more practical and may make up for some of the higher path loss at those frequencies.

The transmission line that connects the antenna to the receiver or transmitter is also a source of power loss. Typically, this loss is specified in dB per 100 feet of transmission line. For example, 100feet of RG-8U coaxial cable has a 5.0dB loss at the same frequency, and $^7/_8$" helix cable has only a 0.9dB loss at 450MHZ. Although transmission lines with a lower loss cost more and are larger in diameter, they offer an advantage if the antenna is at a considerable distance from the receiver or transmitter, Ballanis, (1982).

5. DETERMINATION OF RADIO RANGE

Determination of radio range is a complex matter that has many variables. Some of the steps to take include: -

- Determine the line-of-sight transmission distance
- Select the antenna height above the average terrain
- Calculate the transmitter and receiver transmission line losses at the operating frequency
- Determine transmitter power output and receiver sensitivity in dBm
- Determine transmitter and receiver antenna gain.
- Calculate the path loss at the operating frequency.

Once these parameters have been determined, an estimate of the RF link range is done over smooth earth. Obviously there are more obstacles to overcome in designing a usable radio link.

Determining the line-of-sight distance does not guarantee adequate range. The transmitter power, receiver sensitivity, transmission line loss, antenna loss or gain, and operating frequency must also be considered. The line-of-sight only means that the curvature of the earth does not block the signal.

Fading is a random increase in path loss caused by abnormal propagation conditions. When these conditions occur, path loss may increase by 10-30dB or more for very short periods of time. Therefore, it is important to design the system to compensate for fading. Careful selection of antenna height, antenna gain and low transmission line loss can greatly enhance the fade margin of a radio link. Increasing transmitter power output or lowering the receiver sensitivity can also increase fade margin. Lowering the receiver sensitivity can also be done by using a receiver with a lower noise figure or adding an amplifier between the receiver antenna and the transmission line, which make up for transmission line losses. However, adding an extra RF amplifier can make the receiver more susceptible to interference from unwanted signal.

2.5 MONITORING STATION

The Monitoring station is the Master Control center or the Supervisory Control Centre. This consists of Personal Computers (PC) running on the chosen and applicable software programme. This provides the Man Machine Interface (MMI) for operating the system. It is ideally suited for visualization, supervisory control, data acquisition, and advanced alarming, report and recipe management. Two Pentium III class of computers (PC 1 and PC 2) are connected in parallel to the data bus. This enables them to get the same data from the modems. They are wired to Windows NT, Windows 98 or Windows 2000 network using TCP/IP protocol, and are – therefore receiving field data from the field units via the Radio Modem. Two systems are needed for redundancy purposes, to ensure that when one system is down, the other system can continue the supervisory control. The data obtained from the stations are achieved and made available for display in any format, text or graphics. This data is also available on the Network so that remote systems can be connected via Dial-up Network and is able to view the network status. This ensures that any number of users can view the SCADA system status from any point in the country.

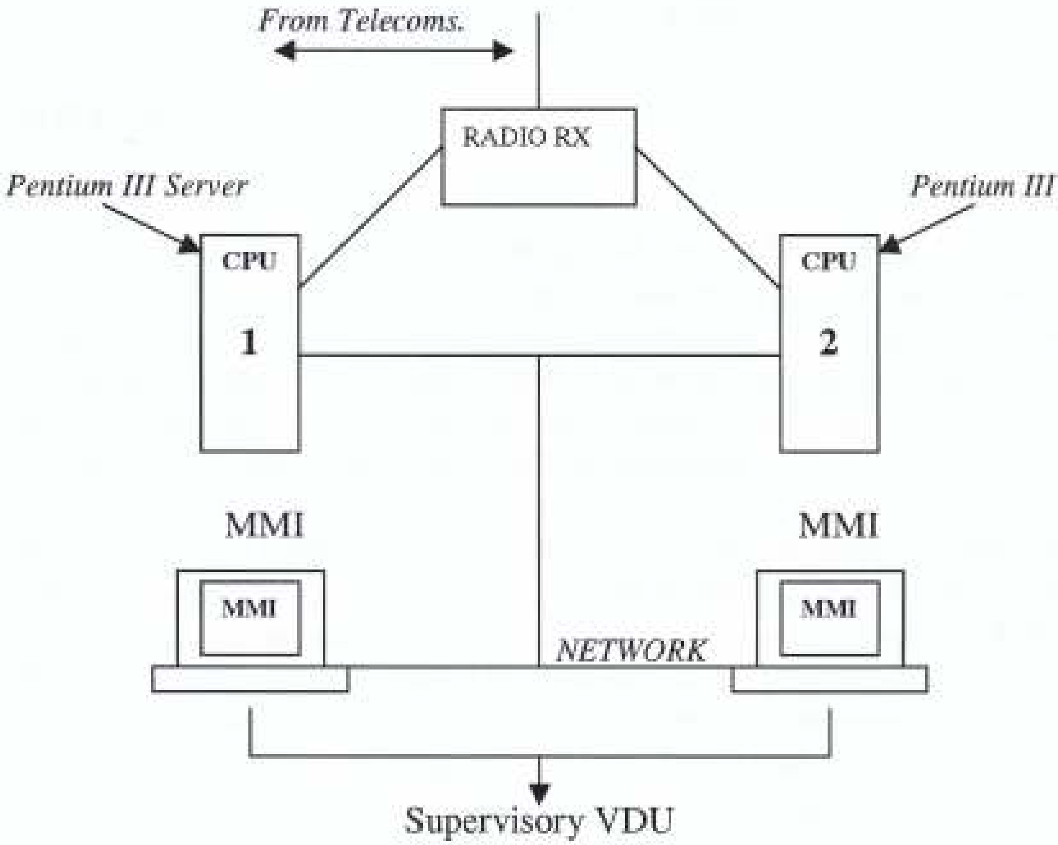


Fig. 2.9 Main SCADA System.

CHAPTER THREE

THE SCADA SYSTEM

3.1 WHY SCADA?

It has been mentioned earlier that PPMC Operations network covers a pipeline distance of over 5000Km spread across the nation. The area that is more prone to vandalisation- the southern part of the country- covers about two-thirds of the pipeline network. To effectively and efficiently monitor this length of pipeline so many remote monitoring points/locations would have to be created and such would be definitely difficult to man physically or manually.

Monitoring and controlling multiple and remote locations is also not always possible or feasible using wire due to high cost, complexity, as well as vandalisation of the lines. This is where the choice of the SCADA system plays a vital role. The SCADA system is cost saving, has better use of the available resources, increased system-performance, better utilized manpower, better safety, allow faster detection of problems, reduce operating and maintenance cost, makes use of radio and hence no need for dedicated telephone lines and no lines to vandalize.

3.2 MODELLING THE SCADA SYSTEM

The SCADA system in this project can be represented by a digitally controlled first order system with diagram as shown in Fig 3.1

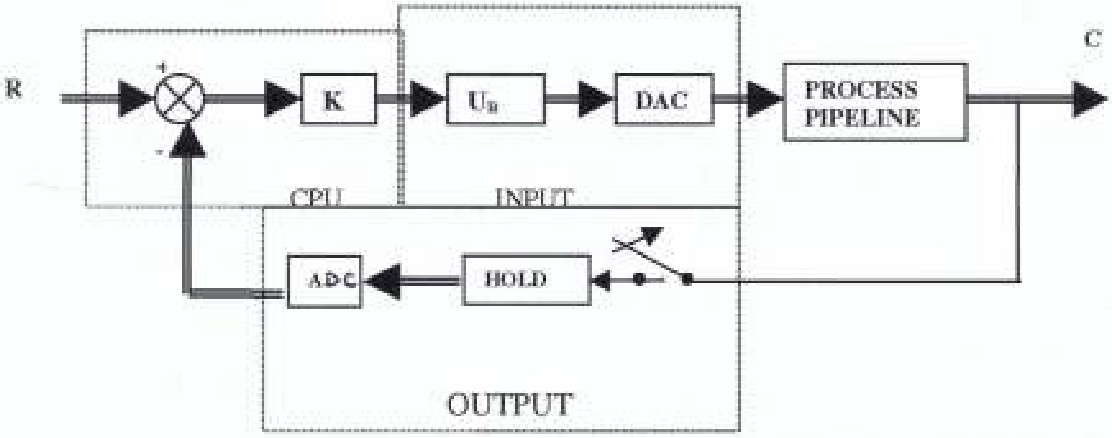


Fig 3.1 Diagrammatic Representation Of The SCADA System.

3.2.1 DESCRIPTION OF COMPONENTS USED IN THE MODELLING

Different aspects of the pipeline network to be monitored and the operational activities involved in this system right from the conception of the idea to its actualization have been identified and properly grouped. These activities have been represented with different blocks and their individual transfer function also determined for ease of computation. Activities involved in this type of system can be broadly grouped into routine or fixed or constant steps and then the non-routine or variable steps.

