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Assessment And Upgrading of SCADA System For Petroleum Pipelines

تقيم وترقية نظام التحكم الاشرافي في منظومة خطوط انابيب النفط

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of M.Sc. in Electrical Engineering (POWER)

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الآيـــــة

قال تعالى:

﴿وَوَصَّيْنَا الْإِنْسَانَ بِوَالِدَيْهِ إِحْسَانًا حَمَلَتْهُ أُمُّهُ كُرْهًا وَوَضَعَتْهُ كُرْهًا وَحَمْلُهُ وَفِصَالُهُ ثَلَاثُونَ شَهْرًا حَتَّى إِذَا بَلَغَ أَشُدَّهُ وَبَلَغَ أَرْبَعِينَ سَنَةً قَالَ رَبِّ أَوْزِعْنِي أَنْ أَشْكُرَ نِعْمَتَكَ الَّتِي أَنْعَمْتَ عَلَيَّ وَعَلَى وَالِدَيَّ وَأَنْ أَعْمَلَ صَالِحًا تَرْضَاهُ وَأَصْلِحْ لِي فِي ذُرِّيَّتِي إِنِّي تُبْتُ إِلَيْكَ وَإِنِّي مِنَ الْمُسْلِمِينَ﴾﴿15﴾

ا لأحقـا ف

DEDICATION

To **My Father** who supported me and stood beside me after God Almighty and was the reason he became a dream come true Some things have no value them have only after the turn into a reality to me a multitude of thanks and appreciation, and I ask God that my Lord will protect you and guide you all that is good and gives your health and wellness and to bless paradise.

To **My Mother** compassionate, which was parked to the side durable hardship upbringing and pray for me to the back of the unseen superiority and success that has reached what we have reached now, it was all after reconciling god almighty. God ask to protect you and provide you with health and wellness and to bless paradise.

To **My wife, brother, Sister,** thank you for your supporting, have and me all the love and appreciation of respect, I am the luckiest man in the world to have such a wonderful family.

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ABSTRACT

In this thesis, assessment and upgrading of SCADA system in Petroleum pipelines is proposed, the Pipeline of Petro energy Company (Sudan branch) was considering as a case study to show the advantage of SCADA system in Petroleum pipelines and how can Achieve steady state operation. The Pipeline Control System uses SCADA to provide information to the operator in the control centre. SCADA systems displays the data transmitted from all the sensors on the pipeline and pump stations to the video monitor and displays the parameters and devices status at each location on the pipeline and pump stations. To make a project easy to understand we used the SCADA Software (wincc6) to simulate the pump station and make connection between a PLC software and SCADA software by using communication drive. the PLC provide information to the SCADA system about the animations of pump station equipments (pump,valve,motor..), by using the ladder program which downloaded in a PLC memory and the SCADA system displays these equipments and parameters.

Sudden changes in the pipeline pressure can indicate malfunctioning equipment, a leak or other undesirable condition. In order to maintain the whole pipeline in safe and smooth operation state and achieve steady state pipeline operation we have to upgrading of SCADA systems by adding more dynamic pressure and flow observation points along the pipeline, where the relevant signals will be acquired and delivered to existing running SCADA system by using remote terminals units. the pressure observation points along the oil pipeline in some of pump stations ,BV rooms and Cp stations in PE pipeline to allow operators to closely monitor pressures and device status at each location on the pipeline and know the exact cause of the failure so that they can

quickly notify the appropriate maintenance personnel. the benefits of SCADA offers in terms of reducing the cost of routine visits to monitor facility operation. The value of these benefits will grow even more if the facilities are very remote and require extreme effort.

المستخلص

في هذه البحث تم تقيم وترقية نظام التحكم الاشرافي في منظومة خطوط انابيب البترول ، حيث تم اعتبار خط انابيب شركة بتروانرجي فرع السودان كنموذج للدراسة ، حيث يبين البحث اهمية استخدام التحكم الاشرافي في خطوط انابيب النفط لتحقيق كفاءة النقل و التشغيل المستقر.

عادة يستخدم نظام الاسكادا في منظومة انابيب النفط ليمد مشغل مركز التحكم بالمعلومات اللازمة وذلك من خلال عرض البيانات من الحساسات والاجهزة الموجودة على خط الانابيب ومحطات ضخ البترول في شاشة العرض الرئيسية التي توضح حالة الاجهزة و قيم القراءات المختلقة من ضغط وحرارة وغيره في كل موقع دا محطات الضخ او في خط الانابيب. ولجعل الامر اكثر وضوحاً تم في هذا البحث استخدام برنامج لمحاكاة نظام الاسكادا مع برنامج اخر لمحاكاة نظام المتحكم المنطقي القابل للبرمجة ، ومن خلال الربط بينهما يقوم برنامج المتحكم المطقي بامداد برنامج الاسكادا بطريقة عمل الاجهزة والحساسات من خلال البرنامج الموجود في ذاكرة برنامج المتحكم المنطقي بيما يتم عرض تلك الاجهزة والحساسات في شاشة برنامج الاسكادا ، دور المشغل هو التعامل مع شاشة الاسكادا واتخاذ القرار المناسب بينما يقوم برنامج الاسكادا بالتخاطب مع برنامج المتحكم المنطقي لتنفيذ تلك الاوامر.

في حالة حدوث تغير مفاجئ للضغط او خط نقل البترول قد يكون ذلك مؤشر لوجود مشكلة تسريب او حالة غير مرغوب بها ، وللمحافظة على نقل البترول بسلامة وسلاسة وكفاءة عالية تحقق التشغيل المستقر لابد من ترقية نظام التحكم الاشرافي ليقوم بذلك وافضل طريقة لذلك باضافة نقاط لملاحظة الضغط والتدفق باستخدام الوحدات الطرفية القابلة للبرمجة وربطها مع نظام الاسكادا الموجود مسبقا، مما يسمح لمشغل مركز التحكم بمراقبة جميع قراءات اجهزة قياس الضغط والتدفق والحرارة على طول خط انابيب البترول وفي محطات الضخ وبالتالي ضمان مراقبة الخط من البداية الى النهاية ، وعند حدوث اي تغير في اي قيمة يمكن للمشغل تحديد موقع الخلل وتحليل المشكلة وبالتالي الاسراع في اخطار فريق الصيانة لذلك فان نظام التحكم الاشرافي في منظومة انابيب البترول وفر كثيراً من الجهد والعناء وقلل كثيراً من تكلفة مراقبة الاشخاص لتلك المناطق البعيدة ووفر كثيراً من المال .

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LIST OF ABBREVIATIONS

Symbol	Nomenclature
PE	Petro Energy Company
SCADA	Supervisory Control and Data Acquisition
HMI	Human Machine Interface
PLOP	Pipeline Operation
RTU	Remote Terminal Unit
IED	Intelligent Electronic Device
PLC	Programmable Logic Control
MTU	Master Terminal Unit
CP	Cathodic Protection
PT	Pressure Transmitter
FT	Flow Transmitter
BV	Block Valve
RS	Recommended Standard
OPC	Ole for Process Control
SQL	Structured Query Language
LAD	Ladder Language
WinCC	Windows Control Centre
PS	Pump Station
LAN	Local Area Network
WAN	Wide Area Network
KRC	Khartoum Refinery Corporation
GNPOC	Greater Nile Petroleum Company
RTAP	Real Time Applications Platform
PCS	Pipeline Control System
I/O	Input Output Module

CFE	Communication Front End
GUI	Graphical User Interface
MMI	Man Machine Interface
UCP	Unit Control Panel
PCV	Pressure Control Valve
MCC	Main Control Centre
SCS	Safety Control System
HC	Heavy Crude
LC	Light Crude
ESD	Emergency Shut Down
AI	Analog Input
AO	Analog Output
DI	Digital Input
DO	Digital Output
SDH	Synchronous Digital Hierarchy
PV	Photo Voltage
TT	Temperature Transmitter
IP	Internet Protocol
DCS	Distributed Control System
PID	Proportional Integral Derivative
CPU	Central Processing Unit
RTD	Resistance Temperature Detector
SCR	Safety Control Relay
SRV	Surge Relieve Valve
RFI	Radio Frequency Interference
ROM	Read Only Memory
RAM	Random Access Memory
EEPROM	Electrically Erasable Programmable Read Only Memory

HQ	Head Quarter

CHAPTER ONE

INTRODUCTION

1.1 Overview:

The most popular way of transporting petroleum products is by the use of pipelines. The use of pipelines eases the movement of petroleum products from one location to the other. The distances covered by these pipelines are in thousands of miles passing through cities and villages [1]. Most of the data that is received by a control station is provided by supervisory control and data acquisition (SCADA) systems. These systems are essentially sophisticated communications systems that take measurements and collect data along the pipeline (usually in metering or pump stations and valves) and transmit the data to the centralized control station. Flow rate through the pipeline, operational status, and pressure and temperature readings may all be used to assess the status of the pipeline at any one time. These systems also work in real time, so there is little lag time between taking measurements along the pipeline and transmitting them to the control station [2]. Equipment status scan times are depending on the communication technology used in the field. This information allows pipeline engineers to know exactly what is happening along the pipeline at all times, which permits quick reactions to equipment malfunctions, leaks, or any other unusual activity along the pipeline, as well as to monitoring load control. Some SCADA systems also incorporate the ability to operate certain equipment along the pipeline remotely, including pump stations, which allows engineers in a centralized control center to adjust flow rates in the pipeline immediately and easily. [3]

The concept of SCADA in the control of pipeline systems is straight forward, but the application is somewhat more complex. A command Initiated from the control centre travels from the control centre workstation, through a series of hierarchical sub-systems, to the device Affected by the command.

The SCADA system in general includes:

- The control centre workstation
- The host level or master computer workstations
- The communications front end (CFE)
- The remote terminal unit (RTU)
- A programmable logic controller (PLC), and
- The various field instruments and devices in the system. [4]

Figure (1.1) is an illustration of the different levels of the SCADA system.

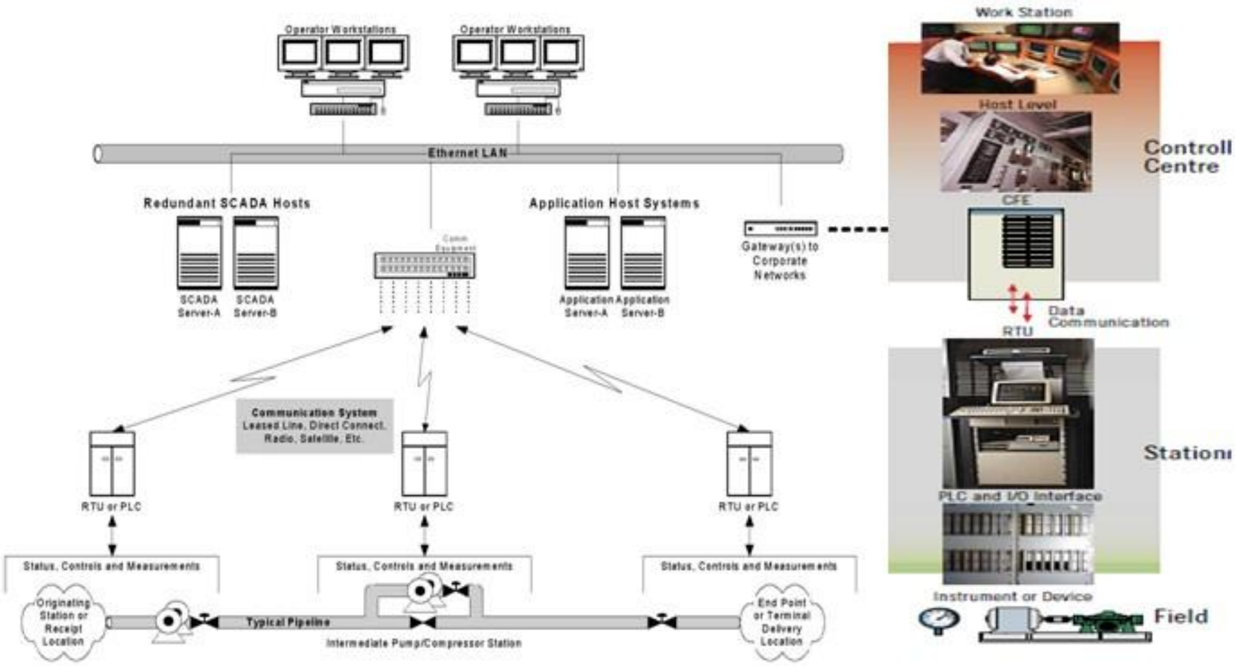

Figure (1.1): levels of the SCADA system

In this thesis, SCADA system and upgrading is proposed. The main focus on Pipeline Control System (PCS), to monitored Pipeline pressure constantly by remotely controlled, because sudden changes in the pipeline pressure can indicate malfunctioning equipment, a leak or other undesirable condition. To achieve steady state pipeline operation. SCADA systems allow operators to closely monitor pressures and device status at each location on the pipeline. Also monitoring all pipeline system and pump stations by Creating more observation points pressure and flow along the oil pipeline, To know the exact cause of the failure so that they can quickly notify the appropriate maintenance personnel. To maintain safe and smooth operation.

1.2 Literature Review:

Supervisory Control and Data Acquisition (SCADA) systems, of one type or another, are everywhere in modern life. Even the oven in a new stove that is equipped with a meat probe sensor can be considered a SCADA system. It can be set to provide heat in the oven to a preset temperature. When the conditions in the oven control are reached, the meat is cooked. The oven then switches from cooking to heat maintenance until you decide it is time to serve the dinner [5]. In a new car, there are monitors and controllers in the system for a myriad of conditions. Turning the key in the ignition starts a chain of events that start the engine. Sensors send thousands of pieces of information every second to monitor and control the car’s essential systems. There are a number of controllers that receive information regarding engine speed, temperatures, air/fuel mixtures, the level of oxygen in the exhaust fumes, and a host of other operating conditions. Just like a SCADA system, the computer analyzes the information and, in response, sends out commands that adjust the way the engine runs. Information is sent to you on a number of displays and alarms. Your speed is shown on the speedometer. A door ajar creates an audible alarm. When you hear the buzzer, you close the door. When you notice the photo-radar unit at the roadside, you can check your road speed to avoid a ticket. Another computerized control system similar in principle to a SCADA system: an automatic pilot. If, for example, the human pilot preset the automatic pilot for a horizontal flight at 3 000 m, on a bearing of 180° (due south) the auto pilot would maintain the flight level and heading. If a strong wind is blowing from the east and nothing was done about it, the wind would blow the plane off course. However, the automatic pilot receives signals from sensors throughout the plane's control system. The automatic pilot analyzes the information and corrects any deviation from the preset course. Changes are displayed for the pilot who monitors and controls the flight of the aircraft. While the auto pilot is making changes and corrections, the pilot can override or take control of operations at any time.

The Pipeline Control System (PCS) is a type of SCADA system. Like the computerized components of the automatic pilot, SCADA gathers data and provides remote control of the equipment related to the data. The PCS is a combination of computer components, programs, and display terminals and communications equipment. The PCS permits operation of the pipeline from the control centre by monitoring and controlling pump units, variable frequency drive units, pressure control valves, and sectionalizing valves along the pipeline. Although SCADA can be compared to the eyes, ears and even hands of the pipeline, it is the operator who is the brain of the system. Like the data monitoring systems in a new vehicle or the controls of the automatic pilot, the Pipeline

Control System (or PCS) uses SCADA to provide information to the operator. In the control centre, PCS displays the data transmitted from all the sensors on the pipeline to the video monitor. The data is monitored and, based on knowledge of pipeline operation decisions are made that will optimize the flow of product down the pipeline to its destination. Once a decision is made, the mouse is used to tell the system to make changes in the pipeline's operation. SCADA carries the "message" to the appropriate piece of equipment, and carries out instructions such as starting, stopping, opening or closing, whatever is specified. [6]

1.3 Thesis Objectives:

The main contributions of this thesis can be summarized as:

- Establishing secure Pipeline Control Systems (PCS), and Achieve steady state pipeline operation.
- Identify the function performed by each level of the SCADA hierarchy and relates each level in the SCADA system to other levels.
- how a control Achieved through a remote location with quicker recognition and response to critical problems that can affect a whole pipeline
- How SCADA system allow an operators to closely monitor pressures and device status at each location on the pipeline.
- Creating observation points for pressure and flow along the oil pipeline and linked with SCADA system through remote terminal units (RTU) to monitoring all parameters of pipeline system.
- Configuration and Simulation of SCADA & PLC System to monitoring and control of pump stations units by using Windows control centre (WinCC).

1.4 Thesis Outlines:

This thesis is organized as follows: An introduction is given in Chapter one. Chapter two discusses the Fulla Petroleum Pipeline System, In Chapter three, a Pipeline control system. In Chapter four, Pump Station Operation Procedure. In Chapter five, Upgrading of SCADA System. In Chapter six, Simulation of Pump Station. Main conclusions and the future work were given in Chapter seven.

CHAPTER TWO

Petroleum Pipeline System

2.1 Introduction:

The most popular way of transporting petroleum products is by the use of pipelines. The use of pipelines eases the movement of petroleum products from one location to the other. The distances covered by these pipelines are in thousands of miles passing through cities and villages. All pipelines that transport crude oil and other liquid petroleum products have the same basic set of equipment, facilities, and procedures .In this thesis Pipeline of Petro energy Company (Sudan branch) will be considering as a case study.

2.2 General Description of Petro Energy Pipeline:

2.2.1 Surface Facilities:

The pipeline project of Petro Energy Company divided into two phases. In phase I, 4 process stations are set up along pipeline, PS#01 PS#03 and PS#04 pig launching and receiving stations and KT#06. Meanwhile, 2 future pump intermediate stations, PS#02 and PS#05 are installed for future expansion by setting up block valves. In phase I, pumping operation started in PS#01 and the oil transported directly to the KT#06. In phase II, when the output reaches 40,000 bpd, PS#03 and PS#04 pig launching and receiving stations are developed to intermediate pump stations. In phase I and phase II, main pump sets driven by variable frequency and explosion proof motors are set up in PS#01. 2 main pumps driven by diesel engines are set in PS#03 and PS#04 in phase II. The crude oil tanks of CPF are used as PS#01oil storage tank. And the Khartoum Refinery Corporation (KRC) oil tanks are used for

Khartoum Terminal. One 1,000m^3 dome roof oil tank and two 200m^3 diesel tanks are set up at each of PS# 03 and PS#04 in phase II. One 200m^3 relief tanks are set up at KT#06 in phase I. Instrumentation in the project are include a flow metering system, instrument detection system, fire alarm system, station control system and SCADA system. The control level in phase I: All signals in PS#01 are displayed locally and provision is made for future automatization in phase II. Station control are realized in KT#06, the signals are transmitted to the station control room. A SCADA system, located in KT#06 Center Control Room, are set up for data collection and management of PS#01, PS#03, PS#04, BV-12 and KT#06 .For PS#01 two 11kV power supplies are fed from CPF. There is no external power source for PS#03 and PS#04 and therefore a diesel generator system are installed. Also air compression unit are installed for starting up the diesel engine. For CP-1, CP-8 stations and two TM (terminal multiplexer) power sources are supplied from PS#01 and KT#06 respectively, a solar power system are adopted in 6 stations from CP-2 to CP-7, for the KT#06 two 6kV power supplies will be fed from the Khartoum refinery.[7]

2.2.2 Pipeline Route:

The pipeline of Fula Field Crude Oil Export Pipeline Project starts from PS#01 (initial station), closes to CPF in Block 6 and ends at Khartoum Terminal (KT#06) jointing in Khartoum Refinery . The route of the pipeline goes northeastward from PS#01, crosses a railway at about 80km of the pipeline, and then follows the railway for about 90km. After following a simple road of Abu Zabad to Abu Haraz for about 65km, the pipeline passes through a plain for a length of about 65km to al Obeid. From Obeid, the pipeline runs parallel to the existing GNPOC pipeline, passes the Pump Station No.3 and Valve Stations from No.6 to No.9 of

GNPOC pipeline, then crosses the Nile, and finally ends at the Khartoum Terminal (KT#06) and terminated at Khartoum Refinery (KRC). The pipeline is about 715.42km in length. The design pressure of the pipeline is 10.0MPa from PS#01 (initial station) to BV-10 (KP 584.5), and 7.5MPa from BV-10 to Khartoum Terminal (KT#06). Spiral Seam Submerged-Arc Welded pipes (API Spec 5L) will be used for this project. The diameter of the pipeline is NPS24 with steel grade of X65, and wall thickness of 0.281in, 0.312in, 0.375in and 0.469in. 3PP (3-layer Polypropylene external coating) shall be used as external coating in sections of the pump station out-let with high oil temperature and some specified crossings including road, railway and track crossing, and the Nile crossing. Figure (2.1) show the pipeline of Fula Field Crude Oil Export in Block 6.

2.2.3 Natural and Weather Conditions of the Route

The pipeline is located in the middle-south of Sudan, which is a Torrid Zone grassland climate with dry and rainy seasons. From June to October it is the rainy season, and from November to May it is the dry season. The average annual rainfall is 318mm, there is significant rain in the south and little rain in the north, and rainstorm is its character. Little rain or no rain occurs in the dry season, when the climate is dry and torrid. The highest temperature is about 50°C, the maximum monthly average is 40°C, and the minimum is 13°C. The maximum wind speed for a 50-year interval is 37.5m/s, the maximum monthly average wind speed is 4.0m/s and that of annual is 3.5m/s, accompanied with sand storm. Natural wood vegetation areas are from 0km to 80km, from 220km to 235km and some intermittent segments from Obeid to Khartoum. The trees are normally not more than 0.3m in diameter and

10m in height, with the occasional big trees. The sections from 80km to 220km, from 235km to 300km and both banks of the Nile crossing are crops, grass and shrub areas. The segment from the Obeid to Khartoum is mainly Gobi desert and sandy ground.

2.2.4 Civilization and Buildings

Villages, towns and cities, which the pipeline route shall go through or be close to, include Abu Zabad, Abu Haraz, Obeid, Adduse, Serrha, Umm Sayyalah and Khartoum. Khartoum is the capital of Sudan, the national transportation hub and is the political, economic and cultural center. Al Obeid is a big city in northern Kordofan, a transportation hub, and economic center of the region, with a large population. Other towns are small with only a few citizens. Villages are different in size with only some residents of farmers or herders. The buildings are thatch cottages in the south and soil based in the north.

