EVALUATION OF THE SCADA SYSTEM IN GTCL

A Thesis

Submitted to the Department of Petroleum and Mineral Resources Engineering

In partial fulfillment of the requirements for the Degree of

MASTER OF PETROLEUM ENGINEERING.

By

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DHAKA-1000, BANGLADESH

May, 2007

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DECLARATION

It is hereby declared that this project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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ACKNOWLEDGEMENT

First of all I would like to express my heartfelt gratitude and profound appreciation to Dr. Mohammed Mahbubur Rahman, Assistant Professor, Department of Petroleum & Mineral Resources Engineering, BUET for his valuable guidance, encouragement and supervision throughout the entire work.

I would like to convey my deep sense of gratitude to Dr. Mohammad Tamim, Professor & Head, Department of Petroleum & Mineral Resources Engineering, BUET, for his valuable suggestions in accomplishing this work.

I would like to thank Mr. Md. Shorab Hossain, Lecturer, Department of Petroleum & Mineral Resources Engineering, BUET, for his cooperation of this work.

I would like to appreciate the authority of Gas Transmission Company Limited (GTCL) for giving me permission to pursue Master of Petroleum Engineering Degree at BUET.

I would like to express my gratitude to Engr. Nizamul Hasan Sheriff (DGM, SCADA), Engr. A. K. M. Shofiqul Haider Chowdhury (Manager, Load Despatch), Engr. Md. Nasir Uddin Chowdhury (Manager, MCC), Engr. Md. Ainul Kabir (Manager, Compressor Project), Engr. Sanwar Hossain (DM, Pipeline), Engr. Pranot Kumar Barua (DM, SCADA), Engr. Ashoke Kumar Biswas (DM, SCADA), Engr. Nowsher Azad (AE, SCADA), Engr. A. K. M. Mizanur Rahman (AE, SCADA) of GTCL for their kind cooperation in providing me with good suggestions and requisite data.

ABSTRACT

Gas Transmission Company Limited (GTCL) was incorporated in 1993 in the unbundling process of gas sector restructuring for owning, operating and maintaining the high pressure gas transmission pipelines forming a part of the national gas grid. Around 70% of total produced gas is transmitted by GTCL pipelines. In order to ensure smooth and efficient pipeline operation, it was decided to incorporate a Supervisory Control And Data Acquisition (SCADA) system by GTCL. It was duly installed and commissioned in 2004.

The main objective of this study is to find out the real impacts of the SCADA system. This is done by carefully studying and itemizing the tangible and intangible benefits directly arising out of the SCADA system. Shortcomings are also identified which need to be removed in order to get maximum benefits from the SCADA system. Financial analysis is performed from two perspectives such as-gas sector perspective and national perspective to justify the implementation of the system. The financial parameters of gas sector perspective reveal that the project is not financially viable while it is viable for national perspective.

TABLE OF CONTENTS

Declaration		iv
Acknowledgement		v
Abstract		vi
Table of Contents		vii
List of Tables		xi
List of Figures		xii
Abbreviations		xiii
Units and Symbols		xv
Currency and Conversion Rate		xv
CHAPTER 1: INTRODUCTION		1
1.1	Objective	2
1.2	Methodology	2
CHAPTER 2: PRESENT STATUS OF GAS SECTOR		3
2.1	Reserve Scenario	3
2.2	Production Scenario	3
2.3	Consumption Scenario	7
	2.3.1 Daily Consumption by the Marketing Companies	11
	2.3.2 Daily Consumption by Different Sectors	12
2.4	Transmission Scenario	13
	2.4.1 Operated Pipeline of GTCL	21
	2.4.2 Gas Transmitted by GTCL	23
	2.4.3 Year wise Gas Transmitted by GTCL	24
	2.4.4 Condensate Transmitted Pipeline of GTCL	24
	2.4.5 Year wise Condensate Transmitted by GTCL pipelines	25
2.5	Present Gas Management Flow System	26
CHAPTER 3: OVERVIEW OF SCADA SYSTEM		28
3.1	SCADA System in GTCL	29
	3.1.1 The Telecommunications System	29

3.1.2 Radio Rooms, Telecommunications Towers, Masts and Monopole 30
3.1.3 The SCADA System 33
3.1.4 The Control Centres and Gas Operating Company Terminals (OCTs) 35
3.1.5 Remote Terminal Units (RTUs), Instrumentation and Metering Skids 36
3.1.6 Microwave Links and RTU Status 39