The first step taken is the conception of the idea, identifying the problems, consultation with the workforce, getting the necessary materials, equipment and tools. All these are regarded as input devices which are represented by $R^*(s)$. Drawing up custody transfer programmes by the oil Movement department of the company, scheduling of pumping activities, carrying out tank nomination and fiscalisation as well as lining up pumps by the operators, laboratory analysis of the product to determine the quality (i.e. meeting the required specification), lining up the receiving tank(s) at the downstream station are all routine activities which must be carried out each time there is a need for product supply. These are regarded as constant activities and are therefore, represented by $H_1(s)$ block with 'K' as the constant.
Monitoring of the pipeline network using the SCADA system involves constant monitoring of the flow of product through the pipeline. This represents the sampling and is denoted by the switch 'T' and the sample and hold block (ZOH).
The last block represents the process (Pipeline network) and here the output is constantly measured. In this case the product flow is determined and comparison made between what passes through the pipeline segment and the actual quantity of product from the transferring station. Normal flows when the pipeline is intact and no flow when the pipeline is tampered with or vandalized. This is fed back into an error detector or summer (the MOSCAD RTU) and necessary actions (corrections) are then taken at the Master Control Center. The block diagram of the system is as shown.

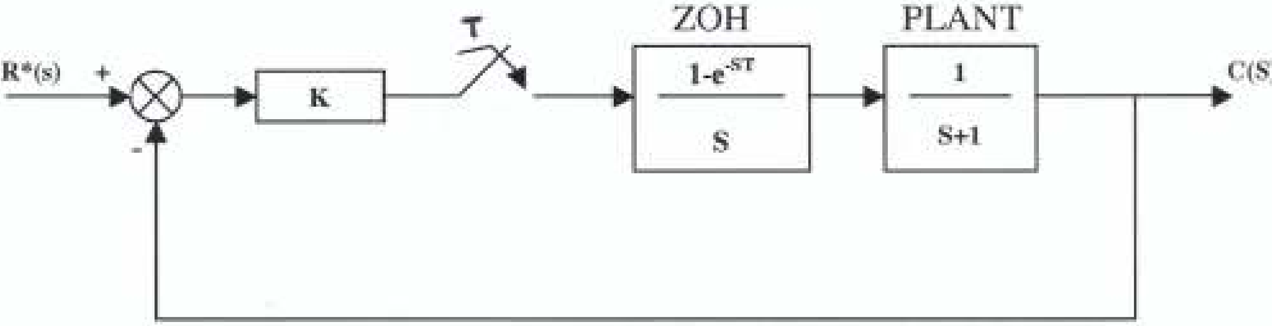


Fig. 3.2 The Block Diagram Of A Digitally Controlled First Order System.

The closed loop transfer function of the above system is

$$\text{T.F.} = \frac{C(s)}{R(s)} = \frac{C(z)}{R(z)} = \frac{H_1(z).\ H_2(z)}{1+H_1(z).\ H_2(z)} \qquad \ldots\ldots\ldots 3.1$$

The individual transfer function

$$H_1(z) = K \qquad \ldots\ldots\ldots\ldots 3.2$$

$$H_2(z) = \xi \left\{ \frac{1-e^{-ST}}{S} \cdot \frac{1}{S+1} \right\} \qquad \ldots\ldots\ldots 3.3$$

$$\xi \left\{ 1-e^{-ST} \cdot \frac{1}{S\,(S+1)} \right\} \qquad \ldots\ldots\ldots\ldots 3.4$$

$$\xi\left\{1-e^{-ST}\right\} = 1-Z^{-1} = 1-\frac{1}{Z} = \frac{Z-1}{Z} \qquad \text{......... } 3.5$$

$$\xi\left\{\frac{1}{S\,(S+1)}\right\}$$ Using partial fraction this becomes

$$\xi\left\{\frac{1}{S} - \frac{1}{S+1}\right\} \qquad \text{..................}3.6$$

And $$= \xi\left\{\frac{1}{S}\right\} = \frac{Z}{Z-1} \qquad \text{........................}3.7$$

$$\xi\left\{\frac{1}{S+1}\right\} = \frac{Z}{Z-e^{-T}} \qquad \text{........................}3.8$$

Substituting for eqns.3.5, 3.7 & 3.8 in eqn.3.3

$$H_2(z) = \frac{Z-1}{Z}\left\{\frac{Z}{Z-1} - \frac{Z}{Z-e^{-T}}\right\} \qquad \text{...........................}3.9$$

$$\frac{Z-1}{Z}\left\{\frac{Z\,(Z-e^{-T}) - Z(Z-1)}{(Z-1)(Z-e^{-T})}\right\}$$

$$\frac{\cancel{Z-1}}{\cancel{Z}}\left\{\frac{\cancel{Z}[\,(Z-e^{-T}) - (Z-1)]}{(\cancel{Z-1})(Z-e^{-T})}\right\}$$

$$\frac{(Z-e^{-T}) - (Z-1)}{Z-e^{-T}}$$

$$\frac{Z-e^{-T} - Z+1}{Z-e^{-T}}$$

$$H_2(z) = \frac{1 - e^{-T}}{Z - e^{-T}} \qquad \text{.............3.10}$$

Substituting eqn 3.2 and 3.10 in eqn. 3.1 we have

$$T.F. = \frac{H_1(z).\ H_2(z)}{1+H_1(z).H_2(z)}$$

$$\frac{K\left\{\dfrac{1 - e^{-T}}{Z - e^{-T}}\right\}}{1 + K\left\{\dfrac{1- e^{-T}}{Z - e^{-T}}\right\}} \qquad \text{..............................3.11}$$

$$\frac{K\left\{\dfrac{1 - e^{-T}}{\cancel{Z - e^{-T}}}\right\}}{\dfrac{Z- e^{-T} + K\,(1- e^{-T})}{\cancel{Z- e^{-T}}}} \qquad \text{..............................3.12}$$

$$\frac{K\,(1- e^{-T})}{Z- e^{-T} + K\,(1- e^{-T})} \qquad \text{..............................3.13}$$

$$\frac{K(1-e^{-T})}{Z-e^{-T}+K-Ke^{-T}} \qquad \text{.............................3.14}$$

$$\frac{K(1-e^{-T})}{Z-e^{-T}-Ke^{-T}+K} \qquad \text{.............................3.15}$$

$$\mathbf{T.F.} = \frac{K(1-e^{-T})}{Z-e^{-T}(1+K)+K} \qquad \text{.............................3.16}$$