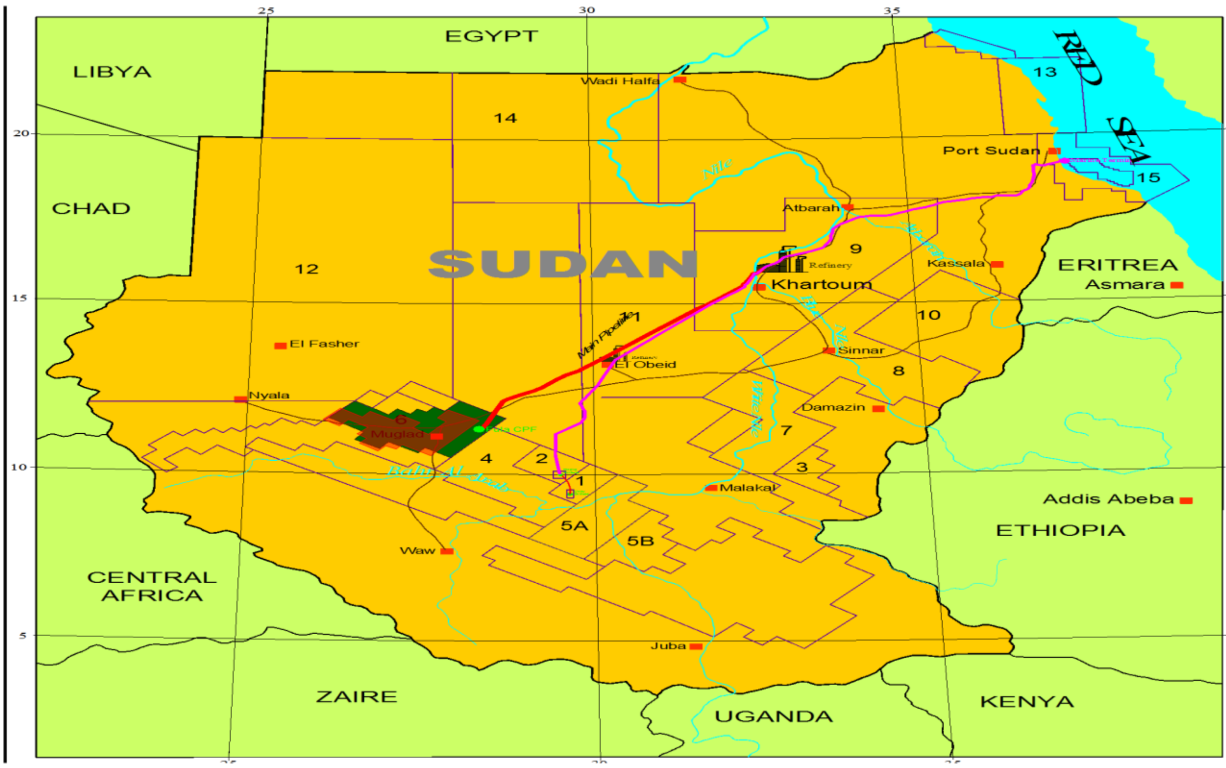

Figure (2.1): The pipeline of Fula Field Crude Oil Export in Block 6

2.3 Pump Stations

The pipeline includes sex pump stations PS#01(Initial Injection Station) Known also as Supply or Inlet station, is the beginning of the system, where the product is injected into the line. Storage facilities, pumps or compressors are usually located at this location; it receives the crude oil from CPF, after filtrating, pumping then transport crude oil to the next station. PS#02 and PS#05 (future standby pump stations) and PS#03 and PS#04 (intermediate stations or Partial Delivery Station) .The Final Delivery Station Known also as Outlet stations or Terminals, this is where the product will be distributed to the consumer. It could be a tank terminal for liquid pipelines or a connection to a distribution network for oil pipelines. The final station in Petro-energy is (KT#6) metering station; Figure (2.2) show the pump stations.

Each pump increases the pressure of a batch by a specific amount. It is possible to operate the station at a variety of pressures by turning on different combinations of pumps. Pumping pressures are even more precisely controlled by throttling using the station pressure control valve (PCV). The challenge for the operator is to maintain the required flow rate and pressures while minimizing the amount of energy used. The control center is located remotely from the pump stations. So, when an operator starts or stops pumps or opens and closes valves, these actions are being carried out remotely. The operator monitors computer screens, and uses the information displayed to decide what actions to carry out. By moving a cursor with a mouse and clicking on an on-screen action button, the operator initiates the action at the station. [8]

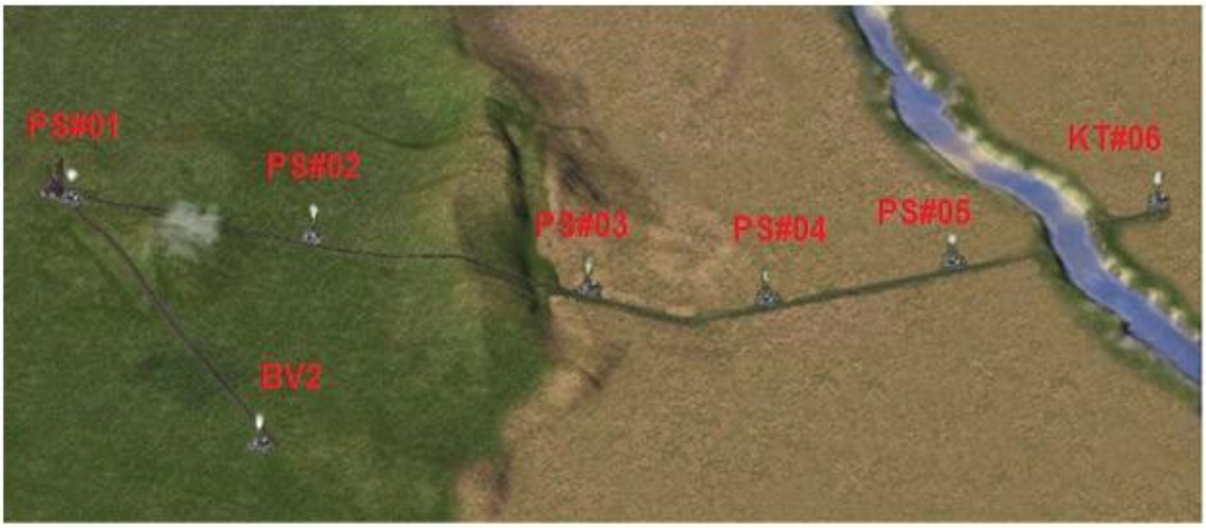

Figure (2.2): The Pipeline Pump Stations.

2.4 Pipeline Block Valve Stations

In order to limit damage in case of an emergency and for the convenience of maintenance of the pipeline system, block valves are installed along the pipeline. The block valves stations are set at easy access, open field, higher land locations, and the distance between the stations are less than 70km. At river billabong large-sized crossing locations, block valve stations are set at both banks. There are 7 block valves stations, a take-off valve station, 5 river bank block valves, 6 pump stations along the pipeline. The block valves are installed buried underground. BV-1, 2, 4, 12, 13 are Bank valve station.BV-6 is Take-off valve station.BV-1, BV-2, BV-3, BV-4, BV-5, BV-7, BV-8, BV-9, BV-10 and BV-11: All the block valves will be manual, full bore, ball valve, table (2.1) show the Distribution of block valve stations.

	Distance (km)	Remark
1	43.73	BV-1 (bank valve station)
2	46.16	BV-2 (bank valve station)
3	105	BV-3 (bank valve station)
4	162.8	BV-4
5	165.5	PS#02
6	217.8	BV-5
7	298.5	BV-6
8	356	BV-7
9	412	BV-8
10	529.5	BV-9
11	584.5	BV-10
12	618.2	PS#05
13	643.59	BV-10-1
14	659.1	BV-11
15	691.86	BV-12 (bank valve station)
16	693.83	BV-13 (bank valve station)

Table (2.1): The Pipeline Block Valve Stations.

2.5 Cathodic Protection System

Cathodic protection systems design is divided into pipeline systems and station systems. According to actual situation of the Project, cathodic protection systems design is main line system CP design.

Pipeline CP includes cathodic protection of large-sized river crossing sections and temporary CP for pipeline sections where the pipeline is surrounded by soil with resistivity value of less than 20Ωm. Cathodic protection of the Pipeline mainly consists of cathodic protection test station installation, cathodic protection for large-sized river crossing section, temporary protection for vigorous corrosive section, electric isolation device equipped to prevent cathodic protection current from loss and from harmful interference on unprotected pipeline, isolation jumper to guarantee continuous electricity of the cathodic protection over the pipeline.

In order to prevent from CP current loss, isolating joints are installed at both extremities of pipeline inlet and outlet of process stations. The CP stations layout and power supply Eight CP stations along the pipelines are installed. They are about located respectively at: CP-1 station (PS#01), CP-2 station (BV-3 station), CP-3 station (stand alone), CP-4 station (BV-6 station), CP-5station (BV-8 station), CP-6station (BV-9 station), CP-7station (PS#05) and CP-8station (KT#06). CP-1 and CP-8 CP stations are use the 220V/50Hz AC power supplied from the stations. The following CP stations are utilize solar power modular with accumulator battery: CP-7station (PS#05), CP-2 station (BV-3 station), CP-4 station (BV-6 station), CP-5station (BV-8 station) and CP-3 station (stand alone) ,table(2,2) show the Distribution of CP Stations.

In order to verify the level of protective potential and current along the buried pipeline, the following potential and current test points are installed along the pipeline, A CP potential test post must be set up in every 1km interval and a current test post are set up in every 10km interval.

CP test posts are installed at the intersections of the pipeline with other existing pipelines, one test post are set up at every insulating joint and crossings. [9]

CP STATION No.		**TYPE OF STATIONS**	
Serial No.	Location (km)	Place	Type
CP-1	0	PS#01	AC
CP-2	81	All alone	DC
CP-3	180	All alone	DC
CP-4	281	PS#03	DC
CP-5	389	All alone	DC
CP-6	508	All alone	DC
CP-7	618	PS#05	DC
CP-8	715.4	KT#06	AC

Table (2.2): The Distribution of CP Stations.

CHAPTER THREE

Pipeline Control System

3.1 SCADA Overview:

3.1.1 Definition of SCADA:

SCADA is an acronym that is formed from the first letters of the term "supervisory control and data acquisition." Aside from the fact that the root term does not refer to the factor of distance, which is common to most SCADA systems, the acronym SCADA is a good one. A SCADA system allows an operator to make set point changes on distant process controllers, to open or close valves or switches, to monitor alarms, and to gather measurement information from a location central to a widely distributed process, such as an oil or gas field, pipeline system, or hydroelectric generating complex. When the dimensions of the process become very large hundreds or even thousands of kilometers from one end to the others--one can appreciate the benefits SCADA offers in terms of reducing the cost of routine visits to monitor facility operation. The value of these benefits will grow even more if the facilities are very remote and require extreme effort. [10]

3.1.2 Applicable Processes:

SCADA technology is best applied to processes that are spread over large areas; are relatively simple to control and monitor; and require frequent, regular, or immediate intervention. The following examples of such processes should help you visualize the range of application types SCADA is suitable for:

- Groups of small hydroelectric generating stations that are turned on and off in response to customer demand are usually located in remote locations, they can be controlled by opening and closing valves to the turbine, they must be monitored continuously, and they need to respond relatively quickly to demands on the electric power grid.
- Oil or gas production facilities--including wells, gathering systems, fluid measurement equipment, and pumps—are usually spread over large areas, require relatively simple controls such as turning motors on and off, need to gather meter information regularly, and must respond quickly to conditions in the rest of the field.
- Pipelines for gas, oil, chemicals, or water have elements that are located at varying distances from a central control point, can be controlled by opening and closing valves or starting and stopping pumps, and must be capable of responding quickly to market conditions and to leaks of dangerous or environmentally sensitive materials.
- Electric transmission systems may cover thousands of square kilometers, can be controlled by opening and closing switches, and must respond almost immediately to load changes on the lines.
- Irrigation systems often cover hundreds of square miles, can be controlled by opening and closing simple valves, and require the gathering of meter values for the water supplied to consumers.

In These examples SCADA has been successfully installed on each of these types of processes as well as many others. The types of control illustrated in these examples may give the mistaken impression that

SCADA is not suitable for more complex control. As we will describe later, the complexity of remote control that is possible with SCADA has grown as the technology has matured. Typical signals gathered from remote locations include alarms, status indications, analog values, and totalized meter values. However, a vast range of information can be gathered with this apparently limited menu of available signal types. More will be said about this here. Similarly, signals sent from the SCADA's central location to the remote site are usually limited to discrete binary bit changes or to analog values addressed to a device at the process. An example of a binary bit change would be an instruction ordering a motor to stop. An example of an analog value would be an instruction to change a valve controller set point to 70 percent. Given simple signal types like these, with some imagination many control changes can be effected. [11]

3.1.3 Elements of a SCADA System:

Figure (3.1) shows the major components of a SCADA system. At the center is the operator, who accesses the system by means of an operator interface device, which is sometimes, called "an operator console." The operator console functions as the operator's window into the process. It consists of a video display unit (VDU) that displays real-time data about the process and a keyboard for inputting the operator's commands or messages back to the process. Other cursor-positioning devices, such as a trackball, mouse, or touch screen may be used. If the system is very simple, it may be sufficient to have a set of annunciator windows that mimic the condition of the remote process. Often, an audible signal will be included.

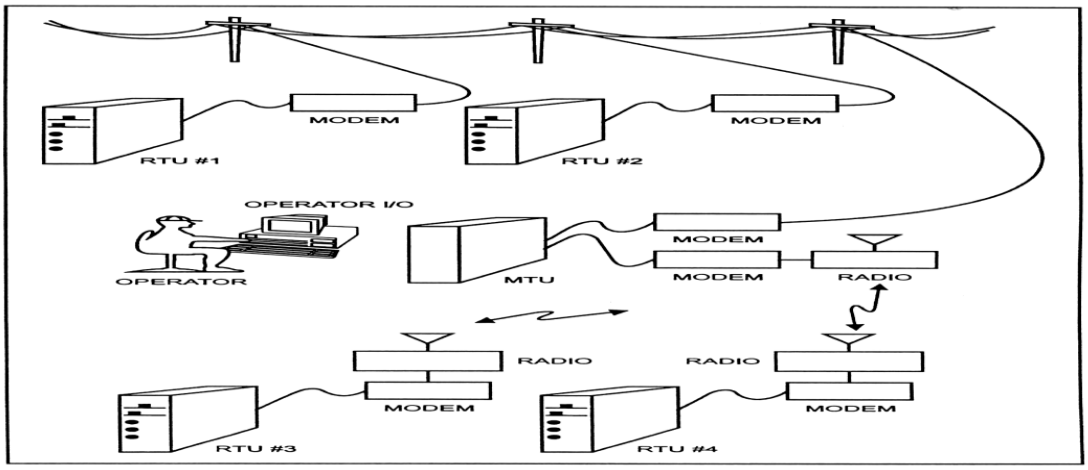

Figure (3.1) Major components of a SCADA system

The operator's input device is usually a computer keyboard, although pointing devices such as trackballs and mice are gaining in popularity. For very basic systems, a set of simple electrical switches may be sufficient. The operator interfaces with the master terminal unit (MTU), which is the system controller. Some industries use the term "host computer" instead of MTU. Throughout this book the two terms can be considered to be interchangeable. The MTU in modem SCADA systems is always based on a computer. It can monitor and control the field even when the operator is not present. It does this by means of a built-in scheduler that can be programmed to repeat instructions at set intervals. For example, it may be scheduled to request an update from each remote terminal unit (RTU) every six minutes. MTUs must communicate with RTUs that are located away from the central location. A SCADA system may have as few as one RTU or as many several hundred [12]. There are two common media of communication, as shown in Figure (3.2): land line, which takes the form of optical fiber cable or electrical cable and is either owned by the company or leased from a telephone utility, and radio. In either case, a MODEM, which Modulates and demodulates a signal on the carrier, is required. Some large systems may use a combination of radio and telephone lines for communication.

One of the distinguishing features of SCADA systems is that their processes tend to be simple. For that reason, the amount of information moved over a SCADA system tends to be rather small, and, therefore, the data rate at which the modem works is also small. Often 300 bps (bits of information per second) is sufficient. Except for those used on electric utilities, few SCADA systems need to operate at data rates above 2400 bps. This allows voice-grade telephone lines to be used, and this bit rate does not overload most radio systems. [13]

Normally, the MTU will have auxiliary devices (e.g., printers and backup memories) attached to it. These devices are considered to be part of the MTU. In many applications, the MTU is required to send accounting information to other computers or management information to other systems. These connections may be via dedicated cables between the MTU and the other computers, but in new SCADA systems they predominantly connect in the form of LAN (local area network) drops. In most SCADA systems, the MTU must also receive information from other computers. This is often how applications programs, operating on other computers and connected to the SCADA computer, provide a form of supervisory control over SCADA.

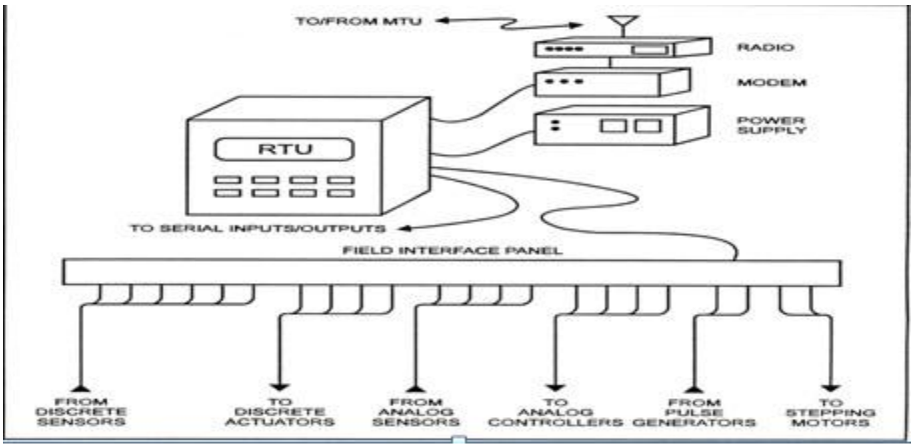

Figure (3.2) An RTU and its Various Connections.

Figure (3.2) shows an RTU and its various connections. As mentioned, the RTUs communicate with the MTU by a modulated signal on cable or radio. Each RTU must have the capability to understand that a message has been directed to it, to decode the message, to act on the message, to respond if necessary, and to shut down to await a new message. Acting on the message may be a very complex procedure. It may require checking the present position of field equipment, comparing the existing position to the required position, sending an electrical signal to a field device that orders it to change states, checking a set of switches to ensure that the order was obeyed, and sending a message back to the MTU to confirm that the new condition has been reached. Because of this complexity, most RTUs are based on computer technology.

The connections between the RTU and field devices are most often made with electrical conductors--that is, wires. Usually, the RTU supplies the electrical power for both sensors and low-power actuators. Depending on the process, reliability requirements may necessitate that an uninterruptible power supply (UPS) be used to ensure that failures of the electric utility do not result in process or safety upsets. This is particularly important if the SCADA system is installed on an electric utility system. Just as the MTU scans each RTU, the RTU scans each of the sensors and actuators that are wired into it. However, the RTU's scanning is done at a much higher scan rate than the scanning of the MTU. [4]

3.2 Levels of Pipeline Control System (PCS):

3.2.1 Control Centre (Operator Level):

Although SCADA can be compared to the eyes, ears and even hands of the pipeline, it is the operator who is the brain of the system. Like the data monitoring systems in a new vehicle or the controls of the automatic pilot, the Pipeline Control System (or PCS) uses SCADA to provide information to the operator. In the control centre, PCS displays the data transmitted from all the sensors on the pipeline to the video monitor. The data is monitored and, based on knowledge of pipeline operation; decisions are made that will optimize the flow of product down the pipeline to its destination. Once a decision is made, the mouse is used to tell the system to make changes in the pipeline's operation. SCADA carries the "message" to the appropriate piece of equipment, and carries out instructions such as starting, stopping, opening or closing – whatever is specified.

The operator is at the top of the command hierarchy working at a workstation usually, one workstation is dedicated to a specific pipeline; however, if necessary, any workstation has the ability to run all of the pipelines for that control center. Each workstation consists of one workstation connected to three or four video monitors, a keyboard, and a mouse. Hardware configurations can be a little different at any control centre. The video monitors display system information and status using a graphic user interface (GUI). Commands are issued using the mouse to point to specific portions of the GUI.

3.2.2 Host Level:

Each workstation consists of one computer and in turn can control one or more lines in the system. Each workstation has up to four video display units to provide information for the operator to monitor the system. Within each control center, the workstations are linked together on a Local Area Network (LAN). The collection of networked workstations is termed the Host System or Host level control in the PCS System. The key element of the Host level operation is the software. Real Time Applications Platform (RTAP) is supplied by Hewlett Packard to serve as the tool kit for development of the PCS SCADA system. Programmers have enhanced and integrated these tools and developed the Pipeline Control System or PCS.RTAP is a collection of programs that work together to gather and display data from the field and to control pump units and valves. The components of RTAP include a:

- scan system
- database
- calculation engine
- event manager
- time keeper
- alarm system
- trending system
- reporting facility and
- a security system.

Taken together, these components form the RTAP environment. Although each process runs independently, they also work together, often sharing information. In the PCS, each line has its own RTAP environment. To understand the relationship of each of the RTAP components, we will depict their relationship using this conceptual diagram. As each component is described, its relationship to the other components will be demonstrated using the diagram in figure (3.3).

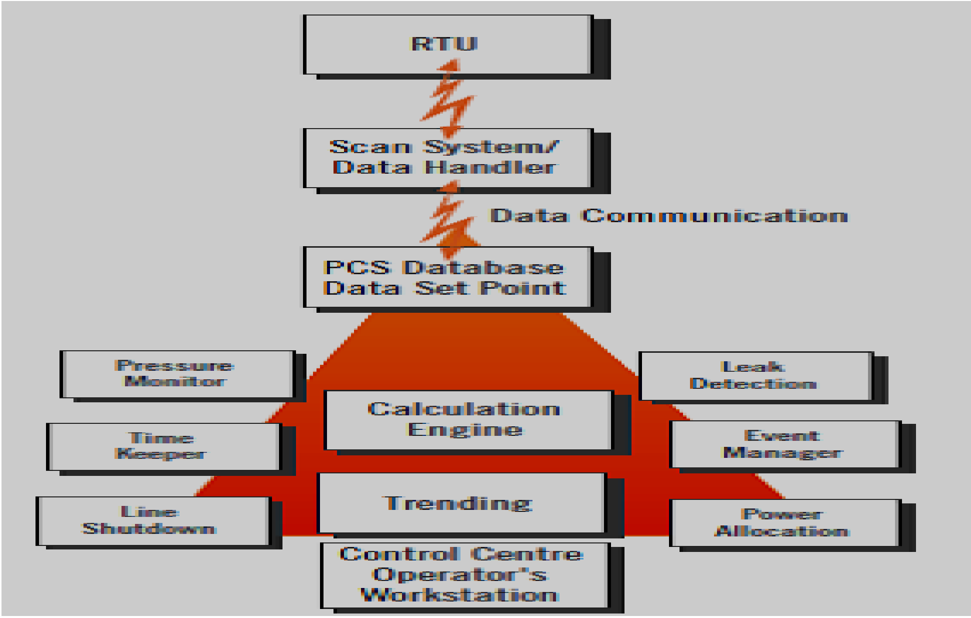

Figure (3.3): RTAP Conceptual Diagram

3.2.2.1 Scan System:

The scan system coordinates the polling or scanning of Remote Terminal Units (RTUs) to gather field data according to preset parameters. These scanning cycles are defaulted to preset limits for each control center as shown in the following example (though these values may be changed as required). In addition, the scanning system may be set up to poll a specific station at a specified interval (once every five minutes for example).The field data consists of all the information gathered from field devices. It includes such information as pressures, set points, unit status, and flow transducer readings. At each field location, the RTU collects the data into "packages". The packages are then sent through the communication system to the host. The scan system "reads" the incoming data from the field devices and writes the information into a data handler. The data handler is a temporary holding space for incoming data. Its purpose is to put the data into its proper place. Sometimes data belongs in more than one place. The data handler places it as directed.