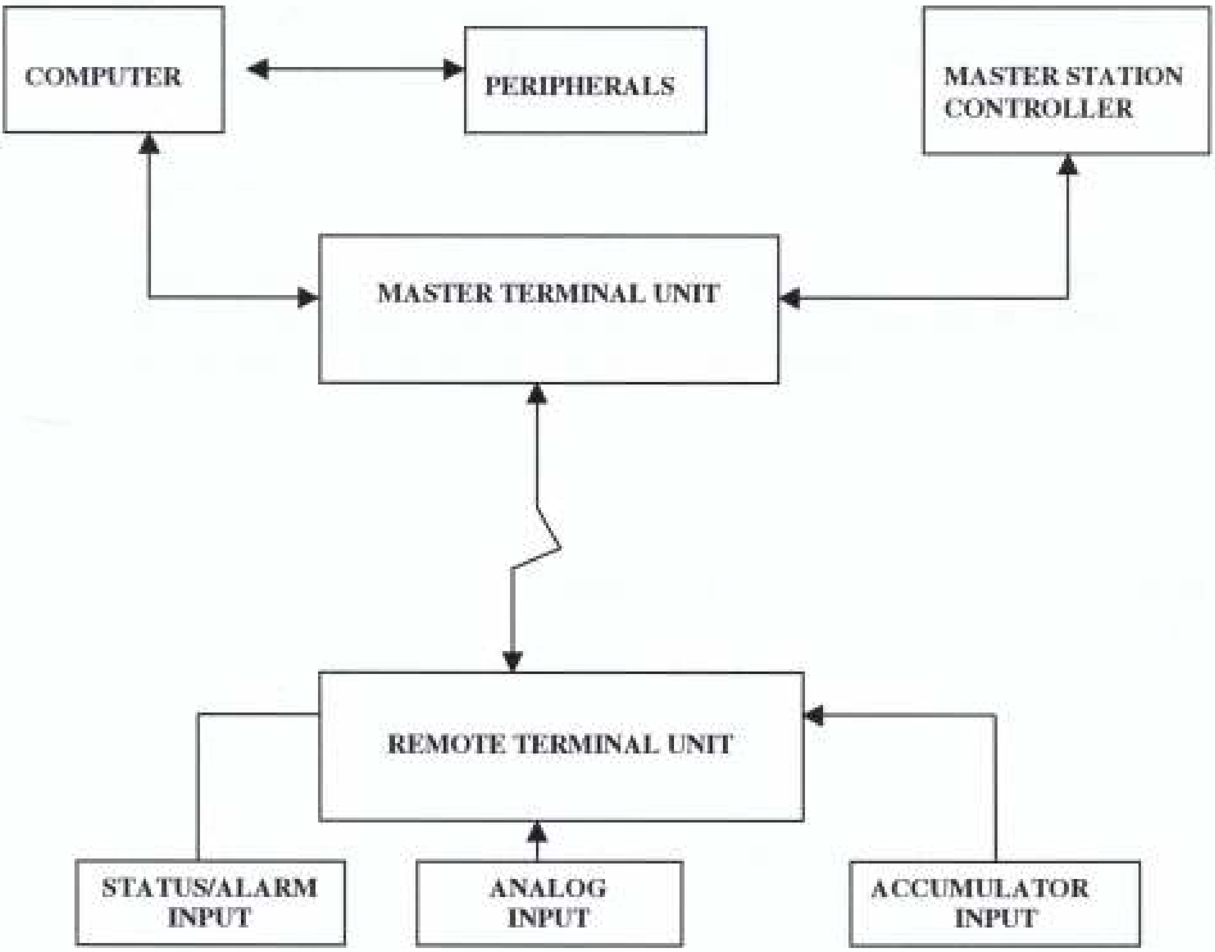


Fig 3.3 Elements Of Data Acquisition And Control System.

3.3 IMPEDANCE MATCHING

Matching the load impedance to the pulse forming network impedance is done primarily to obtain maximum power transfer. Nearly matched impedances are required for maximum efficiency. If $Z = Z_{(t)}$ then there are problems in obtaining high efficiencies, Sarjeant and Dollinger, 1980).

Impedance matching is very essential in the transmission of signal from the source and the reception of it at the destination, or end point monitoring station. Unless there is proper impedance matching between the source and the monitoring station, the signal monitored will be distorted before getting to the end station.

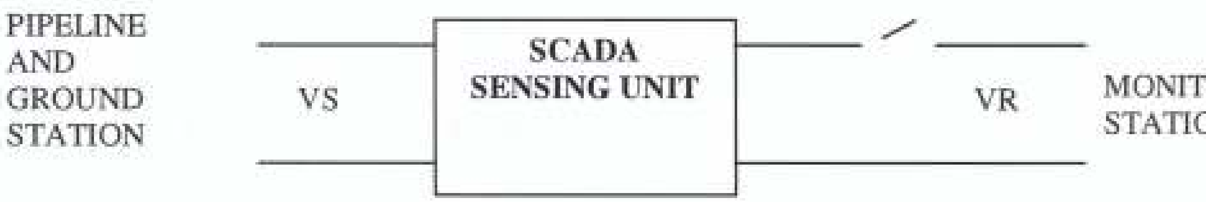


Fig 3.4 Impedance Matching Of The SCADA System.

3.3.1 EQUIVALENT ELECTRICAL CIRCUITS OF THE SCADA SYSTEM

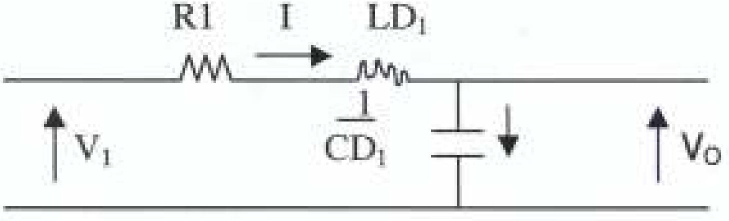


Fig.3.5 Electrical Representation Of The Sensor, Pipeline And Earth System.

Represent all the elements as follows.

$$R_1 = Z_1$$
$$LD_1 = Z_2$$
$$\frac{1}{CD_1} = Z_3$$

$$V_1 - V_0 = (Z_1 + Z_2)I \quad \text{.................................3.17}$$

$$V_0 = Z_3 I \quad \text{.................................3.18}$$

$$\therefore I = \frac{V_0}{Z_3} \quad \text{.................................3.19}$$

substituting for I in 3.17

$$V_1 - V_0 = (Z_1 + Z_2)\frac{V_0}{Z_3} \quad \text{.............................3.20}$$

$$V_1 = (Z_1 + Z_2)\frac{V_0}{Z_3} + V_0 \quad \text{.............................3.21}$$

$$V_1 = \left[\frac{Z_1 + Z_2}{Z_3}\right]V_0 \quad \text{.....................................3.22}$$

$$(T.F)_1 = \frac{V_0}{V_1} = \frac{1}{\left(\frac{Z_1 + Z_2}{Z_3}\right) + 1} \quad \text{..................3.23}$$

$$(T.F)_1 \frac{V_0}{V_1} = \frac{Z_3}{Z_1 + Z_2 + Z_3} \quad \text{.........................3.24}$$

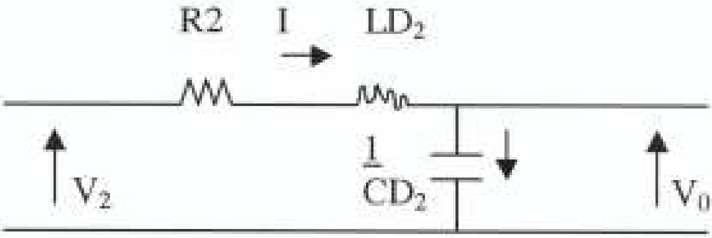


Fig.3.6 Electrical Representation Of The RTU And Communication System.

Represent all the elements as follows: -

$$R_2 = Z_4$$

$$LD_2 = Z_6$$

$$\frac{1}{CD_2} = Z_6$$

$$V_2 - V_0 = (Z_4 + Z_5)I \text{..........................} 3.25$$

$$V_0 = Z_6 I \text{..} 3.26$$

$$\therefore I = \frac{V_0}{Z_6} \text{..} 3.27$$

Substituting for I in 3.25

$$V_2 - V_0 = \left(Z_4 + Z_5\right)\frac{V_0}{Z_6} \text{.......................} 3.28$$

$$V_2 = \left(Z_4 + Z_5\right)\frac{V_0}{Z_6} + V_0 \text{......................} 3.29$$

$$V_2\left\{\frac{Z_4 + Z_5}{Z_6} + 1\right\}V_0 \text{................................} 3.30$$

$$(T.F)_2 \frac{V_0}{V_2} = \frac{1}{\left(\dfrac{Z_4 + Z_5}{Z_6}\right) + 1} \text{.....................} 3.31$$

$$(T.F)_2 \frac{V_0}{V_2} = \frac{Z_6}{Z_4 + Z_5 + Z_6} \text{......................} 3.32$$

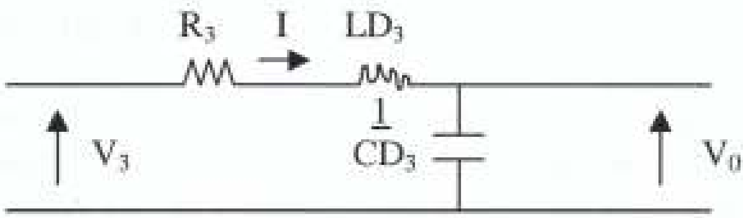


Fig. 3.7 Electrical Representation Of The Monitoring Station.

Represent all the elements as follows: -

$$R_3 = Z_7$$
$$LD_3 = Z_8$$
$$\frac{1}{CD_3} = Z_9$$

$$v_3 - v_0 = \left(z_7 + z_8\right) I \quad \text{.....................3.33}$$

$$v_0 = z_9 I \quad \text{...3.34}$$

$$\therefore I = \frac{v_0}{z_9} \quad \text{..3.35}$$

Substituting for I in (3.33)

$$v_3 - v_0 = \left(z_7 + z_8\right)\frac{v_0}{z_9} \quad \text{........................3.36}$$

$$v_3 = \left(z_7 + z_8\right)\frac{v_0}{z_9} + v_0 \quad \text{........................3.37}$$

$$v_3\left[\frac{z_7 + z_8}{z_9} + 1\right] v_0 \quad \text{...............................3.38}$$

$$(\text{T.F.})_3 \frac{v_0}{v_3} = \frac{1}{\left(\frac{z_7 + z_8}{z_9}\right)} + 1 \quad \text{.................3.39}$$

$$(\text{T.F.})_3 \frac{v_0}{v_3} = \frac{z_9}{z_7 + z_8 + z_9} \quad \text{...................3.40}$$

3.4 REMARKS

Effective and efficient signal transmission in this system is crucial. The signal sensed must be properly transmitted and monitored at the monitoring station without distortion. To achieve this, the impedances at the different stages in the transmission line from the source to the workstation must be properly matched. This is clearly shown in the above analysis.

It can therefore, be deduced that the impedances are properly matched. Hence:

$$(TF)_1 \equiv (TF)_2 \equiv (TF)_3$$

$$\text{or } \frac{V_0}{V_1} \cong \frac{V_0}{V_2} \cong \frac{V_0}{V_3}$$

$$\text{or } \frac{Z_3}{Z_1 + Z_2 + Z_3} \cong \frac{Z_6}{Z_4 + Z_5 + Z_6} \cong \frac{Z_9}{Z_7 + Z_8 + Z_9}$$

Under this condition, the signal sensed on the pipeline will be correctly monitored at the workstation (control room) with minimal distortion.

3.5 SYSTEM FLOW CHART

SYSTEM FLOWCHART

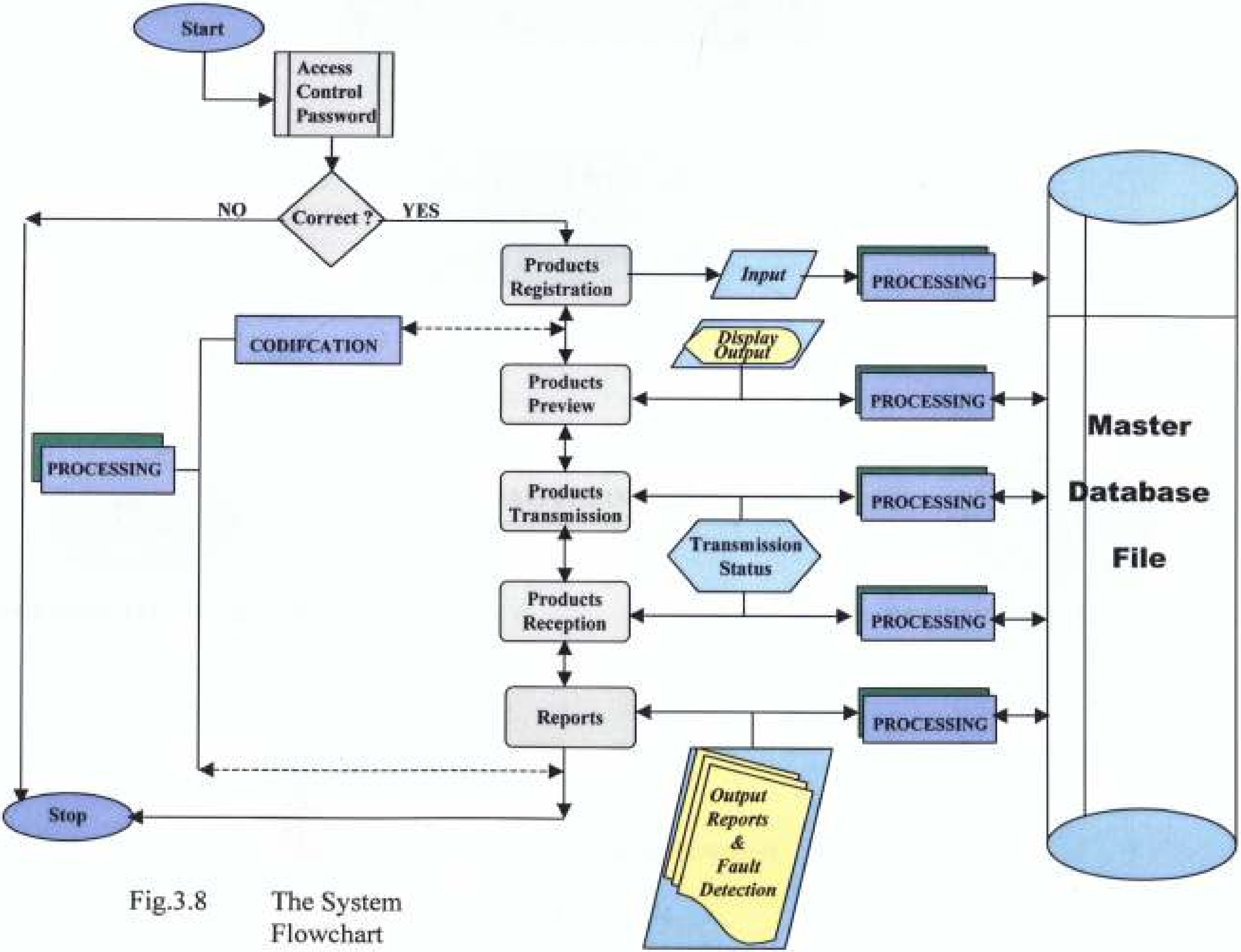


Fig.3.8 The System Flowchart

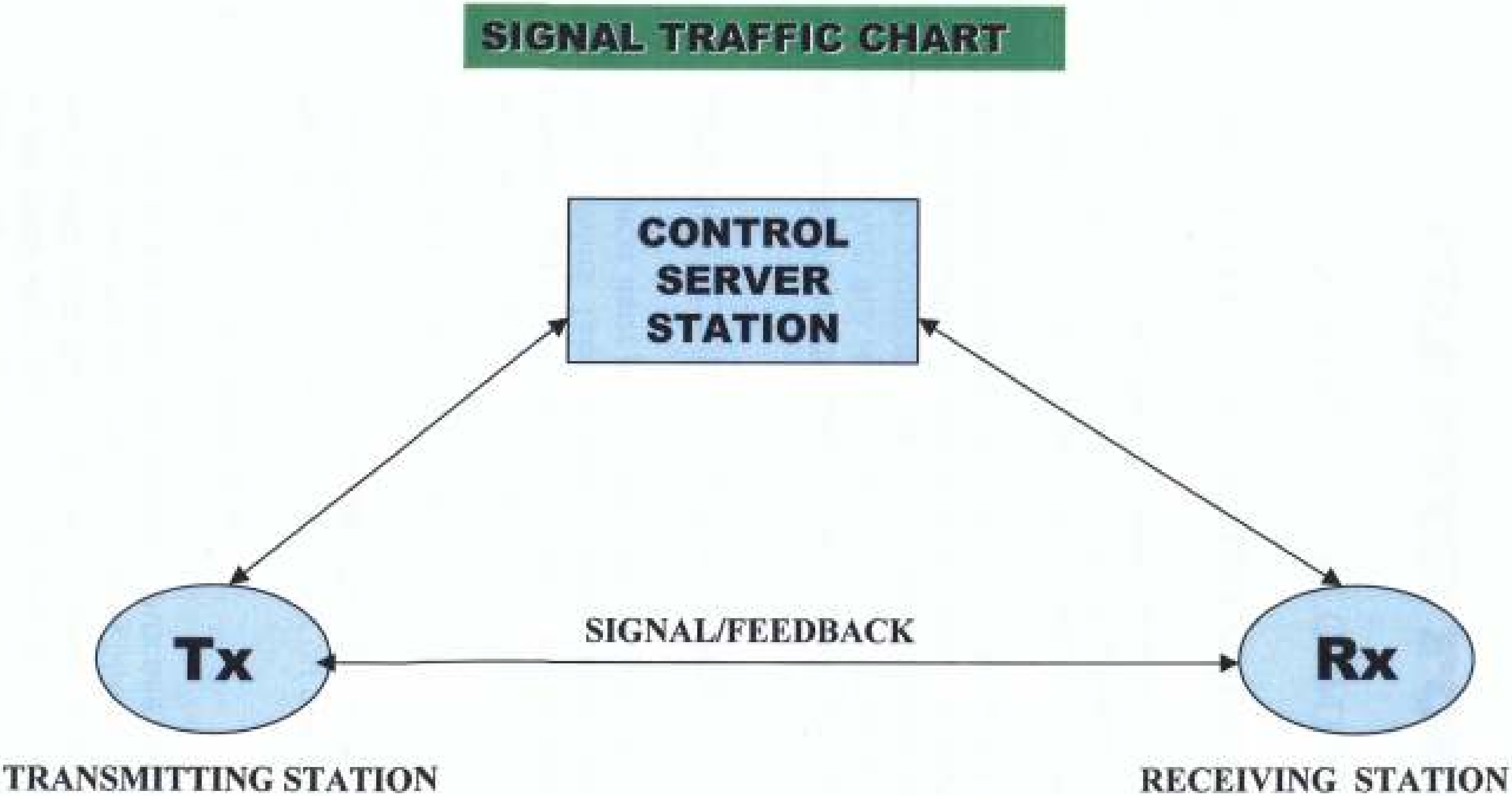


Fig.3.9 Signal Flowchart

CHAPTER FOUR

SYSTEM DEVELOPMENT

4.1 APPLICATION OF THE DEVELOPED SOFTWARE

Petroleum Products Monitoring System Software is designed to monitor the transmission of various kinds of petroleum products. It helps to detect and track down any problem that may occur along the pipelines.
To run the system software, double-click the PPMS icon on the desktop, the introductory window of the system is displayed. Click the "next" button to continue. The main menu called main switchboard is displayed but you are required to enter the password and users name before access can be granted to the system. The system is operated as follows:

1. PRODUCT CODING & REGISTRATION:

   All products must be registered and coded with a unique code. This form contains product code, product name and unit of measure. Example PMS is a code for premium motor spirit. After entering all necessary information, click ok.