3.2.2.2 Database:

The PCS database contains all the specific data for each individual pipe line. The database is the filing system for the RTAP environment. There is a specific place for every piece of data received from the field. The data is arranged according to a precisely controlled hierarchical structure. The database contains information that is static (does not change) like station schematics, valve displays, unit horsepower, algebraic equations used to manipulate data. And dynamic (continually changing) such as pump status (e.g., on/off), control status (e.g., local/remote), valve status (e.g., open/closed), flow rates and volumes. The data can also be described as either raw data or calculated data. Raw data is transmitted by the RTUs directly from the field. Calculated data is arithmetically determined from the raw data. For example, a suction pressure value is raw data, whereas “throttle” is determined by subtracting station discharge pressure from the station case pressure and is termed calculated data. Arithmetical calculation is only one type of “calculation” that can be carried out on each data point.

3.2.2.3 Calculation Engine:

Within the RTAP environment the calculation engine is the workhorse that performs all the calculations, computations and manipulations on the data in the database. The calculation engine performs statistical, Mathematical and logical operations, starts and stops timers, and Evaluates the quality of the data in the database. The calculation engine has three major purposes:

- To evaluate raw data and convert it to process data
- To compare current values to previous values and
- To interpret data and make decisions.

Very complicated operations are carried out by custom-built routines
that are started by the calculation engine. Only the results of the calculation
are used or displayed to the operator. Figure (3.3) shows the relationship between the data handler, database and calculation engine. Each cell or location in the database is called a data point, and can have one or more functions associated with it. A function is any instruction to do something with data. The calculation engine can:

- place data into an algebraic equation
- display data on a screen
- move data to another location
- compare data to a fixed value or
- Compare data to another data value.

3.2.2.4 Alarm System:

The alarm system handles all the messages for PCS. In order of severity, these are:

- Informational messages
- Warnings
- Priority messages and
- Critical messages.

The interconnection of the various components of PCS can be examined in the following examples. A data point in the database has a current station discharge value of 600 psi (or 4137 kPa). The data point also contains other information associated with the station discharge pressure. This information might include:

• Maximum allowable discharge pressure
• Warning levels
• Alarm set points and
• Shutdown levels.

3.2.2.5 Event Manager:

The RTAP event manager keeps track of changes that occur in real time Changes that trigger actions are called events. The event manager Starts actions in response to events. When an event occurs, a trigger message is sent to the event manager. The event manager then notifies other processes of that event. For example, the maximum discharge pressure at Donaldson has been increased by 20 psi. The event manager receives notification of this event and then sends a message to another process to forward this information to the other workstations.

3.2.2.6 Time Keeper:

Time is a central concept to PCS. The time keeper centralizes all time related functions in the RTAP environment. It triggers scheduled actions such as polling RTUs, printing reports, and sending commands. The time keeper can be programmed to invoke a scheduled action at:

• a specified time (for example, every day at 5 a.m.)
• a specific interval (every 30 minutes for example) and
• a specific interval after an event (such as one minute after a command is sent).The time keeper uses both the calculation engine and the event manager to control timing of responses and actions.

3.2.2.7 Trending:

Besides controlling and manipulating incoming and outgoing data, PCS also provides two critical reporting features:

• Graphical trends and

• Digital reports.

Graphical trends provide information to the operator in either a continuous update (real time) or with a fixed start and end time format (historical). They also allow an operator to select the data to be displayed. Digital reports are predetermined packages of historical information.

3.2.3 Communications Level:

The hardware and software in the host level of PCS depends on telephone technology to connect you with the equipment you control and the conditions monitored in the stations along the pipeline. The data communications network is headed up by the communications front end (CFE). The communications front end (CFE) is a microprocessor installed in the control center. Its purpose is to coordinate and organize the communications from the Host to the stations. Commands are sent from the Host level to the communications front-end. The communications front end controls the data flow onto the data circuit. It handles paths, timing, recognition and translation of data flowing to and from the stations. A modem translates the data from the format used in the computer to that used over the communications medium. [13]

The land-based telephone lines used may be a combination of dedicated copper wire, fiber optic cable, in figure (3.4), and microwave radio signals leased from the telephone utilities. These systems operate at a 4800 baud rate. This baud rate translates to a speed of approximately 480 characters per second. Therefore, a large file or a station scan can take from a quarter to a half second to execute from the time of request to the time of execution. When telephone lines cannot supply the level of service required, one option for data transmission is a satellite transmission system. A satellite transmission is a communications medium that uses geosynchronous orbit satellites to transmit signals over long distances. The use of a satellite transmission system may require modifications to the existing SCADA system. The "double hop" configuration of the satellite communication system routes the signal twice through the orbiting satellite. Because of the distances involved, a delay, or time lag of about 1.5 seconds must be added to the duration of every transmission. When compared to the land based system, this additional delay will mean modification to the SCADA system to handle the time lag. Operators must also be aware of this additional delay factor when sending commands or waiting for information. Figure (3.5) show Double Hop Configuration for Satellite Transmission.

Figure (3.4): communications medium

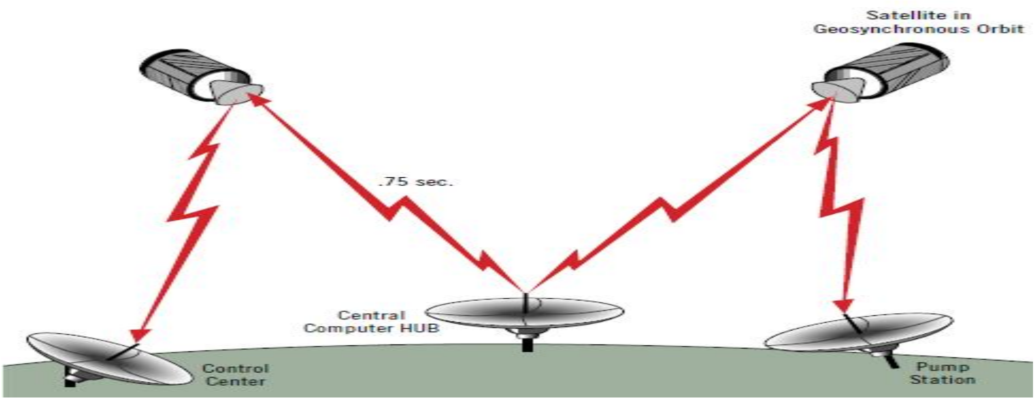

Figure (3.5): Double Hop Configuration for Satellite Transmission.

With the land-based system or microwave system, the information is exchanged between the Host and the RTU in a polling master/slave relationship. This means the RTU sends data to the Host only when requested. In the satellite system, the information is exchanged in a non-polling master/slave way. This means the RTU can send data to the Host at any time. In addition, all the RTUs can send data to the Host at the same time. The “logo cal links” to the RTUs are not multi-dropped, but act like point-to point links. That is, each RTU looks like it has its own dedicated circuit.

A data protocol is a recognized standard that determines how data is handled before and after transmission. There are many different types of data protocols. Protocols are used for all data communications whether by telephone lines, microwave transmissions, or even satellite communications. The RTU sends information to the Host when data has changed. This function is called report by exception. In addition to reporting these changes every five minutes, each RTU sends a full data record to the host. The full data record verifies that no changes have been missed. For example, consider what would happen if a discharge pressure changes to a dangerously high level, and for some reason, the change is missed by the system while the new pressure stabilized and did not change again. The system would not necessarily recognize the wrong value as it is designed to report changes in status. To counter this problem, when the full data record is sent to the host, the data is compared with the database at the Host level and any differences are reported. This way, the longest a dangerous condition can persist is five minutes. In addition, once every minute the Host computer sends out a signal called a "heartbeat." The heartbeat triggers a reply from the RTUs that is used simply to verify that no changes have been sent in the last minute. The communications system is still on line.

3.2.4 Station Level:

The commands you have executed and the units you are controlling are located at the station level. In the SCADA hierarchy, there are remote terminal units (RTUs), programmable logic controllers (PLCs), Input/output (I/O) devices, units and equipment like pumps and valves, and various instruments or devices. All of these devices and components are either located in the Electrical Services Building (ESB), on the station site itself, or are controlled from the station location.

3.2.4.1 Remote Terminal Unit (RTU):

The first piece of equipment encountered by the "Unit Start" command as it enters the station is another computer called the remote terminal unit. The remote terminal unit (RTU) receives commands and dispatches them to a controller which further dispatches it to an input/output device, controlling the unit to be started. The data you see on your monitor in the control center is collected at a central place at each location in the field before it is sent through the communications system to the host. This central field location is the station RTU. There is an RTU at every station on the line. At most stations, the RTU has a monitor and keyboard that can display and operate equipment within the location. In this way, the operator can interact with the local staff to coordinate actions, such as during troubleshooting operations on the pipeline, or for other maintenance purposes. Every RTU on the common data circuit receives all the data on the data circuit. Each station RTU, however, ignores all data that is not addressed to it or to the units or devices under its control. Just like an old fashioned party line, when an RTU detects a signal directed to it or to a unit it controls, it receives the signal from the control centre. Then the RTU in turn sends the data on to the particular unit. If a signal is not addressed to it, the RTU ignores the data. The RTU discerns, selects and sends only information requested by the control center. To gather this information, the RTU regularly requests data from the other devices at the station, such as the PLCs. When the RTU receives the data from the controllers and the Input/output devices controlling the unit, the RTU manipulates it to prepare for transmission. When the Host requests data, the RTU sends it. By having the RTU work with data at the Station level, the communication system is not flooded with raw information. [14]

3.2.4.2 The Programmable Logic Controller:

The next level in the station is a rack of equipment housing the programmable logic controllers (PLCs). The PLCs, in conjunction with the input/output (I/O) devices, actually operate the equipment such as pumps and valves and gathers information from the pipeline monitoring instruments. Located in the same rack of equipment as the PLC, are the input/output modules. The I/O module does the actual physical work of carrying out the commands. All the PLCs at the station are connected to the RTU by serial connections. The PLCs may have different communications protocols. The RTU is programmed to translate the data from the PLCs to the protocol that is used by the Host. A programmable logic controller is a computer designed to:

• control pump units by starting, stopping and changing their speed

• control valves by completely or partially opening or closing

• provide raw and scaled operational data to the RTU (and eventually to You in the control centre) by “listening” to the output from the station Instrumentation, and

• ensure a safe operating environment by independently executing emergency shutdown procedures if necessary. In this way the PLCs are more than just hands. They do more than just start the pump unit. They are actually “smart hands” because they optimize the operation of the pipeline. An alarm annunciator and a man machine interface (MMI) are found at each location. The annunciator provides local system information. The man machine interface (MMI) enables local control of the station when necessary. Newer PLC installations have a graphical user interface (GUI) instead of an annunciator panel with a keyboard and a thermal printer for the programmer/electrician MMI. This GUI is connected to an industrial personal computer which displays suction and discharge locations as well as pressures, set points, and unit status (ON/OFF). The new MMI also enables local control of the station when necessary. There are numerous safety routines and programs designed to monitor operations and take action for the continued safe operation of the pipeline system. The Host, RTU and the PLC are each equipped to take protective action if they lose contact with the other components in the system. If any of the communications links between the host and the RTU or the PLC breaks down, at least one of the others can ensure the station will continue to run safely. The main purpose of the PLC is to read input, apply programming and signal outputs. To accomplish this purpose, new inputs are read from the field instrumentation (sensors), then stored in very specific parts of the memory. The programs in the PLC manipulate the data, then send output to control devices and the RTU. [15]

The PLC's operation depends on three elements: memory, programming, and power. These elements are used in a cycle. Each cycle is called a scan. The term scan was used earlier in describing RTAP. In the RTAP environment, scanning meant reading the data and writing it into memory. A PLC scan is a complete cycle. It starts with reading new inputs and ends with outputting the data after program action. The processor reads the raw data from the station instrumentation, applies programming, then outputs commands to the field devices. When the status of the field device is changed, the flow of product in the pipeline may also change. Combined with physical changes in operation (a change in the type of product being shipped to a heavy crude for example) the changed status of the device produces a new set of readings. At the end of each scan, the PLC sends the latest outputs to the appropriate output interface and receives the latest inputs from the appropriate input interface. The data travels between the PLC and the Input/output sub-system at very high speeds through twin axial, coaxial or fiber optic cable. At the end of each scan, the PLC sends a pulse indicating that the system is operating correctly. If there is a system failure, the pulse is not sent and the fault relay activates. The "UNIT START" command has travelled along a data communications highway from the host to the RTU. The RTU acts like a traffic controller to direct the command to the appropriate Programmable Logic Controller (PLC), where the actual work of carrying out the command begins. Figure (3.6) show the scan cycle of PLC.

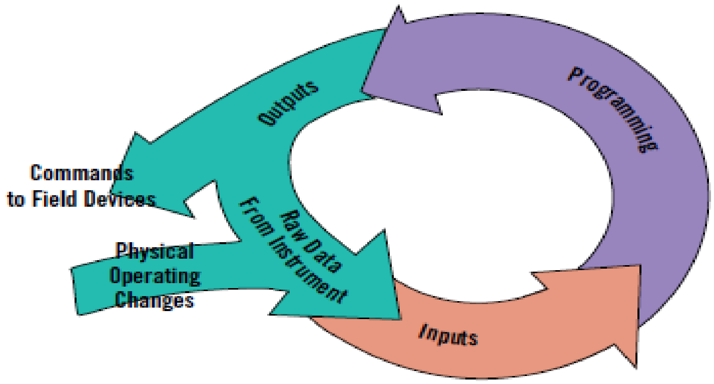

Figure (3.6): Scan Cycle of PLC

When the "UNIT START" command reaches the PLC, the scan function is started. The operating system "looks" at each of the input interfaces and reads the status of each interface into the appropriate area of the input table. Data from the RTU (including the "UNIT START" command) is also read and put into the appropriate place. Starting a pump unit involves more than simply flipping the ON switch. Valves may need to be opened or closed. Instrumentation may need to be brought on line. Safety checks may need to be carried out. Once all the data is read into memory, the PLC processes the data by executing the programming. The programming moves and combines data, and applies arithmetic and logical functions to the data. The program reads the "UNIT START" command, and then applies a program to the data that will generate an output to start the pump. The user programming in the PLC runs through all the conditions and commands before even trying to start the pump. Once the program has finished manipulating the data, it is moved to a storage area. From there, it is read into the output interface, which adjusts the physical status of the devices. All the devices that need to be turned ON or OFF to start the pump unit will be activated.

3.2.5 Devices and Instruments Level:

3.2.4.1 Input/output Interfaces:

The input/output (I/O) system provides the physical connection between the outside world (field device and instruments) and the PLC, in Figure (3.7) Each I/O interface is connected to an instrument or device on the pipeline. Instruments may include pressure or temperature sensors, meters or detection instruments, while devices are primarily pumps and valves. The interface “joins” the instrument or device to the PLC so when changes occur at one end, the corresponding change occurs at the other end as well. Through the interface circuit, the controller can sense and measure physical quantities regarding a machine or process, such as proximity, position, motion, level, temperature, pressure, current, and voltage. On the basis of status or values, the PLC issues various commands that control devices such as valves, pumps and alarms. There are several types of I/O interfaces used for pipeline applications. The two most common, discrete types and the numerical data types, The discrete type deals with ON/OFF or 0/1 type data. A local start from a hardwired push-button or alarms from a field are examples of the discrete input type of I/O. The analog type is used for applications involving numerical inputs. Numerical data from a suction transmitter would be an example of an analog input device.

3.2.4.2 Field Devices:

Field devices refer to the instruments and machines that report and are controlled by SCADA. Instruments and devices represent the bottom level in this depiction of the PCS SCADA hierarchy. Instruments are the eyes and ears of the SCADA system, measuring line conditions and transmitting the data back to you in the control centre through the entire SCADA hierarchy. Instruments include pressure transducers, meters, fire and combustible gas detection devices, densitometers and thermometers. Devices are machines that actually have a physical impact on the flow of the liquids through the pipeline. The key devices are pump units and Valves. When you use the information received from the instruments to make decisions about modifying the flow through the pipeline, you actually make those modifications by changing the status of the devices - turning pumps on or off, or opening, closing or throttling valves. [16]

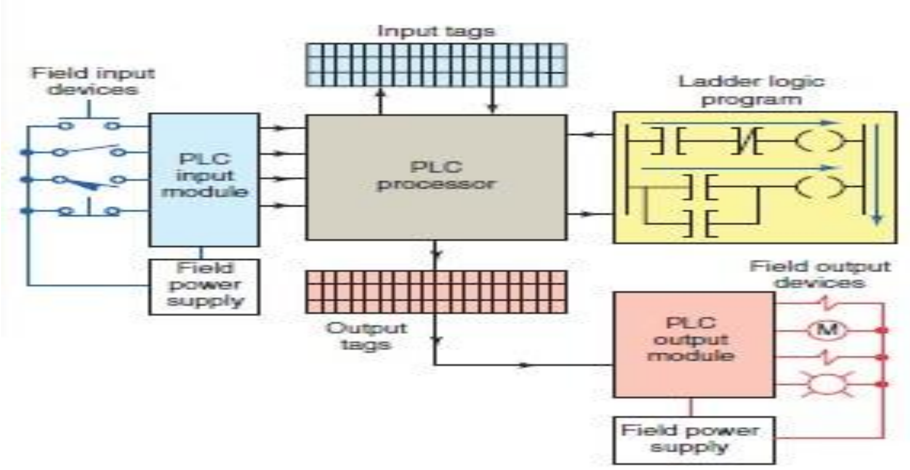

Figure (3.7): Field Devices and PLC Modules

3.3 Unit Start Command:

The “UNIT START” command originated at the control centre workstation, and traveled out to the field where it started a pump. The below table reviews the entire process:

Stage	Who	Does What?
1	OPERATOR	• Gives the “UNIT START” command
2	Host	•Validates and sends the command to the CFE
3	CFE	•Packages and addresses the command •Sends the command to the RTUs through the data circuit via a modem
4	RTU	Translates and Directs the command to the correct PLC
5	PLC	•Sends the command to the output module
6	Output Interface	•Carries out the command
7	Pump (device	•Begins the start up sequence
8	Instrument	•Reads changes in flow or machinery operation
9	PLC	Scans input interface and stores the data in the input table
10	PLC	Manipulates the data according to the programs
11	RTU	•Polls the PLC
12	PLC	Sends data to the RTU
13	RTU - Satellite System	•Checks for changes and sends the information to the Host (through the CFE) RTU - Land-Based Data Circuit: • Waits until polled by the host, and then sends it to the host through the data circuit
14	CFE	Translates the data and sends it to the host
15	Host	The PCS in RTAP acts on the data •Sends the outputs to the control centre work Station
16	OPERATOR	Uses the information to make decisions

Table (3.1): Unit Start Command

CHAPTER FOUR

Pump Station Operation

4.1 HC Pump Startup Operation Procedures:

4.1.1 Pre-check before start

1) Inspect and confirm all valves of pump inlet and outlet line in good condition, all the motorized valves are power on and in remote model.
2) Check and confirm the inlet pressure low than 40 bars.
3) Local site inspect and confirm the start air line and fuel line are unblocked, the shutoff valve of engine should be full open.
4) Check the fuel daily tank level is OK.
5) Check the start air pressure is in the range of 17-30 bars.
6) Check the lube oil level is in the range of Min. and Max. Level scale.
7) Visible check the engine is normal without any leak of medium.
8) Check and confirm there is no alarm in UCP.
9) Confirm pre-lube oil pump in auto status, cooling water circulation pump all cooling fan motors are in auto status.

4.1.2 Three modes to start the pump unit

4.1.2.1 Start from LCP

A) Switch the LCP mode selector to local position and switch the UCP mode selector to remote position, then you can start the pump unit from LCP.

B) Press the start button on LCP, the engine starts and speeds up to 600rpm.

C) Check and confirm all parameters about engine are normal, especially the temperature of cooling water and lube oil.

D) After 300s warming time of period, to increase the speed to 650rpm

E) Close the PCV valve to upload the engine step by step as per MCC crude transportation flow rate request

4.1.2.2 Start from UCP

A) Switch the LCP mode selector to remote position and switch the UCP mode selector to local position, then you can start the pump unit from UCP

B) Press the start button on UCP, the engine start and speed up to 600rpm.

C) Check and confirm all parameters about engine are normal especially the temperature of cooling water and lube oil.

D) After 300s warming time of period, to increase the speed to 650rpm.

E) Close the PCV valve to upload the engine. And Start procedure is finished and you can adjust the speed to required speed as per the MCC flow rate demand.

4.1.2.3 Start from SCS

A) Switch the LCP mode selector to remote position and switch the UCP mode selector to remote position, then you can start the pump unit from SCS.

B) Double click the pump icon on SCS computer; there a window for start operation will come out.

C) Press START to start the engine, the engine will start and speed up to 600 rpm.

D) Check and confirm all parameters about engine are normal, especially the temperature of cooling water and lube oil.

E) After 300s warming time of period, to increase the speed to 650 rpm

F) Close the PCV valve to upload the engine.

G) Start procedure will be finished and you can adjust to required speed as per the request of flow rate order from MCC.

4.2 HC Pump Stop Operation Procedures

4.2.1 Normal Stop

1) Decrease the speed of pump unit to 650rpm.
2) Open the PCV valve to offload the engine.
3) Decrease the speed of Pump unit to 600rpm.
4) You can choose to stop the pump unit in three ways.

a) Switch the LCP mode selector to local position and switch the UCP mode selector to remote position, then you can stop the pump unit from LCP by press the STOP button.
b) Switch the LCP mode selector to remote position and switch the UCP mode selector to local position, then you can stop the pump unit from UCP by press the STOP button.
c) Switch the LCP mode selector to remote position and switch the UCP mode selector to remote position, then you can stop the pump unit from SCS. Double click the pump on SCS computer and a window will come out. Click the STOP button and confirm the order.

5) After 300s cooling down time of period, the pump will stop automatically.

4.2.2 Emergence Stop

Operators can stop pump unit by emergency push button on UCP or LCP if any emergency situation happened to pump unit.

4.3 HC Pump Switching Operation Procedure

1) Pre-check before start the P-02,
   a) Inspect and confirm all valves of pump inlet and outlet line in good condition, all the motorized valves are power on and in remote model.
   b) Check and confirm the inlet pressure low than 40 bars.
   c) Local site inspect and confirm the start air line and fuel line are unblocked, the shutoff valve of engine should be full open.
   d) Check the fuel daily tank level is OK.
   e) Check the start air pressure is in the range of 17-30 bars.
   f) Check the lube oil level is within the range of Min. and Max. Level scale.
   g) Visible check the engine is normal without any leak of medium.
   h) Check and confirm there is no alarm in UCP.
   i) Confirm pre-lube oil pump in auto status, cooling water circulation pump all cooling fan motors are in auto status.
2) Start up the P-02 and increase the speed to 650rpm.