2. PRODUCT LIST PREVIEW:

   This option is provided to view product list and their corresponding code at a time. Click on this button to preview.

3. PRODUCT TRANSMISSION

   This is where main transmission process takes place. Clicking on this form will lead you to another interface form where necessary data about the transmission must be entered. Keying in the code will bring other information about the product and then prompt you to enter other data of transmitted products, which must be batched, and the batch number must be entered into its field. Note that the batch number must be unique to each batch. Other data such as quantity, transmitting station and destination must be entered among others, then click ok. After this, there must be a confirmation signal and this is done in menu five.

4. PRODUCT IN FLOW RECEIPT

At the receiving station, the receiver clicks on this button to get all information about a transmitted product. The batch number is the first data to be supplied. The batch numbers locates the appropriate transmitted product and bring out all information about the product that has been transmitted. The receiver obtains the batch number and other information status, which are originated from the transmitting station. There is an error alert if there is a difference in the quantity transmitted and the quantity received and this helps to detect any breakage on the pipeline.

There must be a feed back signal after any product is received. This is done in the transmission status menu button.

5. TRANSMISSION STATUS

This button is used to send confirmation signal after a product is being transmitted as well as feed back signal after a product is received. Transmission query is also done here in order to view at a glance how products are transmitted and received.

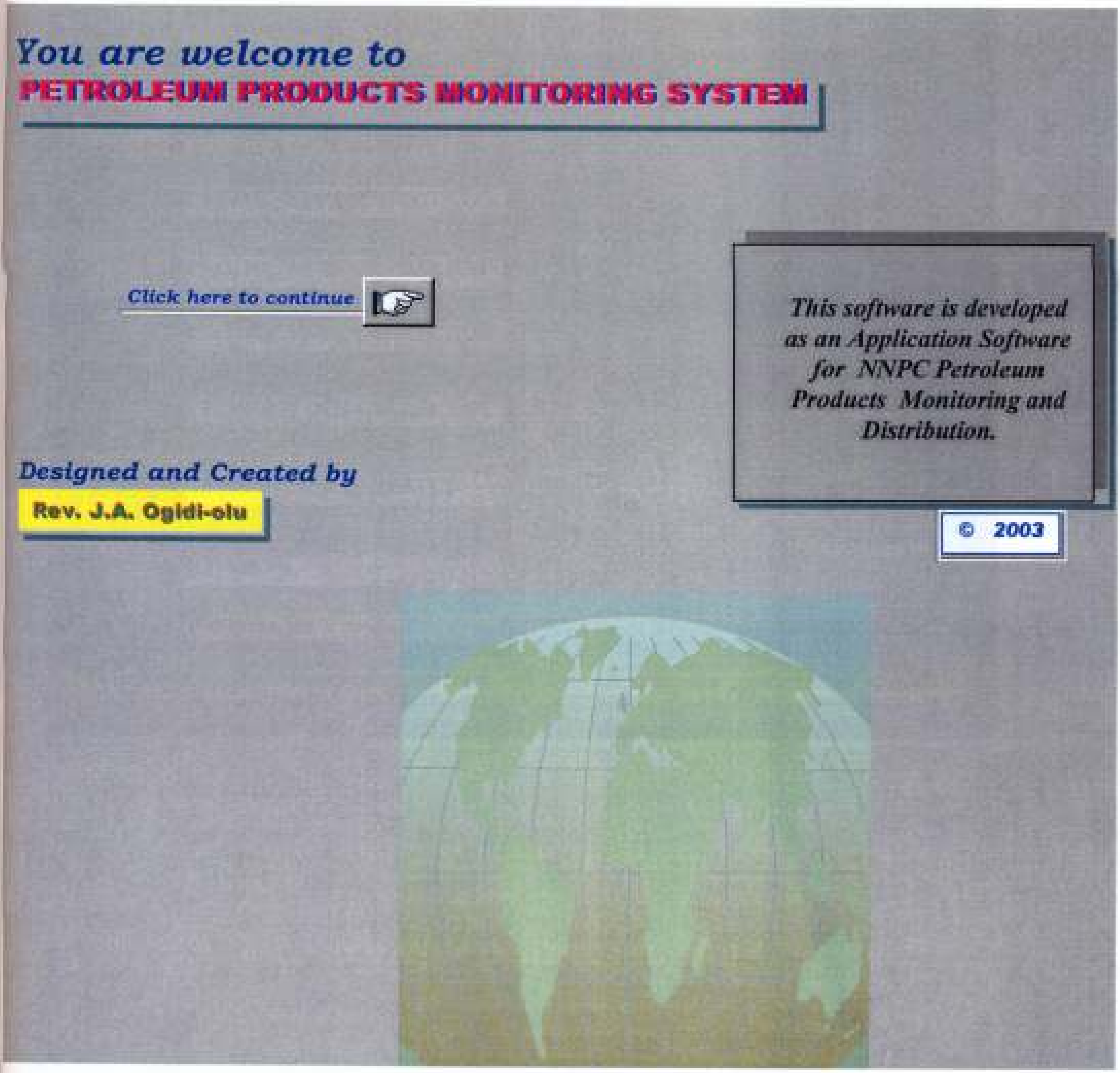
6. SYSTEM REPORT

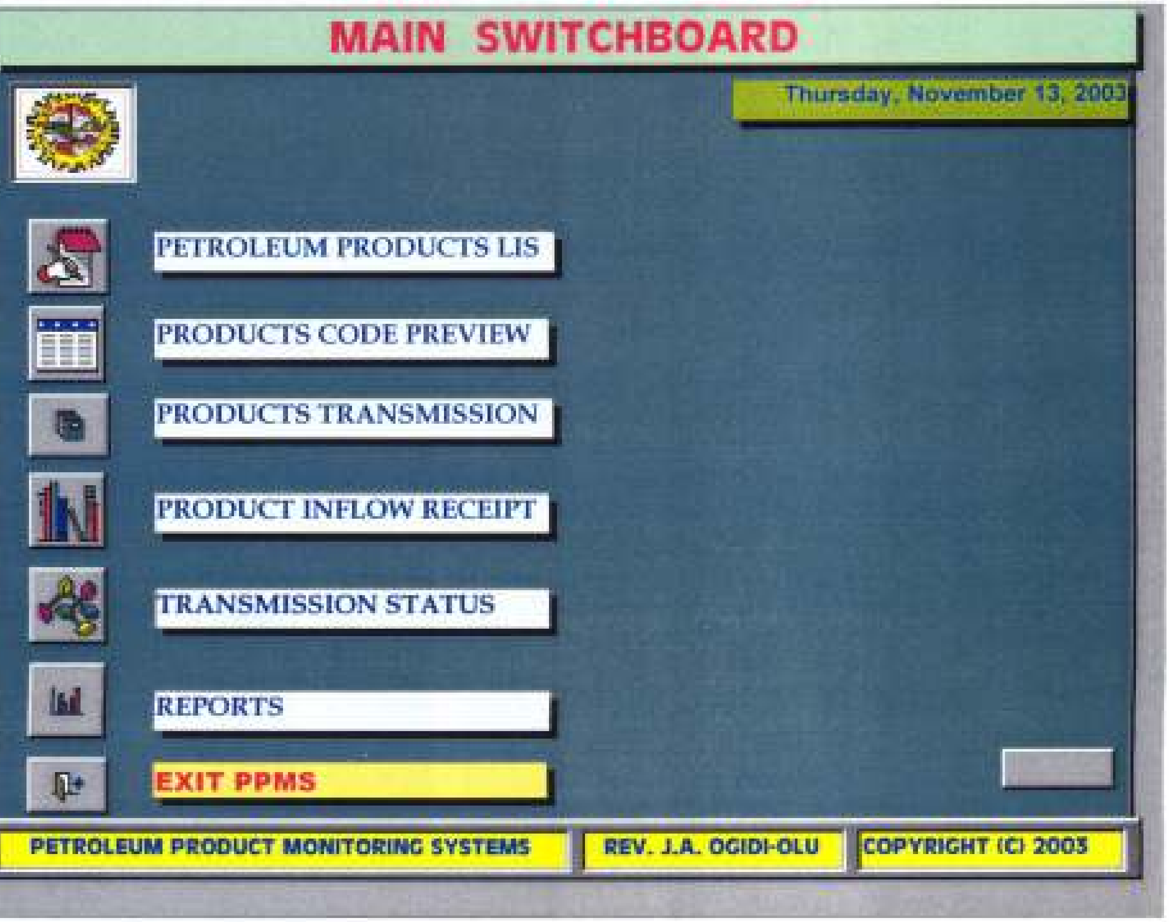
Here all important reports are generated and print out for necessary action or policymaking.
Also copy of any required report can be produced. To do this, click on the report button, click on the small button at the right side of the small form that will be displayed to select a report.
Click Ok and the report will be displayed.
Click on the File menu at the top of the report.
Click on "print" to print the report out.

7. EXIT

This button takes you out completely from PPMS. It closes all databases forms, reports and queries and then quit the program.

Note: This program is designed to work on Network, which is to connect all Depots and pumping stations.


You are welcome to
PETROLEUM PRODUCTS MONITORING SYSTEM
Click here to continue
This software is developed as an Application Software for NNPC Petroleum Products Monitoring and Distribution.
Designed and Created by
Rev. J.A. Ogidi-olu
© 2003


MAIN SWITCHBOARD
Thursday, November 13, 2003
PETROLEUM PRODUCTS LIS
PRODUCTS CODE PREVIEW
PRODUCTS TRANSMISSION
PRODUCT INFLOW RECEIPT
TRANSMISSION STATUS
REPORTS
EXIT PPMS
PETROLEUM PRODUCT MONITORING SYSTEMS
REV. J.A. OGIDI-OLU
COPYRIGHT (C) 2003

NNPCCode	PMS
DESCRIPTION	PREMIUM MOTOR SPIRIT
UNITS	LITRE
BATCH NO.	8
QUANTITY (LITRE	30,000.00
TRANSMISSION STATI	WARRI
RECEIVING STATIO	BENIN
TRANSMISSION TIME	8:00
TRANSMISSION DAT	09-Aug-03
TRANSMITTING OFFIC	MEDAIYEDU

QTY RECEIVED	21,000.00
ATE RECEIVE	09-Aug-03
IME RECIEVE	9:00:00 AM
ECEIVING OFFICE	OGIDI-OLU

OK EXIT

QUANTITY DIFFERENCES 9,000.00

4.2 TRANSMISSION RESULTS

TRANSMISSION STATUS:- 21-Oct-03

BATCH NO	CODE	DESCRIPTION	UNIT	QTY TRANS	SOURCE	DESTINATION	QTY REC.	QTY DIFF.	DATE SENT	DATE REC.
3	AGO	AUTOMOTIVE GAS OIL	LITRE	15,000.00	SAPELE	OLOGBO	10,000.00	5,000.00	8/3/03	8/3/03
4	DPK	DUAL PURPOSE KERO	LITRE	25,000.00	OLOGBO	BENIN	20,000.00	5,000.00	8/3/03	8/3/03
5	PMS	PREMIUM MOTOR SPIRIT	LITRE	10,000.00	AMUKPE	SAPELE	7,000.00	3,000.00	8/4/03	8/4/03
6	AGO	AUTOMOTIVE GAS OIL	LITRE	15,000.00	OLOGBO	BENIN	10,000.00	5,000.00	8/4/03	8/4/03
7	DPK	DUAL PURPOSE KERO	LITRE	20,000.00	WARRI	OGHARA	16,000.00	4,000.00	8/4/03	8/4/03
8	PMS	PREMIUM MOTOR SPIRIT	LITRE	30,000.00	WARRI	BENIN	21,000.00	9,000.00	8/9/03	8/9/03
9	AGO	AUTOMOTIVE GAS OIL	LITRE	30,000.00	WARRI	BENIN	22,000.00	8,000.00	8/9/03	8/9/03
10	DPK	DUAL PURPOSE KERO	LITRE	30,000.00	WARRI	BENIN	19,000.00	11,000.00	8/9/03	8/9/03
1	ATK	AVIATION TURBINE KERO	LITRE	10,000.00	WARRI	SAPELE	10,000.00	0.00	2/8/03	2/8/03
2	PMS	PREMIUM MOTOR SPIRIT	LITRE	20,000.00	WARRI	BENIN	15,000.00	5,000.00	2/8/03	2/8/03

4.3 TYPICAL INSTALLATION SET-UP

A typical installation of the SCADA system on an oil pipeline for the purpose of detecting pipeline vandalisation is as shown in the figures below. The installation makes use of the MOSCAD intelligent RTU. The installation in Fig 4.1 is for line monitoring without Camera, while that of Fig 4.2 has a miniature camera with wide-angle lens. If the proximity sensor detects an intruder, it can also automatically activate the camera to start capturing the image of the intruder and transmit the image to the supervisory control centre. Camera lighting can include Infrared source to illuminate the remote area at nights and at low visibility levels.

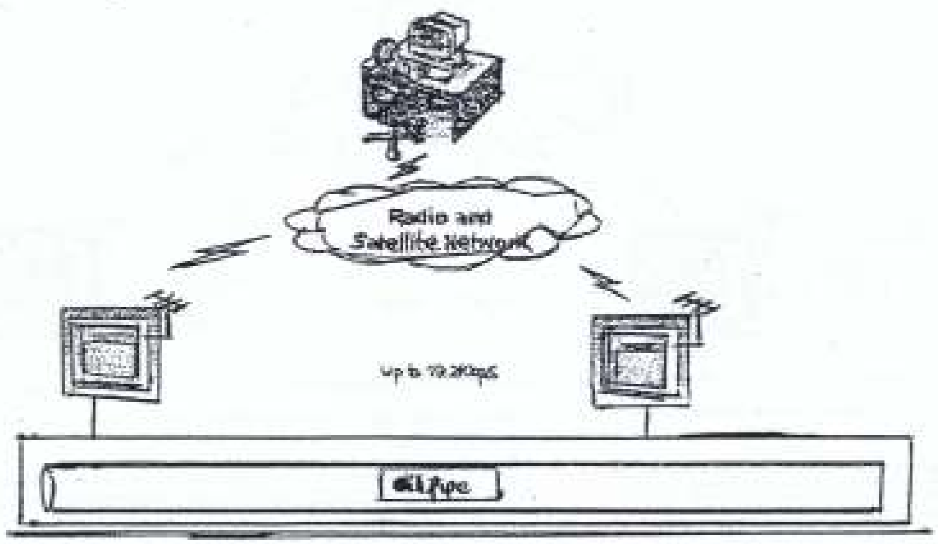


Fig. 4.1 SCADA Installation Without Camera.

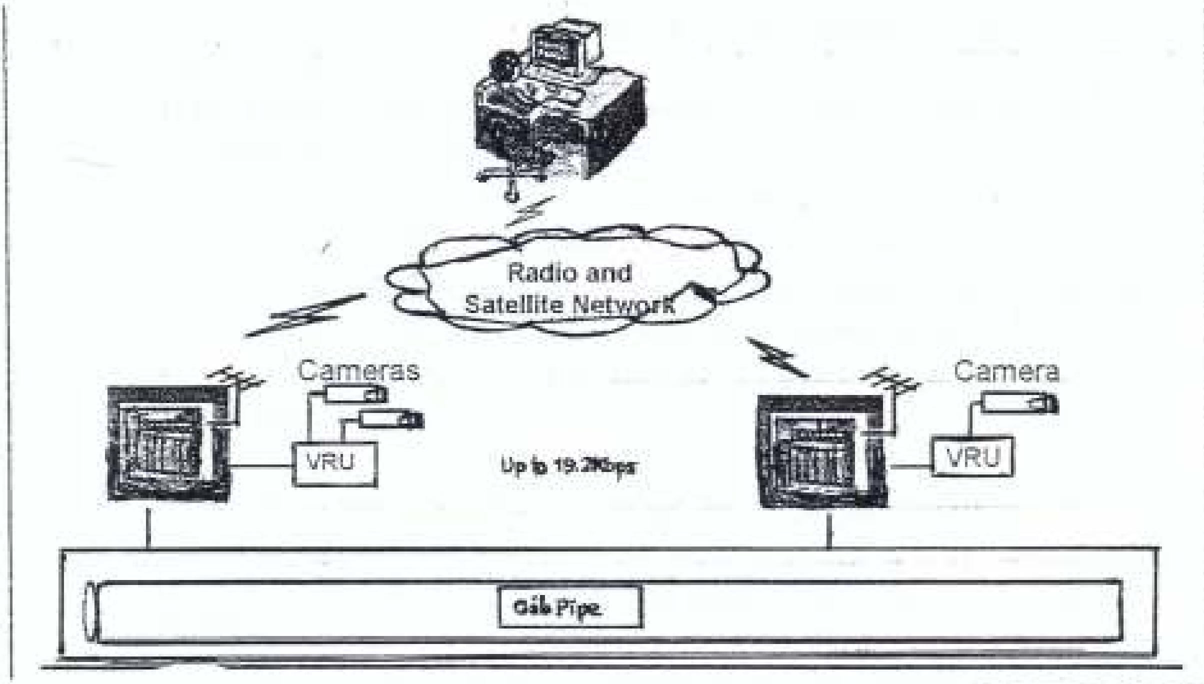


Fig 4.2 SCADA Installation With MOSCAD RTU And Camera.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The Supervisory Control And Data Acquisition (SCADA) has been tested and the application of the developed software has achieved the desired result.