3) Decrease the speed of P-01 to 650rpm.

4) Close the PCV of P-02 and open the PCV of P-01.

5) Increase the speed of P-02 to obtain desired speed.

6) Decrease the speed of P-01 to 600rpm.

7) You could apply any of the three normal modes in "HC Pump Stop Operation"

8) After 300s cooling-down time of period, the P-01 will stop automatically.

4.4 Station Offline Operation Procedure

This procedure applies to the situation that station needs normal offline or bypass.

1) MCC Informs that station start to offline and MCC have informed upstream and downstream to adjust the pressure and flow, the upstream should have decreased the flow rate to an accepted dynamic pressure level.
2) Decrease the station pump speed when the station suctions pressure decreased.
3) Keep the station suction pressure in low level.
4) Open PCV valve of online pumps to take off load and Attention the suction pressure should be lower than 40bar till the pump sets are offline with suction and discharge valves of pump are fully closed.
5) Under the pipeline hydrokinetic pressure gradient effect, the main check valve will open when station suction pressure is higher than discharge pressure, and you can close the ESD-01 and ESD-02 after the main check valve opened.
6) In the case of station shut down from the main pipeline, you have to close the inlet Valve (XV-02) and then close the outlet Valve (XV-04).

4.5 Station Online Operation Procedure

This procedure applies to the situation that the station starts from offline status.

1) Check the suction pressure should be lower than 40bar.
2) Check all valves are in correct status and position, all station drain valve close.

3) Open ESD-01 and ESD-02.
4) Confirm at least one of the two streams main strainers is online.
5) Check and confirm all pump inlet and outlet motorized valves are fully opened; the PCV valve is fully opened.
6) After pipeline is unblocked then you can start pump unit as per either mode in the “HC Pump Startup Operation Procedure”.
7) The process to speed up should be slowly due to the station main check valve is online which keeps impact on the station suction pressure.

4.6 Station Shut Down Procedure

4.6.1 Normal Shut Down

This procedure applies to the situation that pipeline needs shut down the station normally.

1) MCC issue work order to station operator to normal shut down the station.
2) Operator informs station superintendent, foreman and duty engineers; inform upstream station and downstream station.
3) Decrease the station pump speed, normally stop the pump unit.
4) Close the ESD-01 and ESD-02, if necessary can close the motorize valve before the main strainer.
5) Switch off the main breaker of LVS panel.
6) Switch off the main breaker of MAN generator.
7) Normally stops the generator unit.
8) Report to MCC and relevant departments that station shut down.

4.6.2 Emergency Shut Down

This procedure applies to the emergency situation that pipeline needs shut down the station.

1) Operator should report to MCC and superintendent at the first time when the emergency situations happen.
2) Station superintendent should report to HQ immediately and HQ gives the instruction to emergently shut down the station.
3) Operator inform MCC after receive the instruction. There have two processes to shut down the station:
    a) Operator can push the emergency stop button on pump UCP to shut down the pump unit, then close the ESD-01 and ESD-02, after that go to LVS room to push the emergency stop button on generator control panel to shut down generator unit.
    b) Operator can push the emergency shutdown button on safety system control panel to emergency shutdown station, after press the emergency button on safety system control panel, the

system will automatically first shut down the pump unit, close the ESD-01 and ESD-02, and then shut down the generator unit consequently.

Finally you have to report to MCC and relevant departments that station has been shut down. [17]

CHAPTER FIVE

Upgrading of SCADA System

5.1 Introduction of Project:

In order to maintain the whole pipeline in safe and smooth operation state, Petro-energy is planning to add more dynamic pressure and flow observation points along this export pipeline, where the relevant signals will be acquired and delivered to existing running SCADA system by using remote terminals units. Figure (5.1) show the pressure observation points along the oil pipeline in some of pump stations, BV rooms and Cp stations in PE pipeline and the location of block valve rooms. [8]

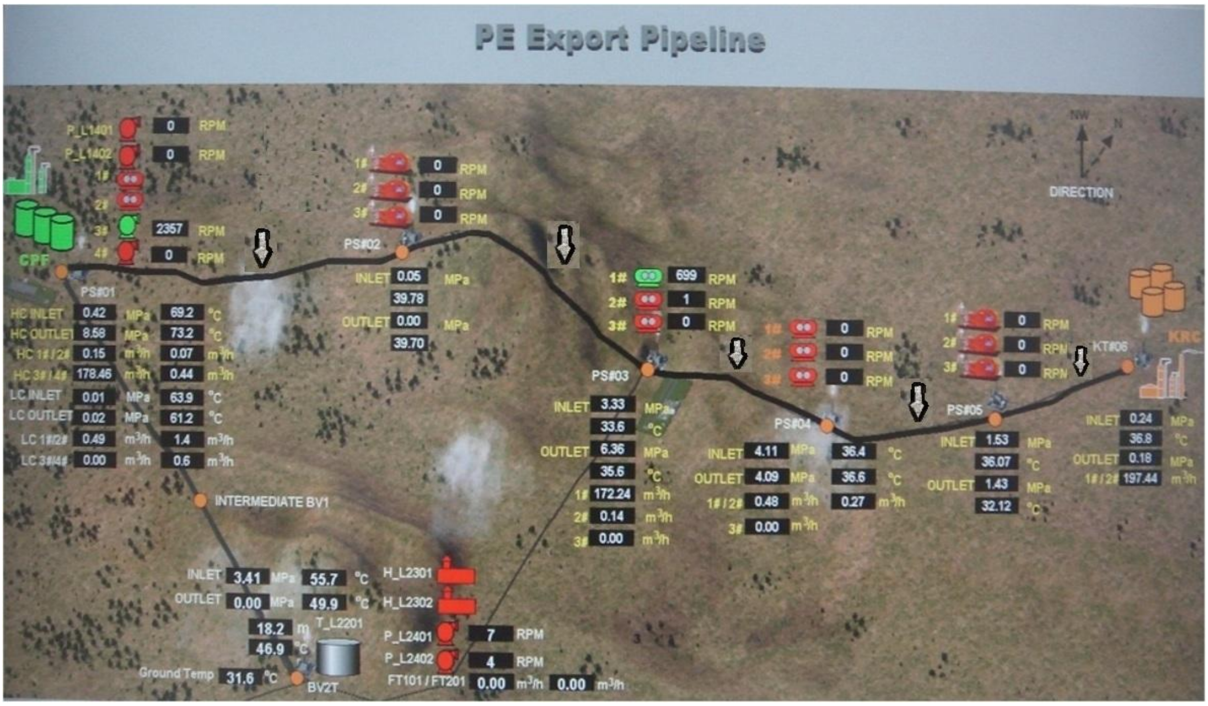

Figure (5.1): the pressure observation points along the pipeline

5.2 Description of Scope of Work:

5.2.1 Provision of RTU System for Data Acquisition:

The following functions are available with the provided RTU system but not limited:

- 32 Bits of CPU with built in memory and memory expanding capacity.
- Features as full function and excellent communication capability.
- Be easy in maintenance, high self diagnostic capability and high operational reliability.
- Be integrated with data acquisition, data processing .data storage and data communication.
- Ethernet port and integrates AI, DI, DO and serial interfaces to meet the expansion needs.
- Low power consumption: less than 3W, and fit for occasions applying solar power.
- Automatic clock synchronization.
- 7.data pulling and update rate reaches 29ms
- The resolution of AI channel is 16 bits to meet accuracy needed by SCADA and future pipeline detection and alert system.
- Storage and backup: has the capability to store field data in SD card. In case of communication failure with the central server, the field data shall be saved in the RTU and the system is then able to upload the data files.
- Be designed and provided to accommodate future network expansion demand and industrial Ethernet switch with management system. [15]
- basic specifications in below table:

Item	Technical Requirement
CPU	ARM9 32-bit/160MHz
Memory	SDRAM/Flash 64MB/32MB
Storage	32GB
AI	4 channels,16 bits,4-20 mA
DIO	8 channels
Relay O	2 channels
Ethernet port	1*10/100 Mbps,RJ45
Serial port	2*RS-232/485
Power input	24 VDC
Working environment	20----70 C

Table (5.1): The basic specifications of RTU.

5.2.2 Provision of Solar Power Supply for BV Rooms:

There are five BV rooms in rural areas that need power supply so in this project, five sets of solar power supply system are used for each BV room, the solar power supply system requirement:

- Control system: Intelligent controller should be used for the operation and control of the solar system, which can conduct overall operation and management to the system. Also it should provide RS232/RS485 communication interface and communication protocol to match site RTU above mentioned for power system monitoring.
- High performance solar panel unit: high efficiency multi crystal cells and high transmittance tempered glass should be applied to fulfill high energy conversion ratio and increase unit power capacity of the system.
- Along service life with characteristics of corrosion resistant, sun proof, water proof ,excellent processing ability as well as stable and reliable.
- Battery: Maintenance free colloid battery which possesses the features as high capacity, long service life, less self discharge ,easy installation, high safety and reliability also can work at the ambient temperature ranging from -30C to 70C of high quality.
- The number of days that battery must operate without solar charge is recommended to consider as 3 days at least.
- The controller can mange battery charging process according to battery status and is able to optimize the battery management capabilities as overcharge/over discharge protection, strong charge Float charge, temperature compensation. When the battery discharges to the defined minimum voltage, the controller can automatically disconnect load from the power supply to protect the battery arrays. When the system voltage is restored, the controller shall automatically resume power supply.
- The proposed power supply is rated 24VDC with load of 300W to support normal consumption of SDH, RTU and Transmitter.

- The lighting protection, surge protection and thermal protection device together with grounding system should be designed and provided.

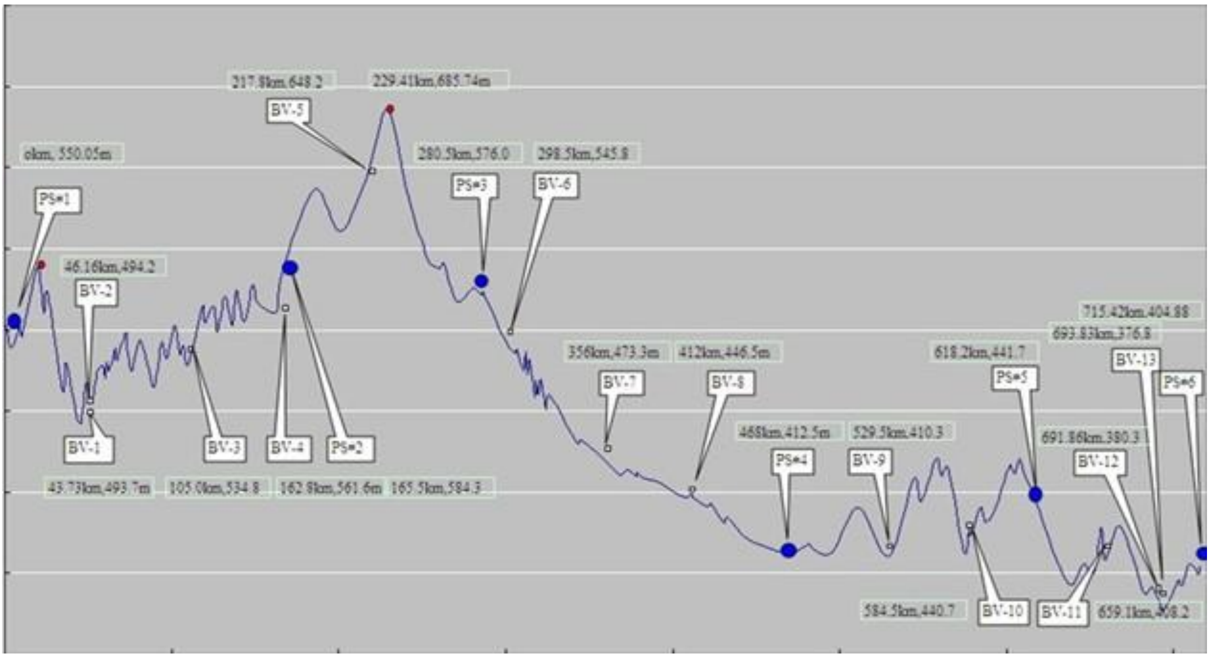

Figure (5.2): The pipeline BV rooms.

5.3 Installation of RTU System in BV Rooms:

5.3.1 Installation of Solar Bracket and PV Modules:

To describing how to interconnect components of solar bracket we must Follow this Installation procedures:

1. Requirements on installation site: energy of PV power plant is sourced from solar energy, so power plant must be such located that sunshine will not be blocked during sunshine time. For easier construction, power plant site must be flat. Hilly areas and rocky areas must be avoided, and the site should be away from trees to prevent shade from blocking cell panels. In addition, power plant must be such located that water passageway and areas where water can be accumulated shall be bypassed.

2. Foundation work:

a) Site leveling: level the site at the construction site provided by the developer. To determine leveling area, consider land area of PV power plant and the reserve land more than meters.

b) Locating and setting out: determine location of PV module infrastructure on the leveled site according to the orientation of PV power plant on site, construction drawings for works, benchmark and coordinate control point. Exactly, place the compass onto the ground horizontally to locate a line parallel to the due south, and then locate the horizontal and axial level lines by means of a square angle according to requirements in the plant drawings in order to locate center of column. Control axis according to drawing requirements and foundation to locate foundation excavation line.

c) Fabricate and mount foundation bracket, and determine method of mounting the foundation bracket as well as bracket height at site (such height 1m higher than the ground at least recommended).

d) Solar panel must be placed onto the bracket in such way that the panel is level and its force is uniform

e) Pay attention to orientation of bracket installation so that the solar panel faces the due south.

f) In case of significant sand and strong wind locally, residual solar panel wires shall be tied to the bracket to prevent damage to wires due to strong wind. Figure (5.3) show the solar system modules

Figure (5.3): the solar system modules

5.3.2 Installation of combiner box:

1. Combiner box is to be mounted under the solar panel, and actual location may be determined through site discussions.

2. Back plate mounting is used for the combiner box, namely, attach the fixing bracket to the back of cabinet firstly, which is fastened with bolts.

3. Ensure the combiner box is protected well against rainwater, moisture and dust.

5.3.2 Installation and wiring of Pressure Transmitter:

1. Install the PT in a BV room.

2. Connect the Cable from PT to the RTU Panel.

3. make sure the connection is correct

4. Complete the wiring between PT and RTU system as Figures (5.4), (5.5)

Figure (5.4): The pressure Transmitter.

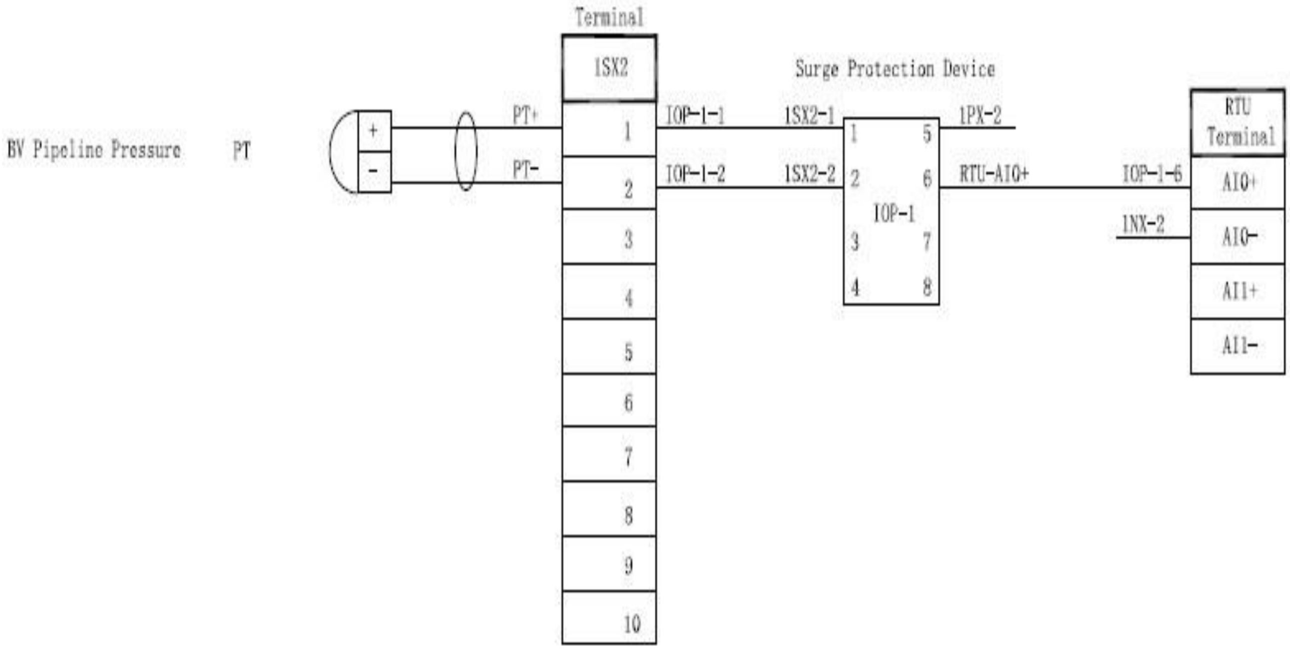

Figure (5.5): connection of PT to RTU system

5.3.3 Installing and Wiring of Batteries:

1. Fabrication of battery bracket: either single bracket or double brackets are fabricated depending on actual conditions on site. Minimum space for placing battery in the cell bracket shall be as follows:

2. Individually unpack cells, during which care shall be taken to prevent any damage to cell.

3. A station requires 24 batteries, which are divided into two parallel groups consisting of 12 serial batteries;

4. Place cell onto the cell bracket in a neat manner as shown in the drawing with even distance; and pay attention to direction of positive pole and negative pole of cell (red side represents positive, and black side represents negative.

5. Firstly, connect cell wires through M8 bolts, during which protect positive and negative poles well to prevent circuit from being formed due to short circuit, resulting in danger.

6. Interconnect individual parallel wires with M8 bolts.

7. Connect positive wire with negative wire, with one side being connected to positive or negative output, and the other side to copper bus bar.

8. A station requires 12 batteries which shall be interconnected parallelly, and it is necessary to connect two copper bus bars. After that, lead out a positive wire and a negative wire.

9. Install fixed fuse base (DC Fuse base DC125A), and it is important that the base is mounted on the positive bus bar side. Connect positive pole of the battery to the wiring terminal above the fuse base.

10. After cells are connected, connect the temperature sensor probe to the basically-central position in any cell slot; and the other probe is connected to MCU.

11. After cells are installed, use a multimeter to check open-circuit voltage of cell See the following diagram for wiring, look at figure (5.6)

12. It is extremely important to avoid short circuit during connection (such as short circuit due to tools like wires ...).

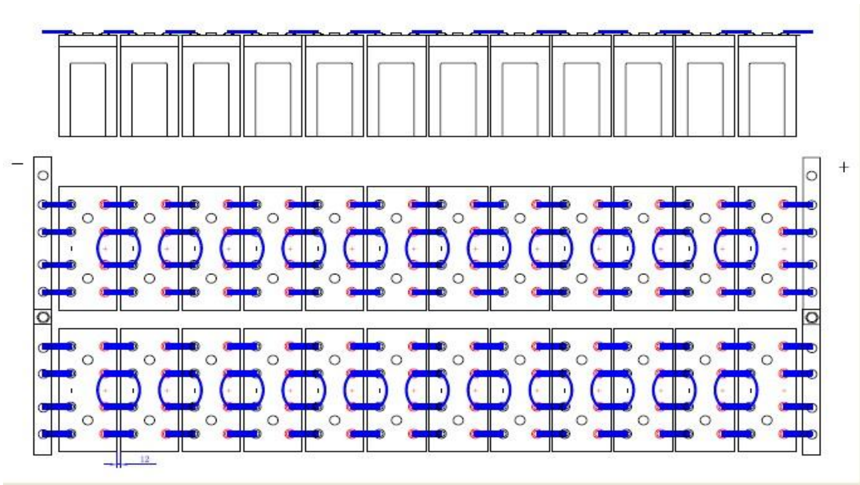

Figure (5.6): The Batteries Wiring.

5.3.4 Connection of System Cables:

5.3.4.1 Solar PV module wiring:

1) Firstly, disconnect fuse and circuit breaker inside the combiner box.

2) To connect and wire PV modules, they shall be covered with non-transparent material to prevent output voltage from resulting in personal injury or damage to modules.

3) Adjacent PV modules are taken as a group. PV modules are firstly connected to the combiner box through MC3 PV cable (4mm2 Red color cable 9m/ 4mm2 Black color cable 9m), and it is important that positive and negative polarity shall be correct.

4) When a group is installed, test the group, during which testing focuses on short circuit between positive polarity and negative polarity in the combiner box. Figure (5.7) show the wiring of the system.

5) After a group is connected and tested, interconnect two PV modules in the group. After such interconnection is finished, immediately test if short circuit from the positive polarity to the negative polarity.

6) remove sheltering coverings across the PV module so that the modules are exposed to sunshine. In the combiner box section, test if its output voltage is normal.

7) Provided that normal testing result is ensured, connect fuse and circuit breaker individually, and measure if total output voltage is normal.

8) After testing is completed, disconnect fuse and circuit breaker.

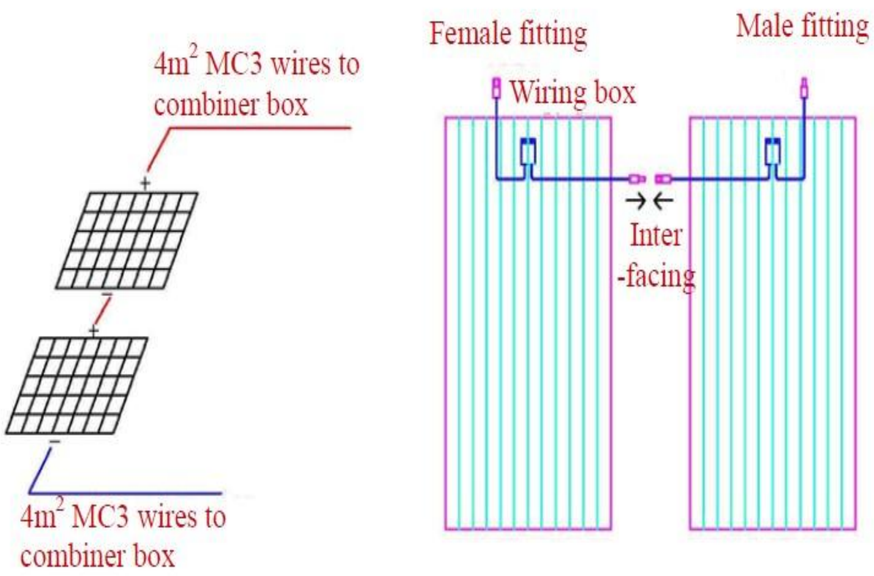

Figure (5.7): PV System Modules Wiring.

5.3.4.2 Wiring of batteries to the PV equipment box wires

1) Select a cable with the appropriate length according to site distance (25 mm^2 DC black cables). If such cable is used as positive wire, it shall be identified by applying red tape on ends or in any other manner. Battery side shall be connected to the wiring terminal under the fuse base, and the negative pole shall be connected into the bus bar at negative pole of the battery.

2) One end of the cable is connected to the BAT circuit breaker in the PV equipment box (Solar Power System), and it is important that positive and negative polarity is correct.

3) Test the circuit breaker to determine if positive-negative wire is short-circuited.

4) After the fuse core is mounted, test the circuit breaker to determine if the open-circuit voltage is normal.

5) Switch on the BAT circuit breaker to observe equipment operation is normal, and test if the SDH breaker and RTU breaker voltages are normal.

5.3.4.3 Wiring of Combiner box to PV equipment box:

1) Through PV cable (10 mm^2, red indicating positive and black indicating negative), connect the positive and negative poles of two output groups of the combiner box to the breakers SA1 and SA2 on the PV equipment box, and the positive polarity and the negative polarity must be correct.

2) Test if there is short circuit.

3) Switch on the fuse and breaker inside the combiner box, and then test if voltage of breakers SA1 and SA2 is normal.

4) After wiring and testing of battery, PV modules and combiner box are finished, power on for integrated testing, ensuring normal input and output voltage of system. Powering-on sequence: switch on BAT breaker, then SA breaker, and finally SDH and RTU breakers (power off in reverse sequence, namely, switch off SDH and RTU breakers, then SA breaker and finally BAT breaker).

5.3.4.4 Wiring of PV equipment box to RTU equipment

1) A set of double-core 2.5 mm^2 stranded copper wire is used to connect the PV equipment box and RTU housing (red and black are preferred for positive and negative polarities): one end of the wire is connected to the RTU breaker in the PV equipment box, and the other end to 24VDC supply terminal in RTU equipment box. It is important to distinguish positive polarity and negative polarity, and test if there is any short-circuit.

2) Connect the PV equipment box with the RTU equipment box through serial wire (RS232 Cable) with DB 9-pin serial port connected to PV equipment box side. Connect serial wires on RTU equipment box side as shown in the drawing in figure (5.8).

3) Connect the temperature sensor cable on battery side into the PV equipment box (Solar Power System).

4) After the above operations are finished and after testing shows that system supply voltage is normal, power on RTU equipment box to observe if the equipment runs normally.

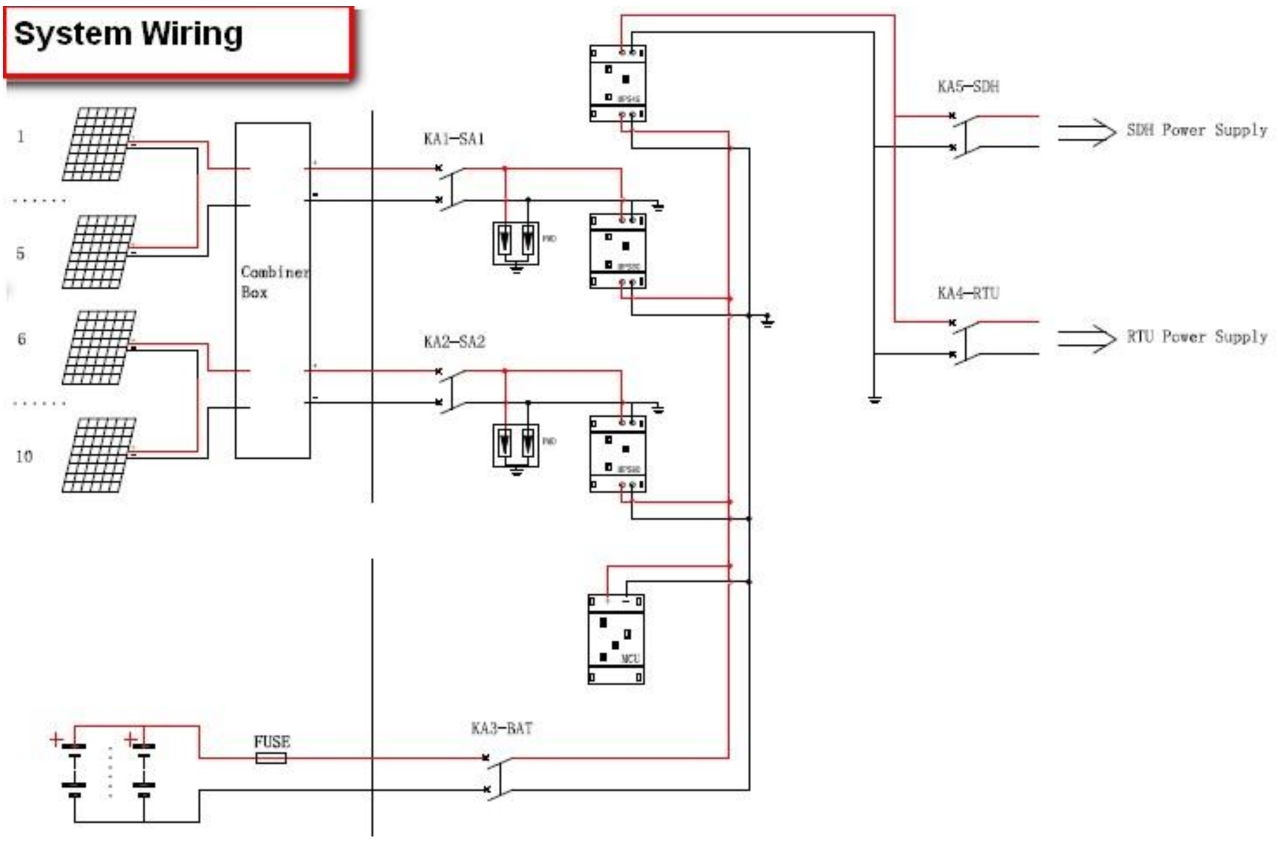

Figure (5.8): The System Wiring.

5.4 Configuration of RTU System:

1. Check the hardware and the wires correct, then power on RTU
2. Connect the laptop to RTU with Ethernet cable
3. Test the ping command, the RTU IP look at the table (5.1)
4. Use the telnet command to logon the RTU.
5. Type the User id: root, password: root

6. Type the command (kill -9 X), X is the PID No. of rtumain program. Then type the command (ps) to check the rtumain processes exist.

7. Download the RTU program from your computer. It’s better to copy the rtufile folder on your laptop in Local disk D.

8. Double click the file; the program file will be downloading to the RTU.

9. Use the telnet, type the command (sh /home/first_moxa.sh).

10. Reboot the RTU and the program will be run after the RTU start. for more Details refer to Appendix (B).

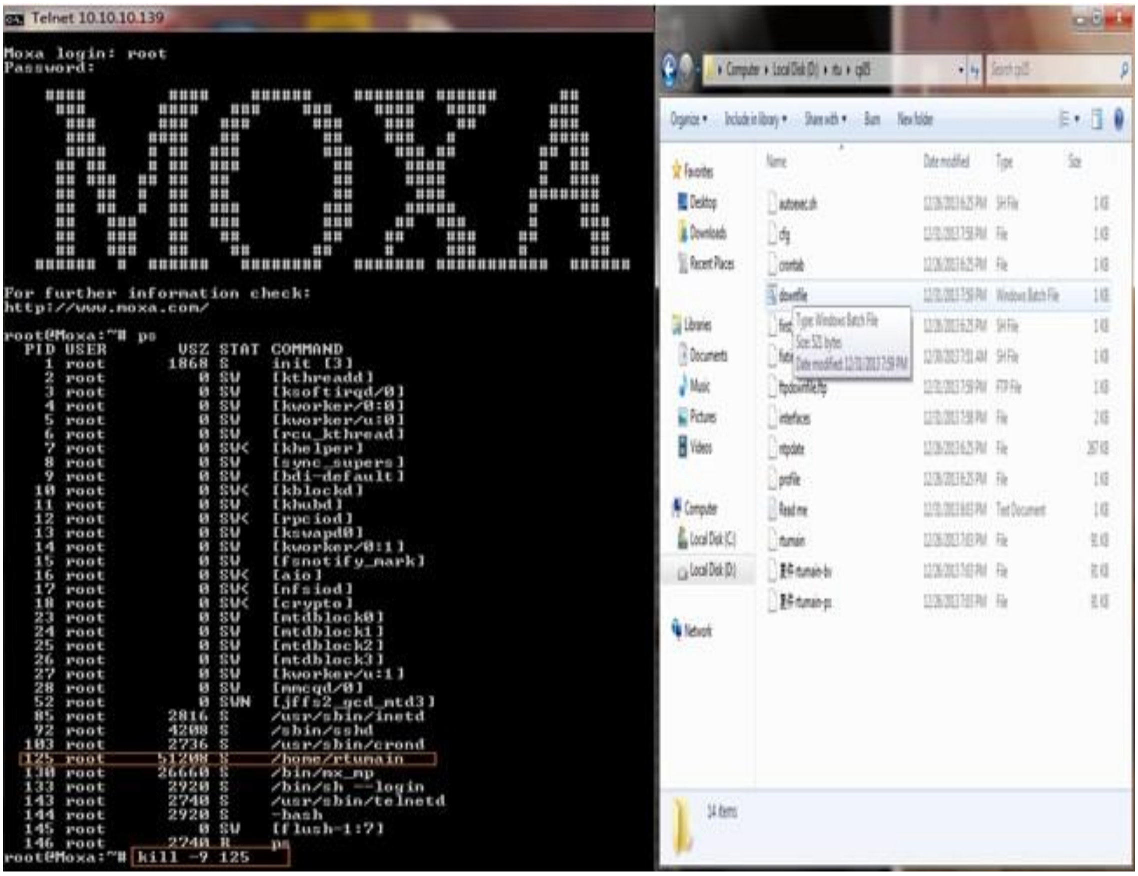

Figure (5.9): The RTU Configuration.

5.5 Simulation of RTU System:

After installing of RTU system and Downloading the Program in the RTU memory, then Use the modscan32 Simulator to simulate the Pressure Transmitter reading on your Laptop and Check the RTU output data, Figures (5.10), (5.11) show the connection Details of the RTU in Modscan Simulator, also use the table (5.2) To get the IP address for each RTU. After Simulation connects the RTU to SDH by using Ethernet cable, now the RTU reading can be display on SCADA system.

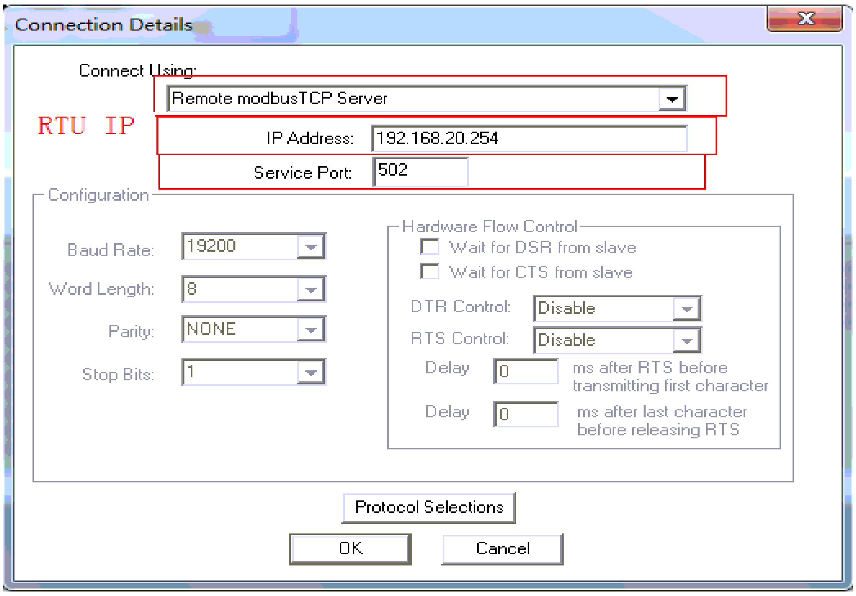

Figure (5.10): Connection Details of RTU.

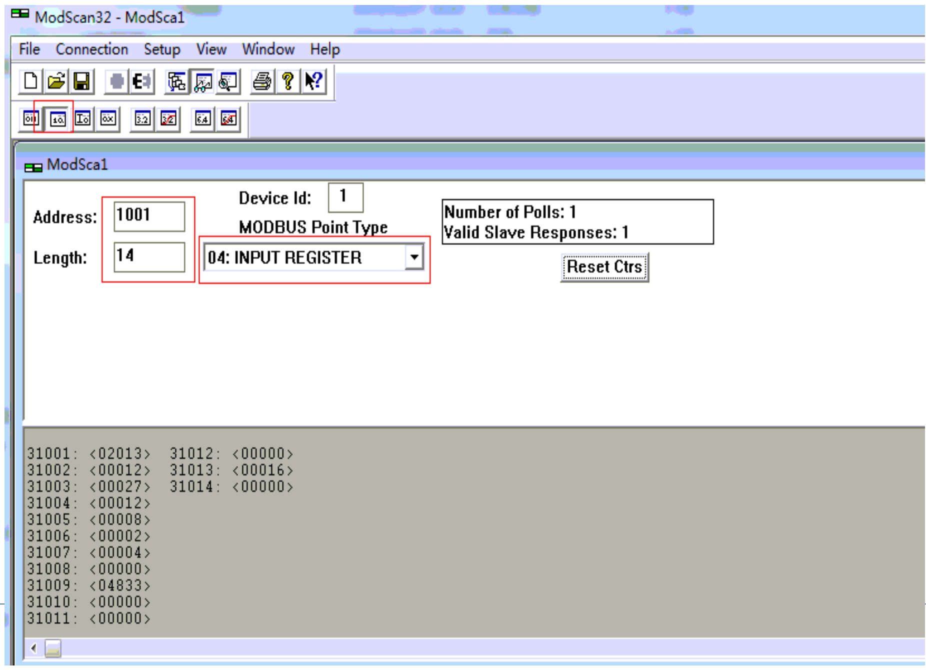

Figure (5.11): The Modscan Simulator.

No.	Station	IP Address
1	PS#01	10.10.10.130
2	BV-2	10.10.10.131
3	CP-2	10.10.10.132
4	BV-3	10.10.10.133
5	PS#02	10.10.10.134
6	CP-3	10.10.10.135
7	BV-5	10.10.10.136
8	PS#03	10.10.10.137
9	BV-7	10.10.10.138
10	CP-5	10.10.10.139
11	PS#04	10.10.10.140
12	CP-6	10.10.10.141
13	BV-10	10.10.10.142
14	PS#05	10.10.10.143
15	BV-12	10.10.10.144
16	KT#06	10.10.10.145

Table (5.2): The IP Addresses of RTU system for all PE pipeline.

CHAPTER SIX

Simulation of Pump Station

6.1 SCADA Software:

SCADA Software is a program that may be installed in the PC which makes it to work like a SCADA System. It can be from the same manufacturer of the PLC or a different one. One of these programs is the Windows Control Center (WinCC6) from Siemens Company. It used to simulate the pump station and to connect with the PLC software (SIMATIC STEP7).wincc6 is powerful HMI system for use under Microsoft Windows XP Professional. HMI stands for "Human Machine Interface", the interface between the human (the operator) and the machine (the process). The actual control over the process is performed by the automation system. WinCC6 communicates with both the operator and the automation system. To develop and configure projects, special editors are provided that can be accessed from the WinCC6 Explorer. [18]

6.1.1 The WinCC6 Runtime:

With the runtime software, the operator can run and monitor the process. In particular, the runtime software has the following tasks:

• Reading of the data stored in the CS database.
• Displaying of the screens.
• Communication with the automation systems.
• Archiving of the current runtime data such as process values and alarm events.
• Running of the process through specified set-points or activation/deactivation.

6.1.2 Project Configuration in WinCC6:

To set up a project in WinCC6, proceed as follows:

1. Start WinCC6.
2. Create a project.
3. Select and install a communication driver.
4. Define the tags.
5. Create and edit your process screens.
6. Specify the WinCC6 runtime properties.
7. Activate your screens in WinCC6 Runtime.

8. Use the simulator to test your process screens. [19]

6.1.3 Creating a tags and Coupling a PLC:

All tags can only be simulated if the communication connection to the PLC is made. Since the tag value in the PLC can be changed by the simulation. Process tags establish the connection between the process and the HMI station. They are configured after a PLC connection is setup. WinCC6 allows combining tags in technological units. This results in a tag structure that is easy to read. The update time for tag values is 1 second. A maximum of 300 tags can be configured.

6.2 PLC Software:

This project use SIMATIC STEP7 300 programming software from Siemens Company. The SIMATIC Manager is a graphic user-interface for online/offline editing of S7 objects (projects, user program files, blocks, hardware stations and tools).With the SIMATIC Manager you can:

- manage projects and libraries,
- activate STEP 7 tools,
- Access the PLC online,
- edit memory cards.

6.2.1 PLC Programming Language:

A program consists of one or more instructions that accomplish a task. Programming a PLC is simply constructing a set of instructions. There are several ways to look at a program such as ladder logic, statement lists, or function block diagrams. Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hard-wired control. The ladder language used in this project. [20, 21]

6.2.2 Communication Driver:

The Communication Driver Is the ‘Translator’ between the SCADA system and the PLC. It is a software program different to the SCADA and makes the PC and PLC to understand between them, via the communication card. Basically the SCADA program generates a data base with the process parameters (Tags name) and the communication driver is in charge of reading and writing of these data in the PLC. It is strongly recommended to use the same manufacturer for the communication card than the PLC. [22]

6.3 Pump Station Simulation:

6.3.1 Case (1):

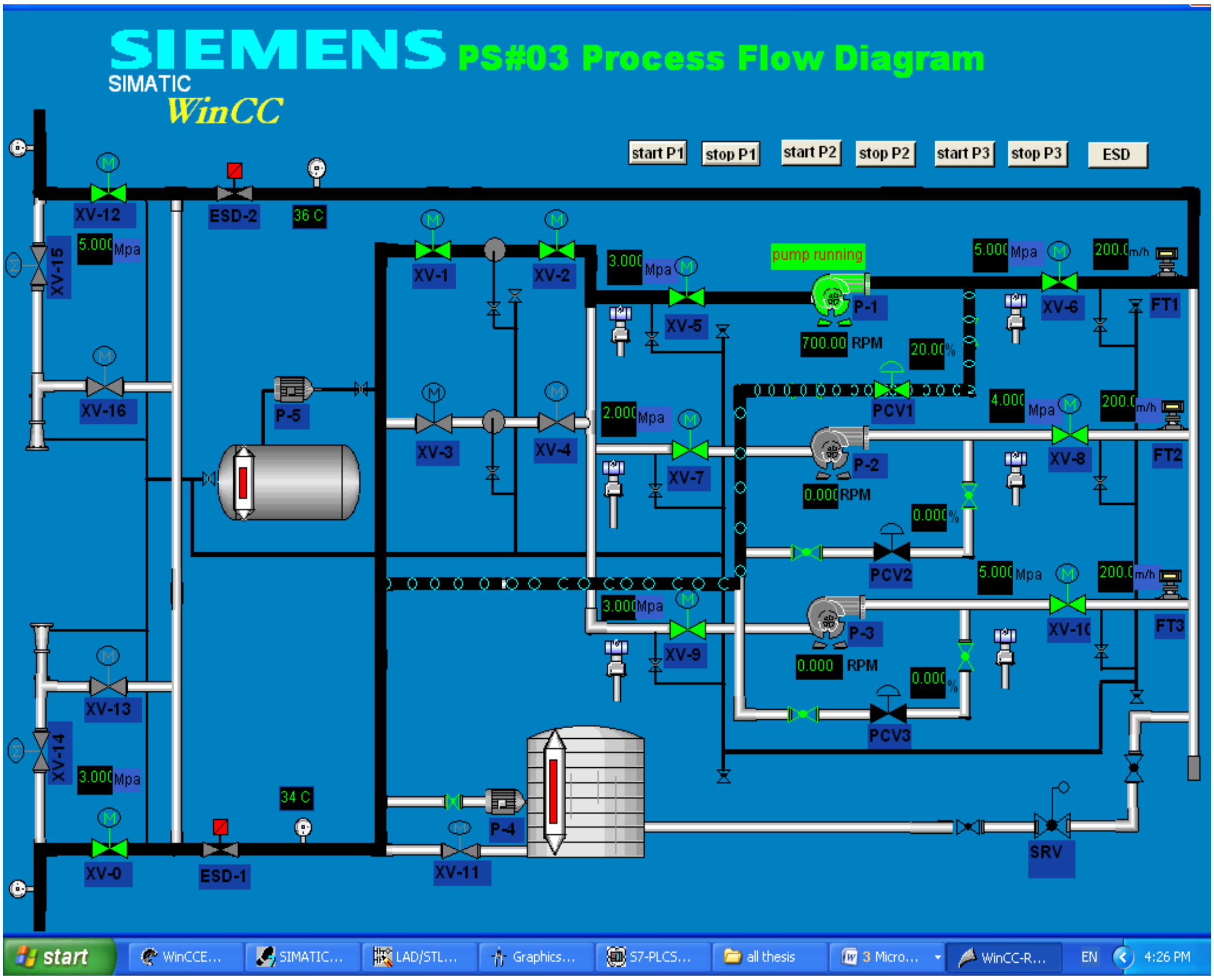

Figure (6.1): Station online and Pump No.1 Running

Figure (6.1) shows the pump station when the pump unit no.1 is running and the inlet and outlet valves of station are open, and the suction and discharge valves of pump unit are full open, also the figure shows the crude oil flows through the suction valve to the pump. Pumps provide added pressure to the liquid to ensure the liquid travels down the pipeline at the proper flow rate. Pressure control valves are different from ON/OFF valves in that pressure control valves can be left partially opened under normal operating conditions, pump station's discharge pressure is controlled with the use of a pressure control valve (PCV). The PCVs regulate pressure by changing the size of opening through which the liquids pass.