If the result of this project is adopted by NNPC, it will go a long way to achieving the following:

- An effective security and monitoring of the over 5000km, NNPC (PPMC) Pipeline Network Nationwide.
- Complete elimination or considerable reduction of Pipeline Vandalisation as vandals will be promptly detected.
- Effective product distribution nationwide and conservation of meagre resources.

Monitoring pipeline integrity using the SCADA system with the aim of detecting and locating pipeline vandalisation is far better than any other method presently in use. The present methods employed by PPMC to check this nefarious activity include: -

(i) Recruitment of guards from the locality of the pipeline right-of –way to monitor the pipeline

(ii) Using staff and armed police men to patrol the pipeline right-of-way (ROW)

These methods are considered risky, time consuming, expensive and ineffective. Though the initial cost of installation of the SCADA system may look enormous, it is definitely not albatross and the long-term benefits are tremendous.

The SCADA system once in place will translate into a lot of cost savings when compared with the loss of revenue due to pipeline vandalisation in the five PPMC operations areas within a year. The effective monitoring of pipeline integrity will give an early and timely detection of line breaks and prevention of the corresponding huge products losses. Down time period will also be considerably reduced from the current high level.

5.2 RECOMMENDATION

The use of the SCADA System described in this project may not be limited to PPMC pipeline monitoring. By choosing a suitable and appropriate primary element (the Sensor) with some little modifications it can be recommended for use in other areas like: -

(i) Checking transmission / communication lines vandalisation in NEPA and NITEL respectively.

(ii) Automatic gas station monitoring and control by gas companies (e.g. Nigerian Gas Company)

(iii) Monitoring and control of integrity of rail lines of the Nigerian Railway Corporation.

REFERENCES

1. Ballanis, C.A. (1982) "Antenna Theory; Analysis and Design" John Willey and sons New York.

2. Breeds, J. (1994) "The satellite Book" 3rd Edition completely revised and updated. Swift Television Publication, England.

3. Chay, R. (2000) "Motorola SCADA Innovation MOSCAD". Publication of MOTOROLA Co; Nigeria, October 2000, pp 1-22

4. Desi, A.F. (2000) "Applied Tech. Mgt." Presentation on SCADA system for NGC (unpublished), October, pp 1-13

5. Golby, J. and Woodward. (1999) "FIND THAT LEAK" IEE Review, 1999, 45, (5), p219-221 A:\find that leak.htm

6. Gopal, M (1988) Digital Control Engineering Willey Eastern Ltd; New Delhi pp 150- 450

7. Hunaidi, O. and Chu, W.T. (1999) "Acoustical characteristics of leak Signal in plastics water distribution pipes." Applied Acoustics Journal (Unpublished).

8. Iloenyosi,F.I. (2000) "Cathodic Corrosion Technologies" Presentation on SCADA system for NGC Network Operations, November, pp 1-20

9. Meteke, G.A. (July 2001) "Pipeline Operations," a paper presented to Chief Officers on Management Development Prog. (Unpublished)

10. Nagarath, I.J. and Gopal, M.(1981) Control Systems Engineering (Second Edition) Willey Eastern Ltd; New Delhi. pp 1-12,448-551

11. Ogidi-Olu, J.A. (1998) "Design and construction of a 2.5m fibre Satellite Dish." A PG project work at The Federal University of Technology, Akure.

12. Okpidi, M.S. (Sept. 2001) "The Need for Effective Utilization of Work and Local Purchase Orders for the Maintenance of PPMC facilities." A project report for NNPC Chief Officers MDP 022.

13. PPMC (1999) "Pipeliners". An in-house journal of PPMC. (July/September), Vol.1, No 8 pp 4-5,8-10,17-18

14. PPMC (2000) "The impact of Pipeline interlink on the distribution of refined petroleum products in Nigeria."PPMC publication, pp 1-11

15. Sarjeant,J.W. and Dollinger,R.E.(1980) High-Power Electronics TAB Professionals and Reference book, Blue Ridge Summit,P.A. pp 20-22