6.3.2 Case (2):

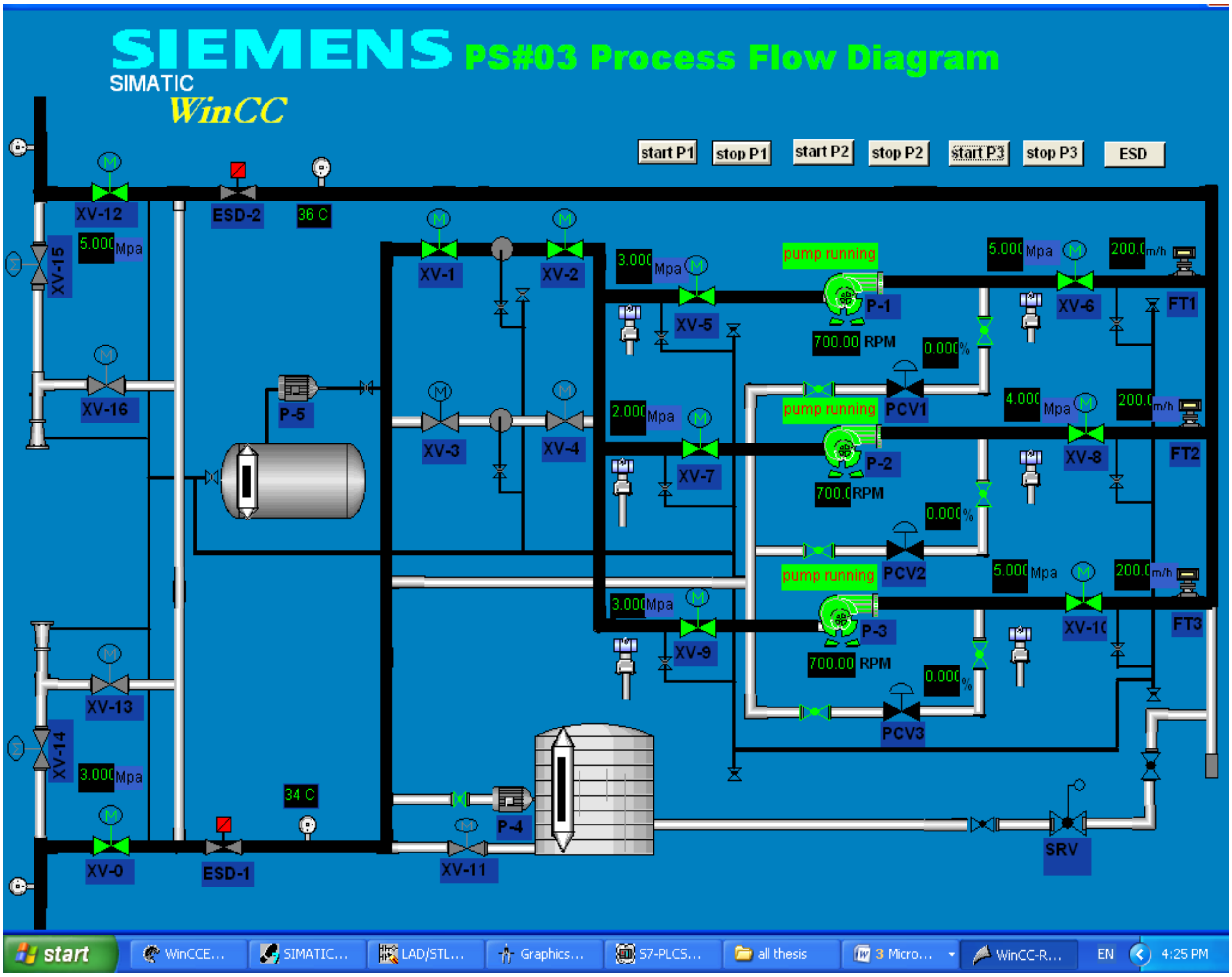

Figure (6.2): Station online and Pump No.1, 2, 3 are running.

Figure (6.2) shows the pump station when the three pumps units are running and the crude oil enters the pump unit through the suction valve. The suction valve is an ON/OFF valve, such as a gate valve or a ball valve. If the valve is open, liquid can flow into the pump unit. If the valve is closed, no liquid can flow into the pump. The liquid has now completed its journey through the pump station. The liquid flows through the discharge isolation valve that leads out to the main line. Once again in the main line, the liquid flows down the pipeline with added pressure energy and is able to maintain the required flow rate.

6.3.3 Case (3):

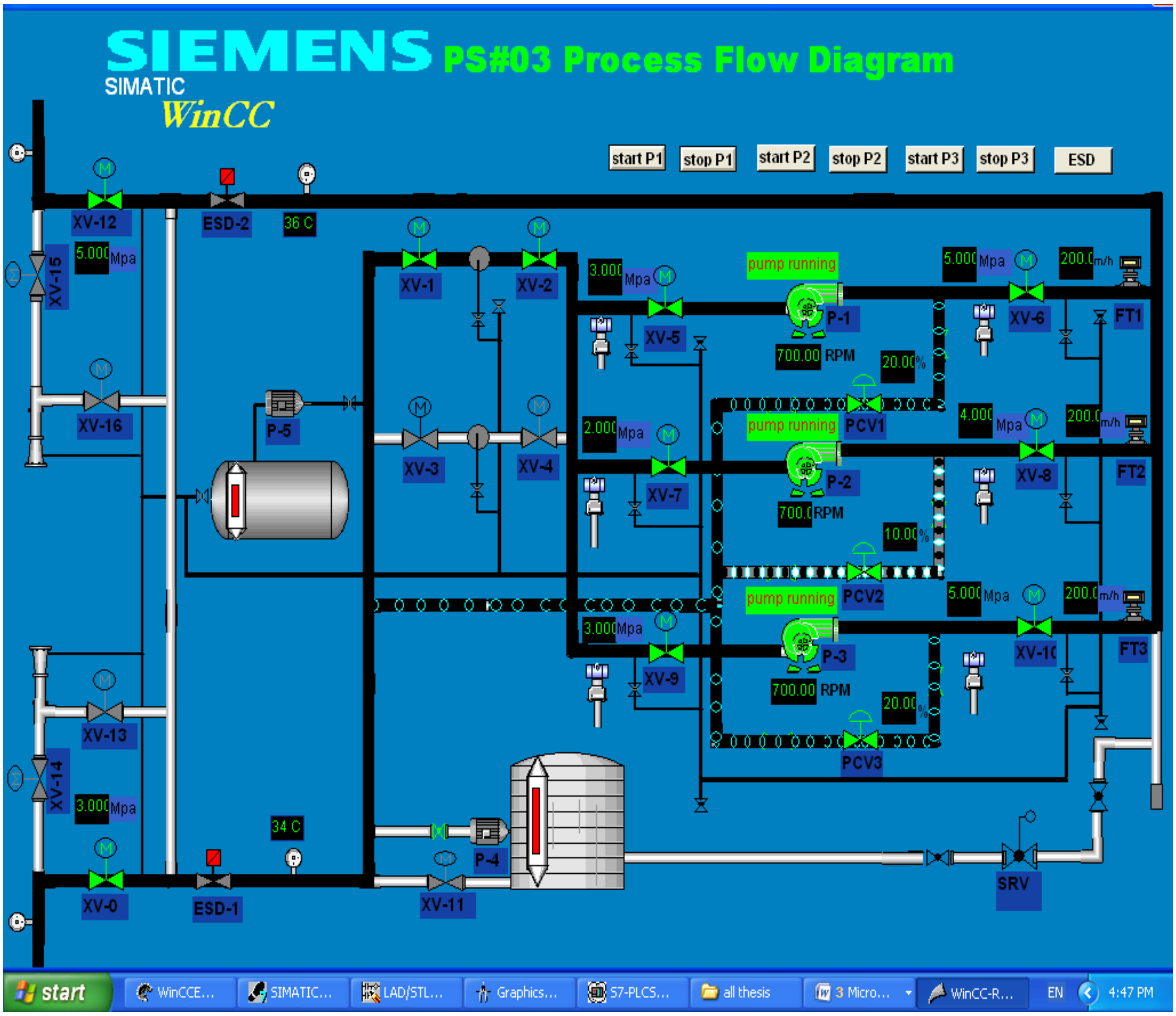

Figure (6.3): The three Pumps are running with a PCV.

Figure (6.3) shows the pump station when the three pumps units are running with PCV and the inlet and outlet valves of station are open, and the suction and discharge valves are full open, also the figure shows the path of crude oil from suction to discharge of station, there are no alarm because the pressure in acceptable limits. The PCVs regulate pressure by changing the size of opening through which the crude oil passes. After the PCV, the crude oil flows through a check valve and back into the main line.

6.2.4 Case (4):

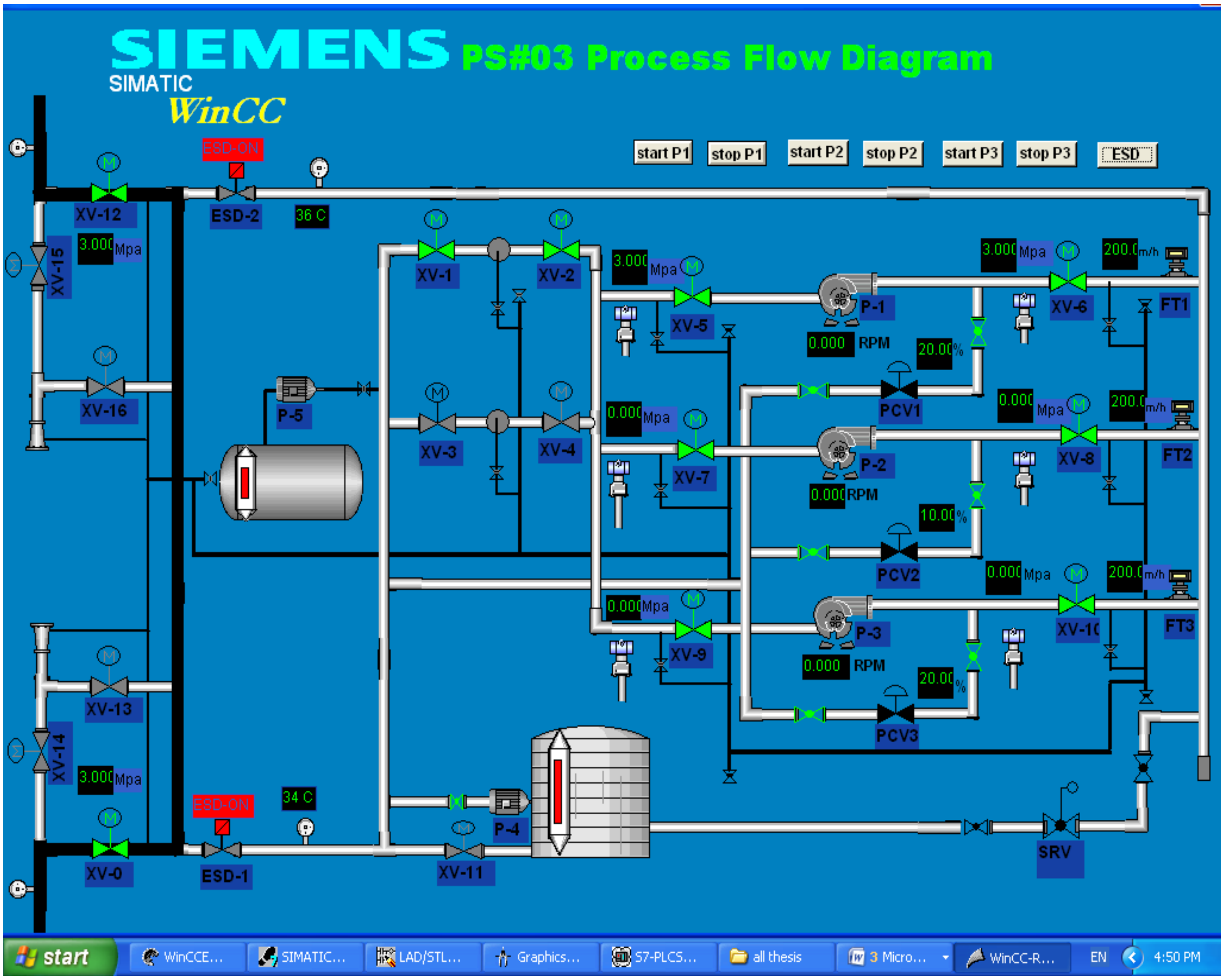

Figure (6.4): The Station Offline and the ESD valve is on.

Figure (6.4) shows the pump station bypass when the ESD valve is on and the inlet valve of station is open, and the suction and discharge valve of pumps units are full close so the crude oil is unable to enter the pump units and must continue down the pipeline. Also the figure shows the path of crude oil from suction to discharge of station through bypass pipe.

Two of the main reasons for bypassing a station are to allow for maintenance of the station and in an emergency situation such as gas alarm, fire alarm or the release of fluid within the station.

6.2.5 Case (5):

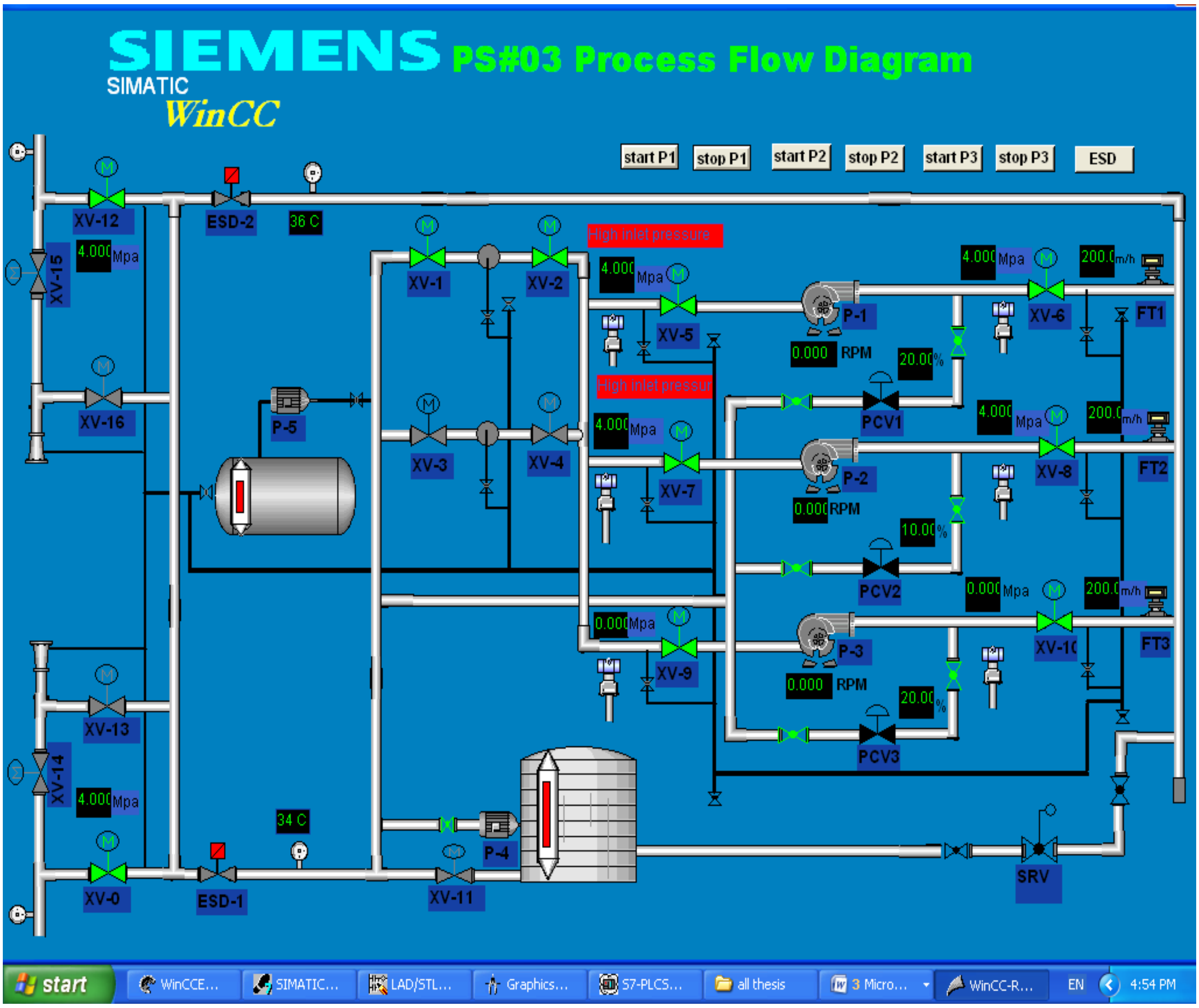

Figure (6.5): High pressure alarm.

Figure (6.5) shows the pump station when the pump unit no.1 trip due to high inlet pressure alarm. There are alarms from inlet and out let pressure transmitters if the pressure exceeds the set point. In this case also the surge relieve valve open to make path from the discharge line to the relieve tank.

6.2.6 Case (6):

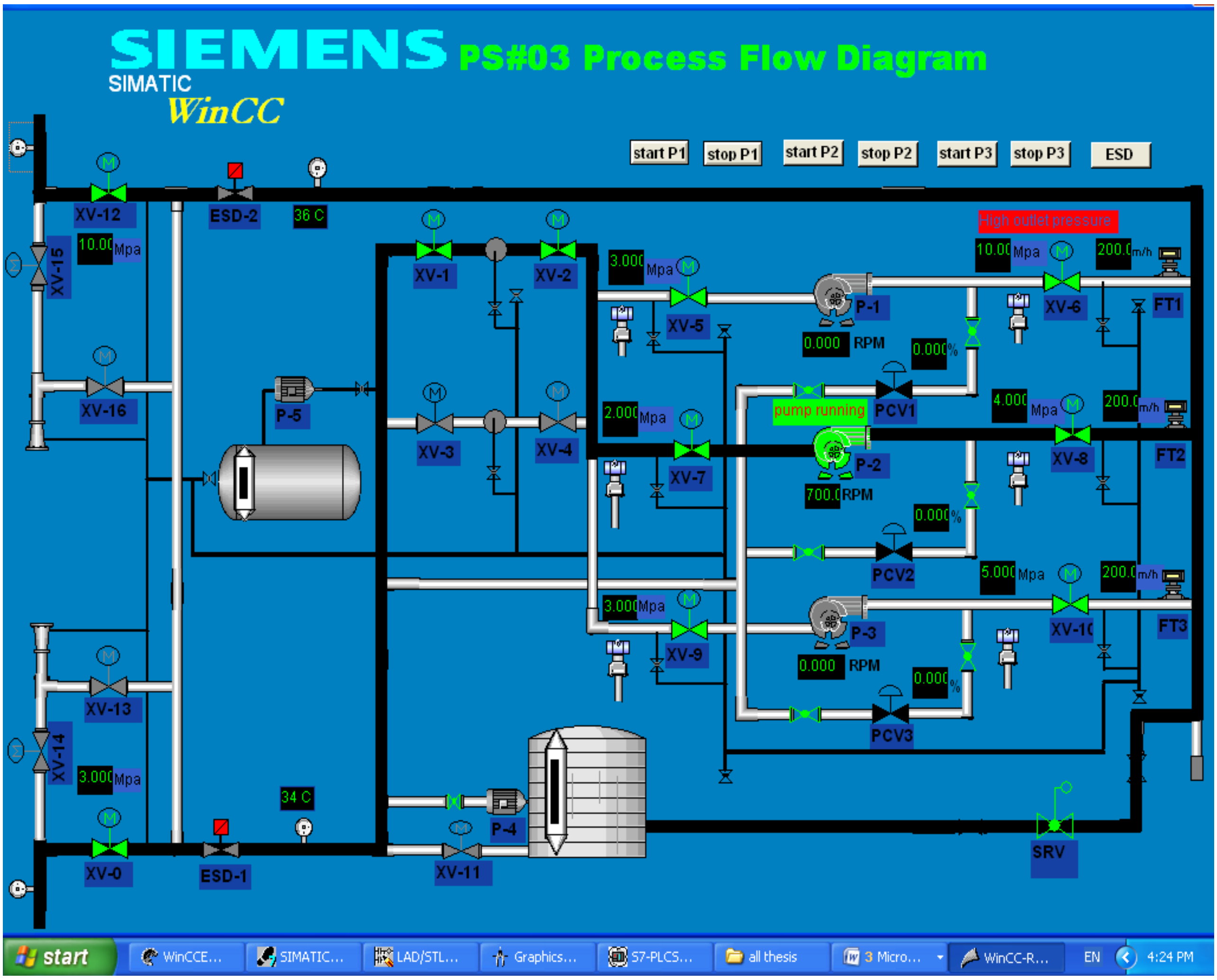

Figure (6.6): surge relieve valve.

Figure (6.6) shows the pump station when the pump unit no.1 trip due to high outlet pressure. There is an alarm from outlet Pressure Transmitter. In this case the operator must be open the surge relieve valve to make path from the discharge to the relieve tank.

6.2.7 Case (7):

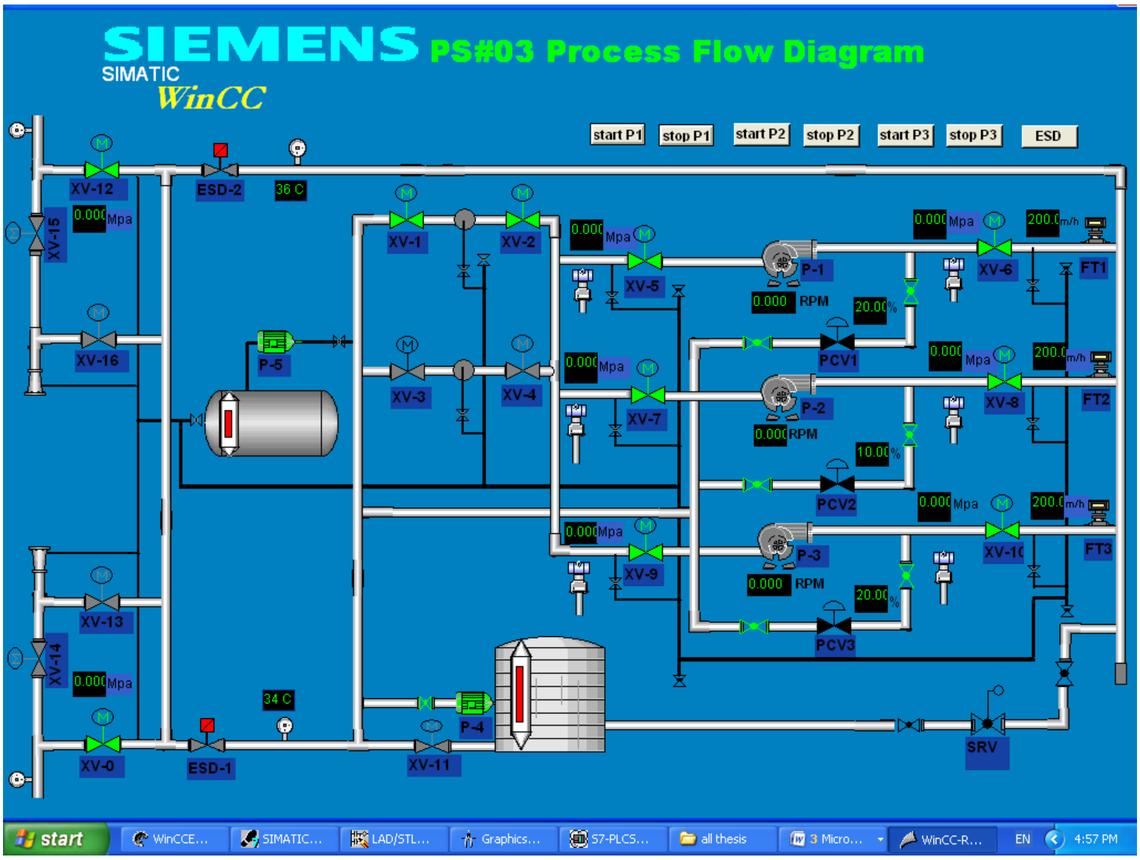

Figure (6.7): drain system.

Figure (6.7) shows the drain system of station. The waste oil from the pig launcher, pig receiver, strainer and pumps will be gathered to the sump tank. The Storage tank also can be used as relief tank when the pressure exceeds the set-point of the surge relief valve. When the two tanks are full the injections pumps (P-4, P-5) inject the crude oil from tanks into main line.

CHAPTER SEVEN

CONCLUSIONS AND FUTURE WORK

7.1 Conclusions:

In this thesis the Pipeline of Petro energy Company (Sudan branch) and al obaied Pump station (PS#03) were considering as a case study, the pump station for simulation of the SCADA system with a PLC and the pipeline for SCADA upgrade project. The Objectives of SCADA system in Petroleum pipeline:

- To provide effective & efficient monitoring and control of entire pipeline network.
- Remote controls of important station equipment, process set points, block valves from SCC or MCC.
- Emergency shutdown of entire pipeline from MCC.
- Acquisition & display of pipeline parameters, alarms from attended stations, scraper stations, C.P. Stations & block valves at MCC.

A SCADA system allows an operator to make set point changes on distant process controllers, to open or close valves or switches, to monitor alarms, and to gather measurement information from a location central to a widely distributed process, such as an oil or gas field, pipeline system. When the dimensions of the process become very large hundreds or even thousands of kilometers from one end to the others one can appreciate the benefits SCADA offers in terms of reducing the cost of routine visits to monitor facility operation. The value of these benefits will grow even more if the facilities are very remote and require extreme effort.

In order to maintain the whole pipeline in safe and smooth operation state, it is better to add more dynamic pressure and flow observation points along a pipeline, where the relevant signals will be acquired and delivered to existing running SCADA system by using remote terminals units. The pressure observation points along the oil pipeline in some of pump stations, BV rooms and CP stations in PE pipeline.

7.2 Future Work:

The below items are suggestions for a future work in petroleum pipeline:

- Using a remote control for the important equipments like a valve in BV rooms, an electro-hydraulic actuator that hydraulically opens or closes a valve in response to an electrical signal (actuator) in all BV rooms and use the solar system to supply these equipments.
- SCADA system shall have a high level of reliability achieved through redundancy and the design of the system because the main reason for the SCADA failure is the communication network failure. A PLCs and PCs have low failure rates compared to communication network. The availability of the communication network should be increased for a more reliable SCADA system.
- Using the application software of SCADA system such as pig tracking for tracks movement of pig, and using an intelligent pig.
- Proper maintenance of station can ensure reliable functioning of SCADA system. Also the calibration for instrumentation and devices every time.
- Adding more dynamic pressure and flow observation points along a pipeline for leak detection and Installing a CCTV system in all

BV and CP rooms and connect it through SCADA system

- Creating an offline simulation program for the pump station for training in each station. It will be very useful for a new trainee operator.

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APPENDIX.A

A.1 Symbols of Ladder Program for Pump Station Simulation:

Symbol	Address	Data type	Comment
C 0	C 0	COUNTER	counter speed p1
P1-FT	MW 16	WORD	flow transmitter of pump1
P1-PCV	PIW 260	WORD	opining percent of PCV1
P1-PCV-Road	Q 1.5	BOOL	crude oil direction of PCV1
P1-PCV-switch	M 1.5	BOOL	pressure control valve of pump1
P1-PTi	PIW 256	WORD	inlet pressure transmitter of pump1
P1-PTi-alarm	Q 1.3	BOOL	inlet pressure alarm for pump1
P1-PTo	PIW 258	WORD	outlet pressure transmitter of pump1
P1-PTo-alarm	Q 1.4	BOOL	outlet pressure alarm for pump1
P1-RPM	MW 14	WORD	speed of pump1
P1-Vi	M 1.1	BOOL	inlet Valve of pump1
P1-Vi-Road	Q 1.1	BOOL	crude oil direction p1
P1-Vo	M 1.2	BOOL	outlet Valve of pump1
P2-FT	MW 26	WORD	flow transmitter of pump2
P2-PCV	PIW 268	WORD	opining percent of PCV2
P2-PCV-Road	Q 2.5	BOOL	crude oil direction of PCV2
P2-PCV-switch	M 2.5	BOOL	pressure control valve of pump2
P2-PTi	PIW 264	WORD	inlet pressure transmitter of pump2
P2-PTi-alarm	Q 2.3	BOOL	inlet pressure alarm for pump2
P2-PTo	PIW 266	WORD	outlet pressure transmitter of pump2
P2-PTo-alarm	Q 2.4	BOOL	outlet pressure alarm for pump2
P2-RPM	MW 24	WORD	speed of pump2
P2-Vi	M 2.1	BOOL	inlet Valve of pump2
P2-Vi-Road	Q 2.1	BOOL	crude oil direction p2
P2-Vo	M 2.2	BOOL	outlet Valve of pump2
P3-PCV	PIW 276	WORD	opining percent of PCV3
P3-PCV-Road	Q 3.5	BOOL	crude oil direction of PCV3
P3-PCV-switch	M 3.5	BOOL	pressure control vavle of pump3
P3-PTi	PIW 272	WORD	inlet pressure transmitter of pump3
P3-PTi-alarm	Q 3.3	BOOL	inlet pressure alarm for pump3
P3-PTo	PIW 274	WORD	outlet pressure transmitter of pump3
P3-PTo-alarm	Q 3.4	BOOL	outlet pressure alarm for pump3
P3-RPM	MW 34	WORD	speed of pump3
P3-Vi	M 3.1	BOOL	inlet Valve of pump3

P3-Vi-Road	Q 3.1	BOOL	crude oil direction p3
P3-Vo	M 3.2	BOOL	outlet Valve of pump3
pump1	Q 1.0	BOOL	pump number 1
pump2	Q 2.0	BOOL	pump 2
pump3	Q 3.0	BOOL	pump 3
stp-P1	M 0.2	BOOL	stop push button p1
tp-P2	M 0.4	BOOL	stop push button p2
stp-P3	M 0.6	BOOL	stop push button p3
str-P1	M 0.1	BOOL	start push button p1
str-P2	M 0.3	BOOL	start push button p2
str-P3	M 0.5	BOOL	start push button p3
C 1	C 1	COUNTER	counter flow meter p1
C 2	C 2	COUNTER	counter speed p2
C 3	C 3	COUNTER	counter flow meter p2
C 4	C 4	COUNTER	counter speed p3
C 5	C 5	COUNTER	counter flow meter p3
T 0	T 0	TIMER	timer RPM p1
T 1	T 1	TIMER	timer FT p1
T 2	T 2	TIMER	timer RPM p2
T 3	T 3	TIMER	timer FT p2
T 4	T 4	TIMER	timer RPM p3
T 5	T 5	TIMER	timer FT p3
ESD-switch	M 0.0	BOOL	emergency shut down switch
ESD	Q 0.0	BOOL	emergency shut down
SRV	M 4.1	BOOL	Surge relieve valve
SRV-Road	Q 4.1	BOOL	Surge relieve valve Road

A.1 Ladder program for Simulation of Pump Station in Chapter 6 by using Simatic Step7 version 5.5 Program.

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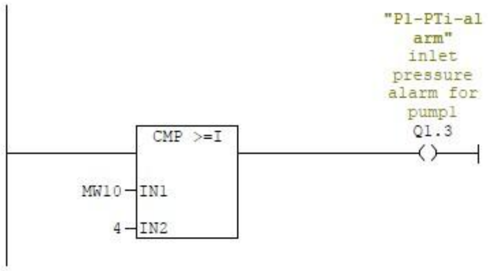

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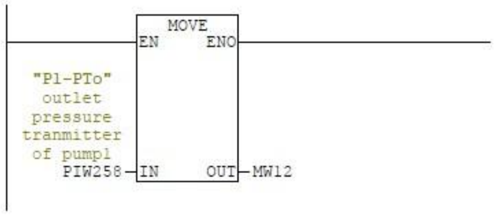

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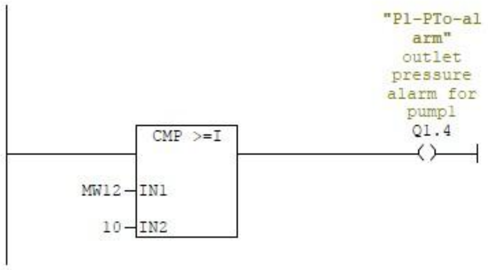

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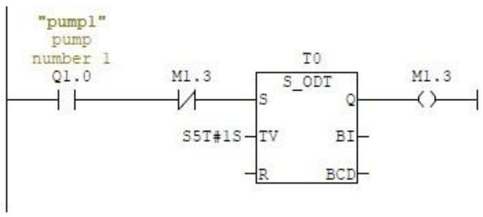

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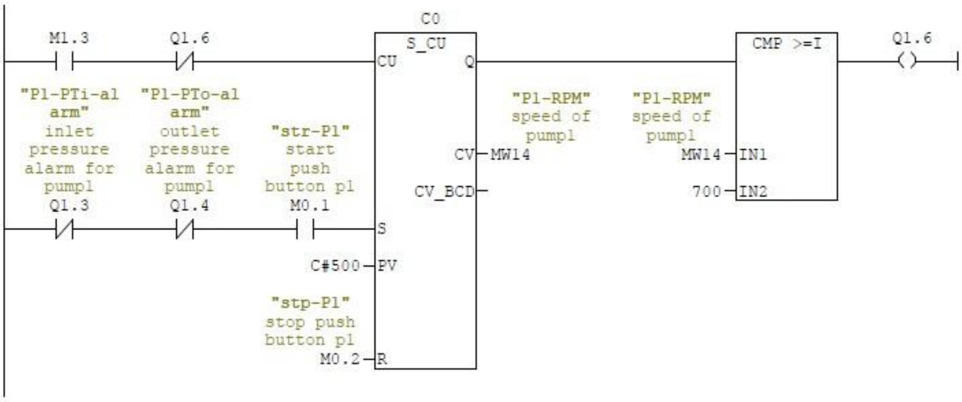

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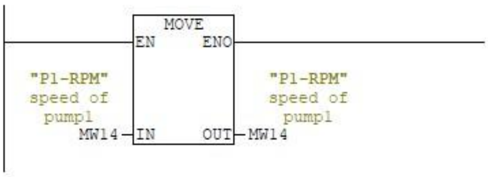

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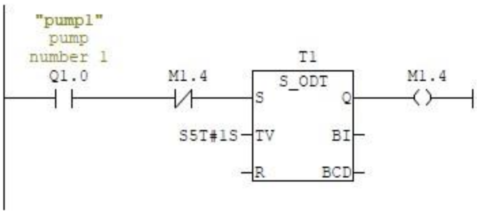

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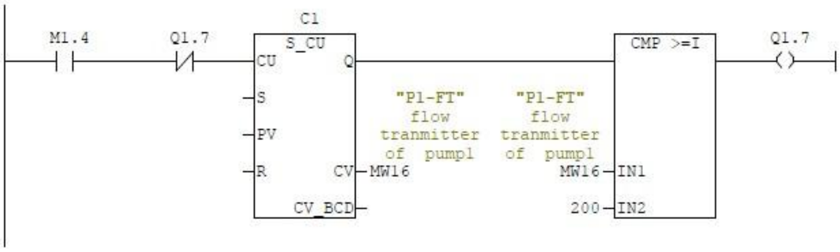

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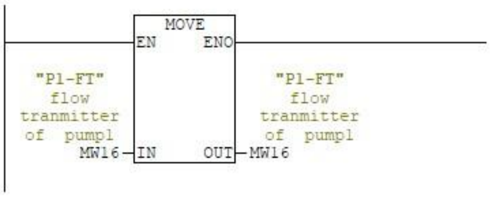

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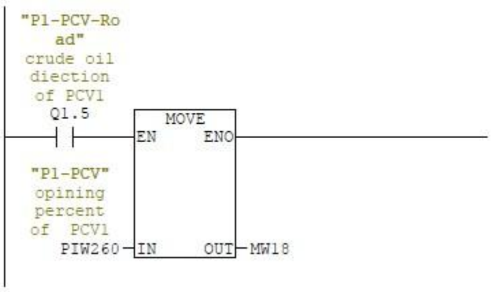

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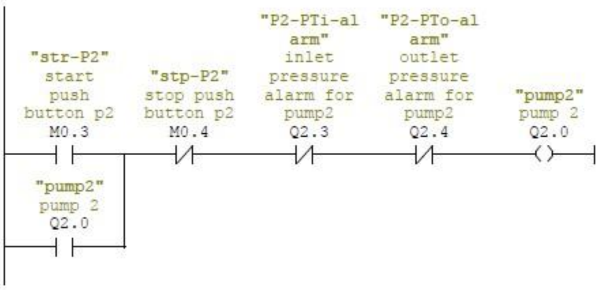

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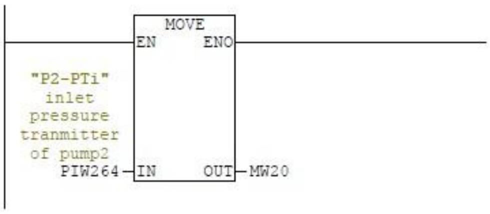

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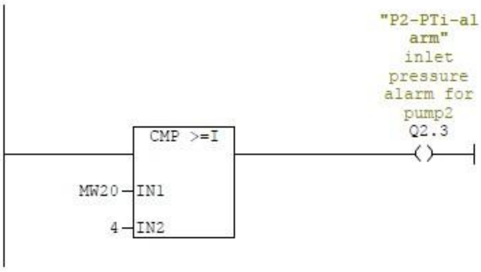

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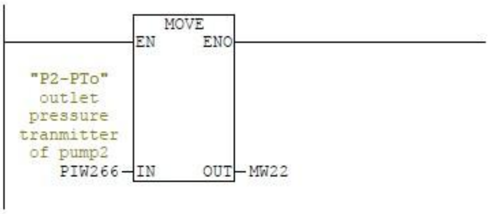

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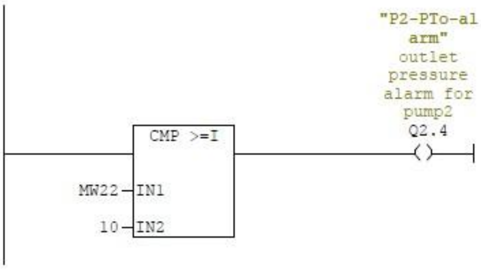

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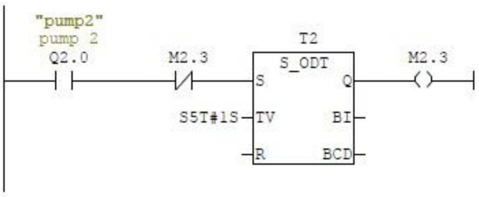

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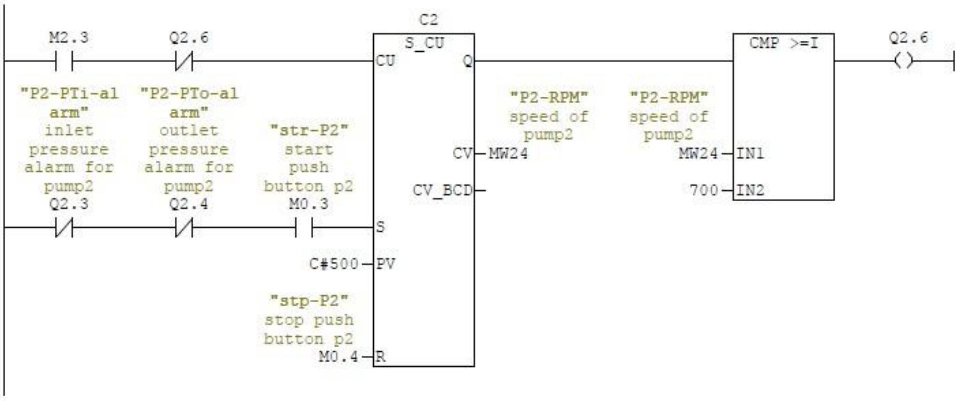

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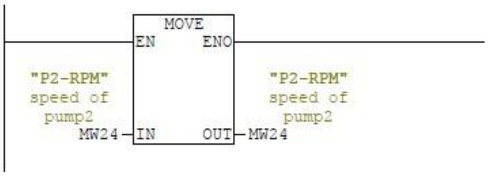

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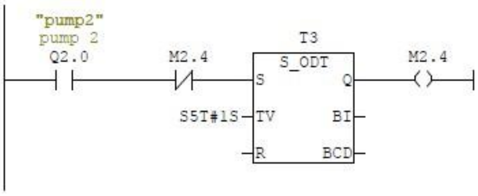

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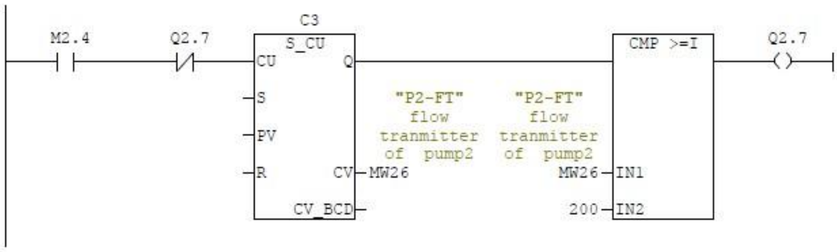

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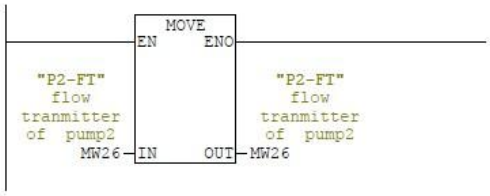

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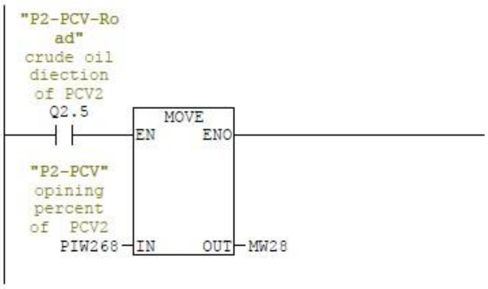

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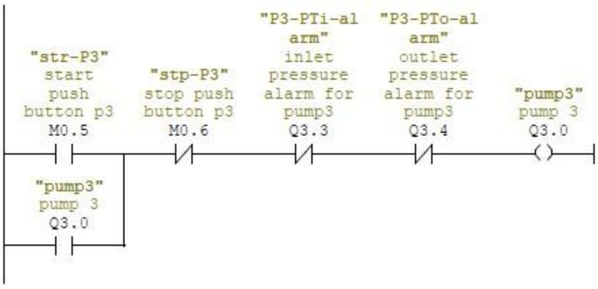

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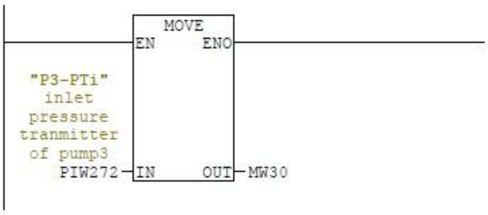

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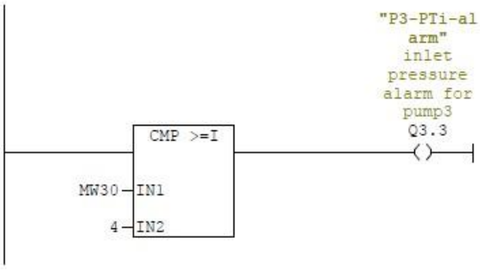

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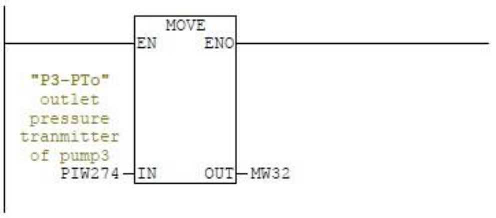

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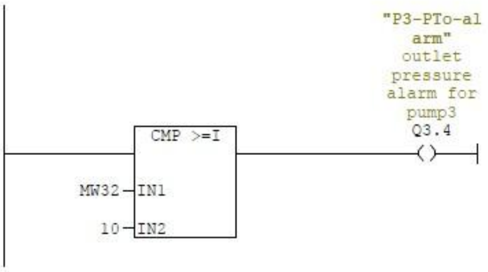

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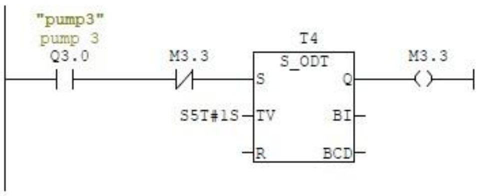

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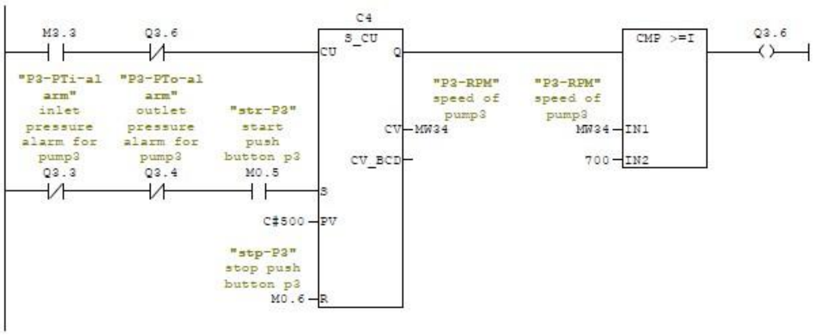

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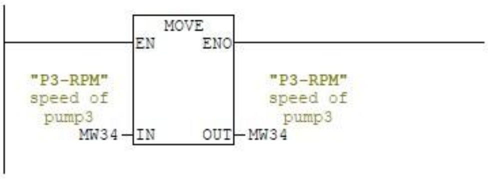

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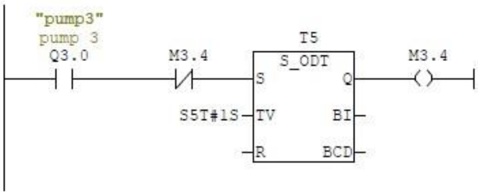

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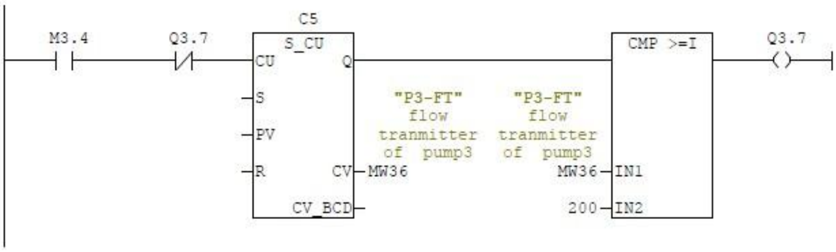

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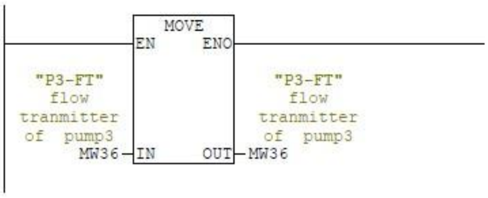

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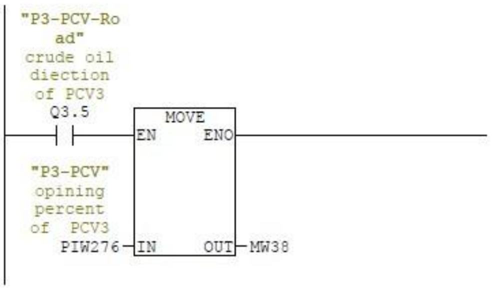