APPENDIX 1 - PPMS PROGRAMING CODES

```
'-------------------------------------------------------------------------------
Option Compare Database
Option Explicit

Private Sub CodeButton_Click()
DoCmd.OpenForm "frmViewCode"
End Sub


Private Sub Command11_Click()
DoCmd.OpenForm "TransEntry"
End Sub

Private Sub Querybutton_Click()
DoCmd.OpenForm "frmMainStatus"
End Sub

Private Sub Report_Click()
DoCmd.OpenForm "frmMainReport"
End Sub

Private Sub Transacts_Click()
DoCmd.OpenForm "BatchQryfrm", acNormal
End Sub

Private Sub TransUpdate_Click()
DoCmd.OpenForm "CodeIdUpdate"
End Sub

Private Sub Xsetup_Click()
DoCmd.OpenForm "Setup User Right frm"
End Sub

Private Sub Exit_Click()
DoCmd.Close
DoCmd.Quit
End Sub
'------------------------------------------------------------------------

Option Compare Database
Option Explicit

Public Function VerifyAccessToFunction(xID, xLe)
   Dim x

   If Forms![frmMainScrn]![USER ID] > 0 Then 'USER RIGHTS ALREADY SETUP
      x = Forms![frmMainScrn]![Level]
      If x Like xLe Then
         VerifyAccessToFunction = False
      Else
         VerifyAccessToFunction = True
      End If
   Else   ' No User Rights -  Access Valid by default
```

```
      VerifyAccessToFunction = False
   End If
End Function

Public Function DisplayAccessDenied()
   SendKeys "{ESC}", True
   MsgBox "UNAUTHORIZED ACCESS ATTEMPTED", vbCritical
End Function
'------------------------------------------------------------------------------------------
Public Function VerifyAccess(xNm, xCo)
   Dim db As Database, urec As Recordset
   Static Trials As Integer

   DoCmd.Hourglass True
   If IsNull(Trials) Then Trials = 0
   Set db = DBEngine.Workspaces(0).Databases(0)
   Set urec = db.OpenRecordset("Setup User Rights Tbl", DB_OPEN_DYNASET)
   urec.FindFirst "[User Name]='" & xNm & "' And [User Code]='" & xCo & "'"
   If urec.EOF Then
      MsgBox "No User Setup Yet !", vbCritical
      'Forms![frmMainScrn]![USER ID] = 0
      urec.Close
      DoCmd.Hourglass False
      DoCmd.Close
      Exit Function
   End If

   If urec.NoMatch Then
      Beep
      MsgBox "INVALID USER ENTRY...ACCESS DENIED", vbCritical
      Trials = Trials + 1
      If Trials >= 3 Then
         Trials = 0
         urec.Close
         DoCmd.Hourglass False
         DoCmd.Quit
      Else
         DoCmd.Hourglass False
         urec.Close
      End If
   Else
'     Forms![frmMainScrn]![USER ID] = urec![ID] 'put on FedAduit
'     Forms![frmMainScrn]![level] = urec![level] 'put on FedAduit
      urec.Close
      DoCmd.Hourglass False
      DoCmd.Close
      DoCmd.SelectObject acForm, "MainSB"
   End If

End Function
```

```
Private Sub Verify_Click()
   Dim o
   o = VerifyAccess(uName, uCode)
End Sub

'-----------------------------------------------------------------------------
Option Compare Database
Option Explicit

Sub SeekX()

    Dim dbsNorthwind As Database
    Dim rstProducts As Recordset
    Dim intFirst As Integer
    Dim intLast As Integer
    Dim strMessage As String
    Dim strSeek As String
    Dim varBookmark As Variant

    Set orthwind = OpenDatabase("Code Table2x")
    ' You must open a table-type Recordset to use an index,
    ' and hence the Seek method.
    Set rstProducts = _
       dbsNorthwind.OpenRecordset("Products", dbOpenTable)

    With rstProducts
       ' Set the index.

.Index = "PrimaryKey"

       ' Get the lowest and highest product IDs.
       .MoveLast
       intLast = !ProductID
       .MoveFirst
       intFirst = !ProductID

       Do While True
          ' Display current record information and ask user
          ' for ID number.
          strMessage = "Product ID: " & !ProductID & vbCr & _
             "Name: " & !ProductName & vbCr & vbCr & _
             "Enter a product ID between " & intFirst & _
             " and " & intLast & "."
          strSeek = InputBox(strMessage)

If strSeek = "" Then Exit Do

          ' Store current bookmark in case the Seek fails.
          varBookmark = .Bookmark

          .Seek "=", Val(strSeek)

          ' Return to the current record if the Seek fails.
```

```
        If .NoMatch Then
          MsgBox "ID not found!"
          .Bookmark = varBookmark
        End If
      Loop

      .Close
    End With

    dbsNorthwind.Close

End Sub

'-------------------------------------------------------------------------------
Option Compare Database
Option Explicit

Private Sub Command22_Click()
DoCmd.Close
End Sub

Private Sub Form_Load()
[NNPCCode].SetFocus

 DoCmd.GoToRecord , , acNewRec
End Sub

Private Sub OK_Click()
'On Error GoTo ERR_HANDLER:
   Dim MYDB As Database, MYSET As Recordset
    ' Dim ans As String

    Set MYDB = DBEngine.Workspaces(0).Databases(0)
    Set MYSET = MYDB.OpenRecordset("Transactsx")

    MYSET.MoveLast
    MYSET.AddNew

    Do Until MYSET.EOF

        MYSET.MoveNext

    Loop

    MYSET.Close
    MYDB.Close
        DoCmd.DoMenuItem acFormBar, acRecordsMenu, acSaveRecord, , acMenuVer70
        DoCmd.GoToRecord , , acNewRec
        [NNPCCode].SetFocus

MsgBox ("RECORD SUCCESSFULLY UPDATED")

End Sub
```

```
'------------------------------------------------------------------------------------------------------------
Private Sub cmdGo_Click()
'On Error GoTo MSG
If [txtPurpose] = " " Then
 MsgBox "YOU HAVE NOT CHOOSE YOUR REPORT", vbCritical, "IVENTORY
MANAGEMENT SYSTEM"
   [txtPurpose].SetFocus
 Exit Sub
End If
If Me.txtPurpose = "PRODUCT LIST" Then
   DoCmd.Close
   DoCmd.OpenReport "ProdList", acViewPreview
ElseIf Me.txtPurpose = "TRANSMISSION REPORT" Then
   DoCmd.Close
   DoCmd.OpenReport "Transmission", acViewPreview
ElseIf Me.txtPurpose = "TRANSMISSION STATUS" Then
   DoCmd.Close
   DoCmd.OpenReport "Confirmation", acViewPreview
ElseIf Me.txtPurpose = "TRANSMISSION FEEDBACK REPORT" Then
   DoCmd.Close
   DoCmd.OpenReport "TransRecBalance", acViewPreview

End If

Exit Sub
End Sub

Private Sub Exit_Click()
DoCmd.Close acForm, "frmMainREPORT"

End Sub
'------------------------------------------------------------------------------------------------------
Option Compare Database
Option Explicit

Private Sub Command22_Click()
DoCmd.Close
End Sub

Private Sub Form_Load()
 DoCmd.GoToRecord , , acNewRec
[NNPCCode].SetFocus
End Sub

Private Sub OK_Click()
Dim FACT, FACT1 As String
Dim MSG, STYLE, TITLE, Response As String

        MsgBox "RECORD UPDATED"
        DoCmd.GoToRecord , , acNewRec
        [NNPCCode].SetFocus

End Sub
```

```
'***************************************************************************
Private Sub OK2_Click()

  Dim MYDB As Database, MYSET As Recordset

   Set MYDB = CurrentDb
   Set MYSET = MYDB.OpenRecordset("Codes Table2x")
   MYSET.FindFirst "[NNPCCode] = ' " & Me.NNPCCode & " ' "

  If MYSET.NoMatch Then
      MsgBox ("RECORD NOT FOUND")
   End If


   MYSET.Close
   MYDB.Close

End Sub
'------------------------------------------------------------------------------------
Option Compare Database
Option Explicit

Private Sub Command22_Click()
DoCmd.Close
End Sub

Private Sub Form_Load()
 [QTYREC].SetFocus
End Sub

Private Sub OK_Click()
Dim FACT, FACT1, REST, TTL As String
Dim MSG, STYLE, TITLE, Response As String
FACT = [QTYDIFF]
'[TAMOUNT].Locked = False
'[TAMOUNT].SetFocus

      If IsNull([QTYDIFF]) Then
         [QTYDIFF] = 0
         [OK].SetFocus
        Exit Sub
      End If

         [QTYDIFF].Locked = False
         [QTYDIFF] = Val([QTY]) - Val([QTYREC])
         [QTYDIFF].Locked = True
'        MsgBox "RECORD SUCCESSFULY UPDATED"

         If [QTYDIFF] = "0" Then
           MsgBox "THE QUANTITY IS CORRECTLY DELIEVERED", 32, "PPMS"
'             [amt].SetFocus
          DoCmd.GoToRecord , , acNewRec
```

```
        '[NNPCCode].SetFocus
         DoCmd.Close

             Exit Sub

        ElseIf [QTYDIFF] > "0" Then
        MsgBox "ERROR ALART.....  " & [QTYDIFF] & " LITRES IS LOST IN
TRANSMISSION"
         DoCmd.GoToRecord , , acNewRec
         DoCmd.Close
        '[NNPCCode].SetFocus
             Exit Sub
        End If

       End Sub

'***********************************************************************
Private Sub OK2_Click()

  Dim MYDB As Database, MYSET As Recordset

   Set MYDB = CurrentDb
  Set MYSET = MYDB.OpenRecordset("Codes Table2x")

  MYSET.FindFirst "[NNPCCode] = ' " & Me.NNPCCode & " ' "

 If MYSET.NoMatch Then
     MsgBox ("RECORD NOT FOUND")
  End If

  MYSET.Close
  MYDB.Close
End Sub
'------------------------------------------------------------------------
Option Compare Database
Option Explicit

Private Sub cmdGo_Click()
'On Error GoTo MSG
If Me.txtPurpose = "TRANSMISSION SIGNAL" Then
  DoCmd.Close
  DoCmd.OpenForm "ConfirmQryfrm"
ElseIf Me.txtPurpose = "RECEIPT FEEDBACK" Then
  DoCmd.Close
  DoCmd.OpenForm "ConfirmQryfrm2"
ElseIf Me.txtPurpose = "TRANSMISSION ENQUIRIES" Then
  DoCmd.Close
  DoCmd.OpenReport "Confirmation", acViewPreview
End If

Exit Sub
MSG:
End Sub
```

```
Private Sub Exit_Click()
DoCmd.Close acForm, "frmMainStatus"
End Sub
'-----------------------------------------------------------------------------------------------------

Private Sub LooCok_Click()
MsgBox ("CONFIRMATION SUCCESSFUL")
DoCmd.Close
End Sub

Private Sub LocExit_Click()
DoCmd.Close
End Sub

Private Sub LooCok_Click()
DoCmd.Close
   DoCmd.OpenForm "ConfirmTransfrm"
End Sub

Private Sub LocExit_Click()
DoCmd.Close
End Sub

Private Sub LooCok_Click()
DoCmd.Close
   DoCmd.OpenForm "Feedbackfrm"
End Sub

Private Sub LocExit_Click()
DoCmd.Close
End Sub

Private Sub LooCok_Click()
MsgBox ("FEEDBACK SUCCESSFULLY COMPLETED")
DoCmd.Close
End Sub
```

APPENDIX II

A brief summary of the servicing jobs for the installation of this SCADA system as it affects the instrumentation is as shown in table V

Table 5 BEME/Scope Of Work For A Typical SCADA System Installation for 100Km Distance.

ACTIVITY	WORKSCOPE	QTY	UNIT PRICE	AMOUNT $
INSTALLATION OF FLOW SWITCHES (SENSORS)	1. Supply of flow switch (es)	1	2,000	2000
INSTALLATION OF DCS INSTRUMENT	1. Provision of Engineering station.	1	15000	15000
	2. Provision of operator station	1	25000	25000
	3. Provision of operator console	1	12000	12000
	4. Provision of communication consoles (MOSCAD)	2	120,000	240,000
	5. Supply of UPS unit, distribution boards.	1	80,000	80,000
	6. Supply and installation of Duplex field control station.	2	25,000	50,000
	7. Supply and installation of event, log and shift printers.	1	5,000	5,000
	8. Supply of hard copier unit.	1	6,500	6,500
	9. Supply of terminal board cubicle	2	500	1,000
	10. Supply of HF bus cable	LOT		10,000
	11. Supply of software	LOT		15,000
	12. Contingency			40,000
	TOTAL			**501,500**