APPENDIX.B

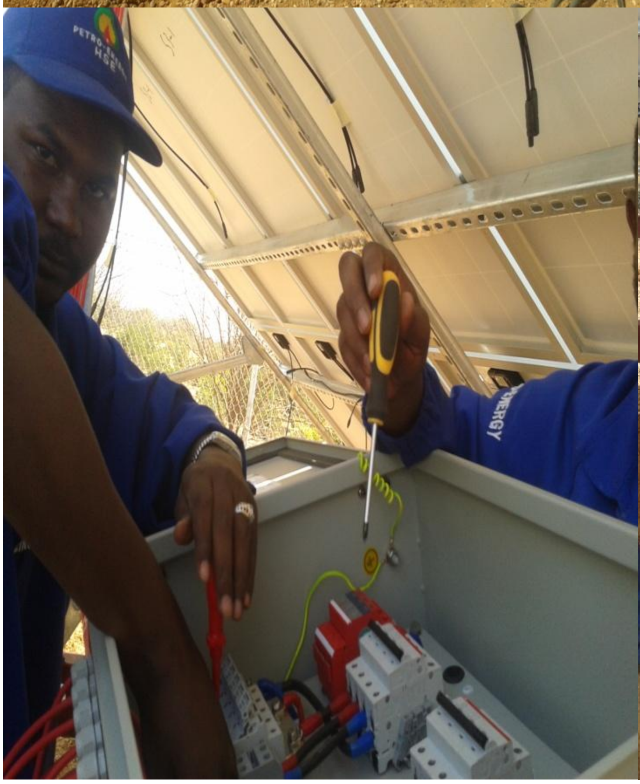
B.1 SCADA Upgrade Project Pictures:





PETRO-ENERGY


PETRO-ENERGY



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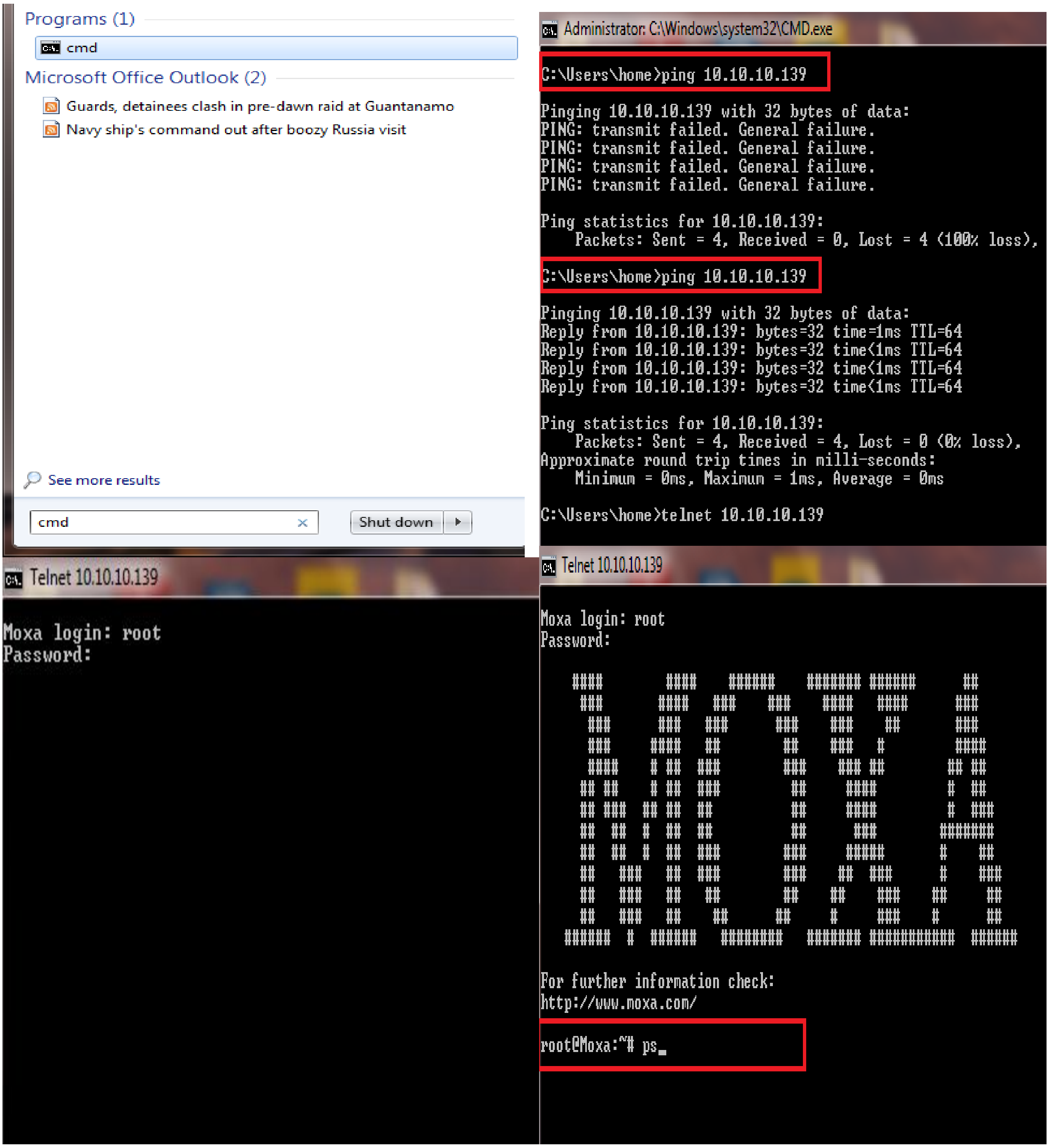
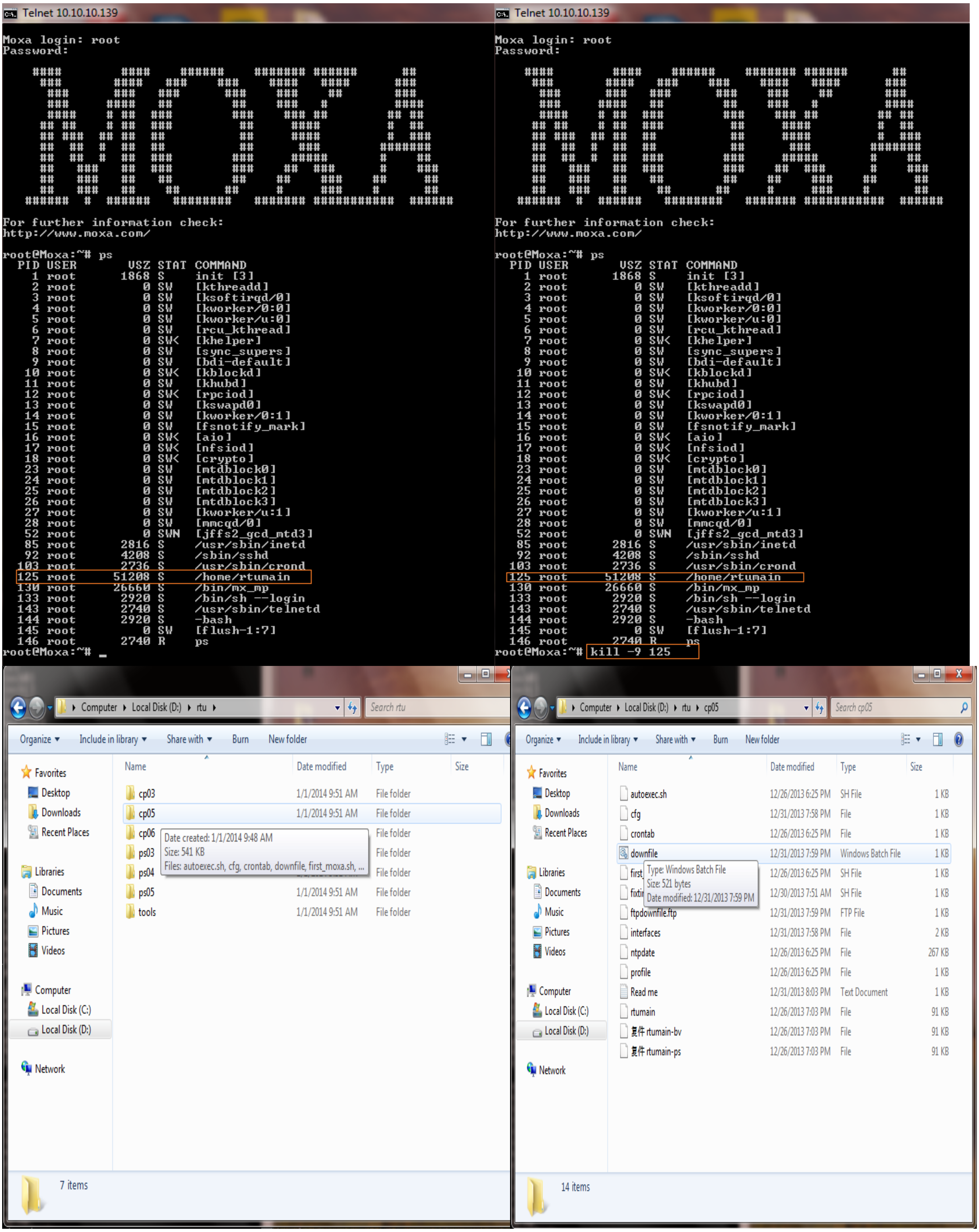
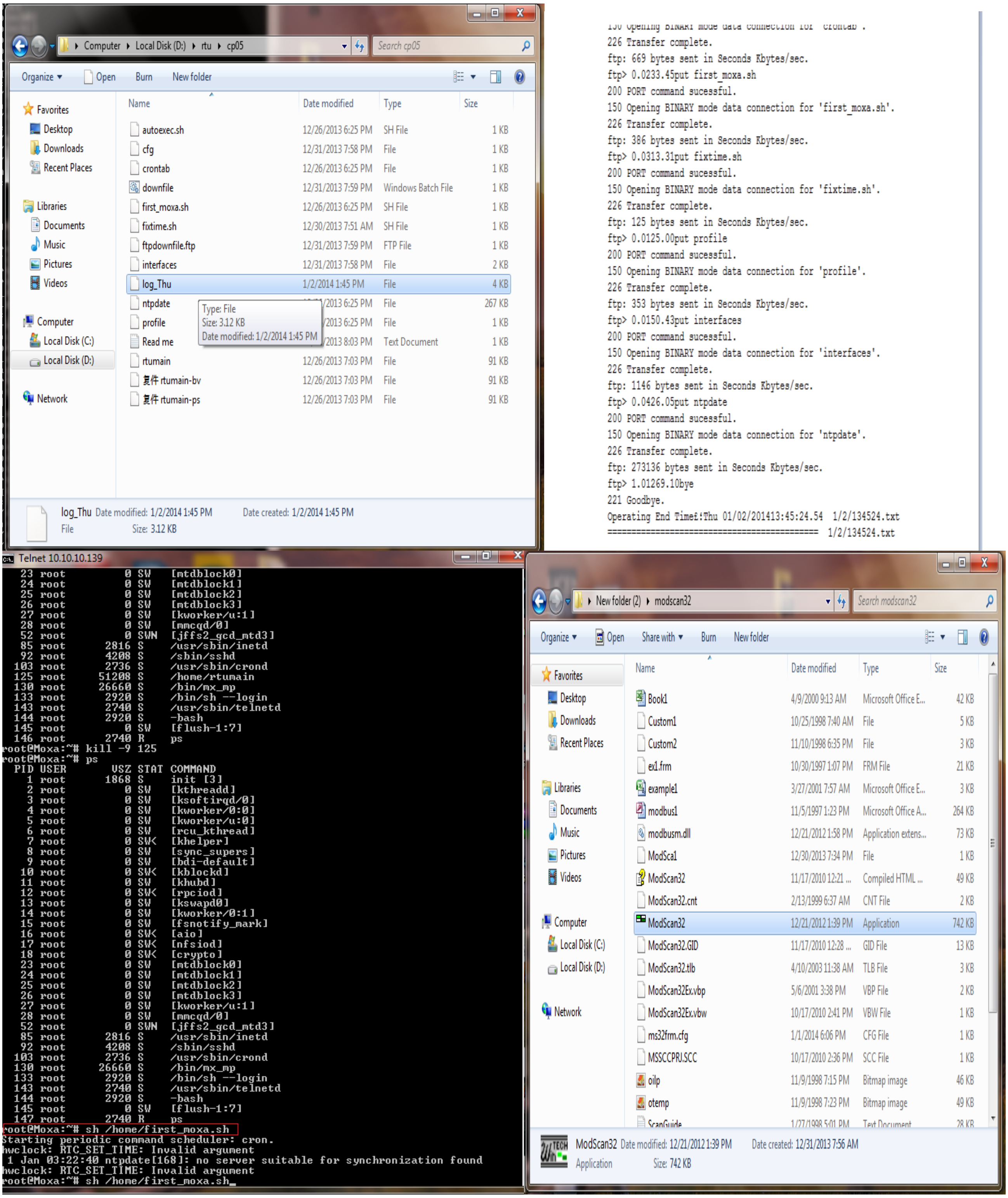
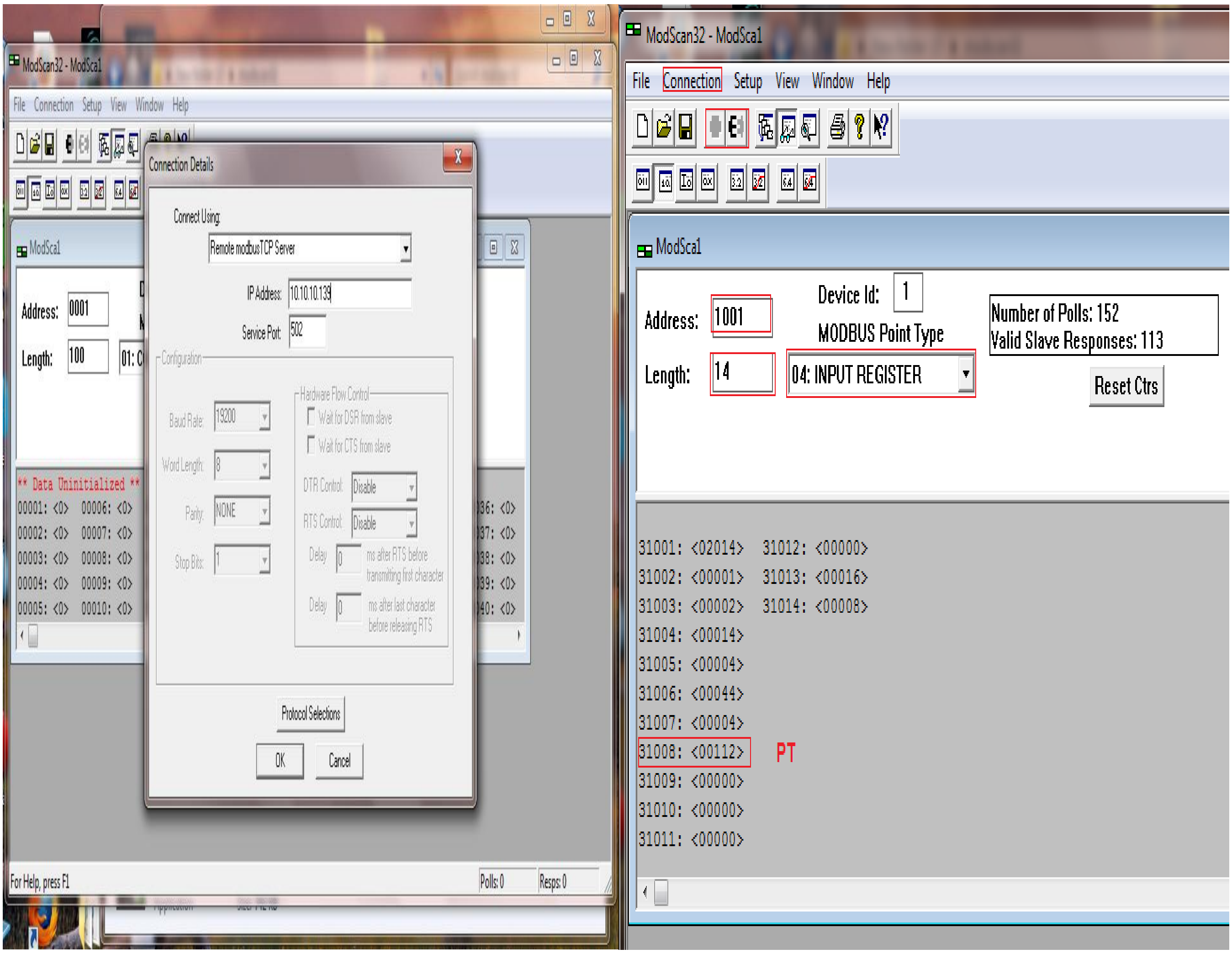



Telnet 10.10.10.139
Moxa login: root
Password:
For further information check:
http://www.moxa.com/
root@Moxa:~# ps
PID USER VSZ STAT COMMAND
1 root 1868 S init [3]
2 root 0 SW [kthreadd]
3 root 0 SW [ksoftirqd/0]
4 root 0 SW [kworker/0:0]
5 root 0 SW [kworker/u:0]
6 root 0 SW [rcu_kthread]
7 root 0 SW< [khelper]
8 root 0 SW [sync_supers]
9 root 0 SW [bdi-default]
10 root 0 SW< [kblockd]
11 root 0 SW [khubd]
12 root 0 SW< [rpciod]
13 root 0 SW [kswapd0]
14 root 0 SW [kworker/0:1]
15 root 0 SW [fsnotify_mark]
16 root 0 SW< [aio]
17 root 0 SW< [nfsiod]
18 root 0 SW< [crypto]
23 root 0 SW [mtdblock0]
24 root 0 SW [mtdblock1]
25 root 0 SW [mtdblock2]
26 root 0 SW [mtdblock3]
27 root 0 SW [kworker/u:1]
28 root 0 SW [mmcqd/0]
52 root 0 SWN [jffs2_gcd_mtd3]
85 root 2816 S /usr/sbin/inetd
92 root 4208 S /sbin/sshd
103 root 2736 S /usr/sbin/crond
125 root 51208 S /home/rtumain
130 root 26660 S /bin/mx_mp
133 root 2920 S /bin/sh --login
143 root 2740 S /usr/sbin/telnetd
144 root 2920 S -bash
145 root 0 SW [flush-1:7]
146 root 2740 R ps
root@Moxa:~#
Telnet 10.10.10.139
Moxa login: root
Password:
For further information check:
http://www.moxa.com/
root@Moxa:~# ps
root@Moxa:~# kill -9 125
Computer › Local Disk (D:) › rtu ›
Search rtu
Organize Include in library Share with Burn New folder
Favorites
Desktop
Downloads
Recent Places
Libraries
Documents
Music
Pictures
Videos
Computer
Local Disk (C:)
Local Disk (D:)
Network
Name Date modified Type Size
cp03 1/1/2014 9:51 AM File folder
cp05 1/1/2014 9:51 AM File folder
cp06 File folder
ps03 File folder
ps04 File folder
ps05 1/1/2014 9:51 AM File folder
tools 1/1/2014 9:51 AM File folder
Date created: 1/1/2014 9:48 AM
Size: 541 KB
Files: autoexec.sh, cfg, crontab, downfile, first_moxa.sh, ...
7 items
Computer › Local Disk (D:) › rtu › cp05
Search cp05
Name Date modified Type Size
autoexec.sh 12/26/2013 6:25 PM SH File 1 KB
cfg 12/31/2013 7:58 PM File 1 KB
crontab 12/26/2013 6:25 PM File 1 KB
downfile 12/31/2013 7:59 PM Windows Batch File 1 KB
12/26/2013 6:25 PM SH File 1 KB
12/30/2013 7:51 AM SH File 1 KB
Type: Windows Batch File
Size: 521 bytes
Date modified: 12/31/2013 7:59 PM
ftpdownfile.ftp 12/31/2013 7:59 PM FTP File 1 KB
interfaces 12/31/2013 7:58 PM File 2 KB
ntpdate 12/26/2013 6:25 PM File 267 KB
profile 12/26/2013 6:25 PM File 1 KB
Read me 12/31/2013 8:03 PM Text Document 1 KB
rtumain 12/26/2013 7:03 PM File 91 KB
复件 rtumain-bv 12/26/2013 7:03 PM File 91 KB
复件 rtumain-ps 12/26/2013 7:03 PM File 91 KB
14 items


226 Transfer complete.
ftp: 669 bytes sent in Seconds Kbytes/sec.
ftp> 0.0233.45put first_moxa.sh
200 PORT command sucessful.
150 Opening BINARY mode data connection for 'first_moxa.sh'.
226 Transfer complete.
ftp: 386 bytes sent in Seconds Kbytes/sec.
ftp> 0.0313.31put fixtime.sh
200 PORT command sucessful.
150 Opening BINARY mode data connection for 'fixtime.sh'.
226 Transfer complete.
ftp: 125 bytes sent in Seconds Kbytes/sec.
ftp> 0.0125.00put profile
200 PORT command sucessful.
150 Opening BINARY mode data connection for 'profile'.
226 Transfer complete.
ftp: 353 bytes sent in Seconds Kbytes/sec.
ftp> 0.0150.43put interfaces
200 PORT command sucessful.
150 Opening BINARY mode data connection for 'interfaces'.
226 Transfer complete.
ftp: 1146 bytes sent in Seconds Kbytes/sec.
ftp> 0.0426.05put ntpdate
200 PORT command sucessful.
150 Opening BINARY mode data connection for 'ntpdate'.
226 Transfer complete.
ftp: 273136 bytes sent in Seconds Kbytes/sec.
ftp> 1.01269.10bye
221 Goodbye.
Operating End Time:Thu 01/02/201413:45:24.54 1/2/134524.txt
Telnet 10.10.10.139
root@Moxa:~# sh /home/first_moxa.sh
Starting periodic command scheduler: cron.
hwclock: RTC_SET_TIME: Invalid argument
1 Jan 03:22:40 ntpdate[168]: no server suitable for synchronization found
hwclock: RTC_SET_TIME: Invalid argument


ModScan32 - ModSca1
File Connection Setup View Window Help
ModSca1
Address: 0001
Length: 100
** Data Uninitialized **
Connection Details
Connect Using:
Remote modbusTCP Server
IP Address: 10.10.10.139
Service Port: 502
Configuration
Baud Rate: 19200
Word Length: 8
Parity: NONE
Stop Bits: 1
Hardware Flow Control
Wait for DSR from slave
Wait for CTS from slave
DTR Control: Disable
RTS Control: Disable
Protocol Selections
OK
Cancel
For Help, press F1
Polls: 0
Resps: 0
ModScan32 - ModSca1
File Connection Setup View Window Help
ModSca1
Address: 1001
Device Id: 1
MODBUS Point Type
Length: 14
04: INPUT REGISTER
Number of Polls: 152
Valid Slave Responses: 113
Reset Ctrs
31001: <02014>
31002: <00001>
31003: <00002>
31004: <00014>
31005: <00004>
31006: <00044>
31007: <00004>
31008: <00112>
PT
31009: <00000>
31010: <00000>
31011: <00000>
31012: <00000>
31013: <00016>
31014: <00008>