CHAPTER 4: TECHNICAL SPECIFICATION OF SCADA SYSTEM IN GTCL 41

4.1 Control Centre Hardware 41
4.1.1 SCADA Server 41
4.1.2 Telemetry 42
4.1.3 SCADA Management Workstation 43
4.1.4 Pipeline Applications Workstation 43
4.1.5 Control Room Workstations 44
4.1.6 Large Screen Display 44
4.1.7 Printers 45
4.1.8 LAN Equipment 45
4.1.9 GPS Clock 46
4.1.10 Remote Access Modem 47
4.2 Head Office Hardware 47
4.3 Remote Terminal Units(RTU's) 48
4.4 Telecommunication System 49
4.4.1 Communication Systems 50
4.4.2 PABX Network 50
4.4.3 Trunk Radio System 52
4.4.4 Communications Management system 54
4.4.5 Gas Data Acquisition Control 54
4.4.6 Site Data Acquisition 57
4.5 Instrumentation 58
4.5.1 Differential Pressure Transmitter 58
4.5.2 Pressure Transmitter 59
4.5.3 Temperature Transmitter 59

4.5.4 Turbine Meter 59

4.5.5 Main Line Valve (MLV) Solenoid Valves 60

4.5.6 Level Instruments 60

CHAPTER 5: EVALUATION OF THE SCADA SYSTEM 61

5.1 Benefits 61

5.1.1 Response Time 61

5.1.2 Man Power 61

5.1.3 Liquidated Damages 62

5.1.4 Condensate Loss 62

5.1.5 Voice Communication 63

5.1.6 Decision Making 63

5.1.7 Accuracy of Data 63

5.1.8 Billing Period 64

5.1.9 Gas Compositions 64

5.1.10 Daily Gas Report 64

5.1.11 Operational Capacity 65

5.1.12 Cathodic Protection 65

5.2 Shortcomings of the System 67

5.2.1 Remote Control Valve 70

5.2.2 Leak Detection 70

5.2.3 Line Pack 71

5.2.4 Load Scheduling 72

5.2.5 Load Balancing 73

5.2.6 Pigging 74

5.2.7 Pipeline Efficiency 75

5.2.8 Trained Manpower 76

CHAPTER 6: FINANCIAL ANALYSIS 77

6.1 Calculation of Cash Outflow 77

6.2 Calculation of Cash Inflow 79

6.2.1 Savings from Site Offices 79
6.2.2 Savings from Liquidated Damages 81
6.2.3 Savings from Condensate 85
6.3 Gas Sector Perspective 87
6.3.1 Net Present Value 87
6.3.2 Internal Rate of Return 90
6.3.3 Profitability Index / Benefit Cost Ratio 90
6.3.4 Pay Back Period 91
6.3.5 Average Accounting Return 93
6.4 National Perspective 95
6.4.1 Market value of Urea 95
6.4.2 Market Value of Power 95
6.4.3 Net Present Value 97
6.4.4 Internal Rate of Return 99
6.4.5 Profitability index/ Benefit Cost Ratio 99
6.4.6 Pay Back Period 100
6.4.7 Average Accounting Return 101
6.4.8 Summary of Financial Analysis 102

CHAPTER 7: CONCLUSIONS & RECOMMENDATIONS 103

7.1 Conclusions 103
7.2 Recommendations 104

Bibliography 105

Appendix A 107

Appendix B 114

LIST OF TABLES

Table 2.1	Present Gas Production	4
Table 2.2	Consumption of Gas	8
Table 2.3	Transmission Pipelines of Different Companies	18
Table 2.4	Spur Pipe Lines	22
Table 2.5	Condensate Pipelines of GTCL	25
Table 5.1	Comparative Statement of Benefits of Pre and Post SCADA System	66
Table 6.1	Investment Cost	77
Table 6.2	Operating Cost	78
Table 6.3	Utility Expenses	78
Table 6.4	Salary and Wages of the Personnel	79
Table 6.5	Savings from Site Offices	80
Table 6.6	Particulars of Liquidated Damages with Different Companies	81
Table 6.7	Shutdown Status of CUFL at Pre & Post SCADA	82
Table 6.8	Liquidated Damages of Fertilizer Factories	83
Table 6.9	Shutdown Status of Raujan Power Station at Pre & Post SCADA	84
Table 6.10	Liquidated Damages of PDB	85
Table 6.11	Total Cost due to Purging of Condensate Line in 2003	86
Table 6.12	Total Cost due to Purging of Condensate Line in 2005	87
Table 6.13	NPV at Different Discount Rate	89
Table 6.14	Benefit Cost Ratio at 15% Discount Rate	91
Table 6.15	Pay Back Period	92
Table 6.16	Average Accounting Return	94
Table 6.17	Market value of Urea	95
Table 6.18	NPV at Different Discount Rate	98
Table 6.19	Benefit Cost Ratio at 15% Discount Rate	99
Table 6.20	Pay Back Period	100
Table 6.21	Average Accounting Return	101
Table 6.22	Summary of Financial Analysis (at 15% Discount Rate)	102

LIST OF FIGURES

Figure 2.1	Company wise Production	5
Figure 2.2	State Company wise Production	6
Figure 2.3	IOC wise Production	7
Figure 2.4	Marketing Company wise Daily Consumption of Gas	11
Figure 2.5	Sector wise Daily Consumption of Gas	12
Figure 2.6	A line Diagram of a National Gas Grid Line	17
Figure 2.7	Company wise Operated Pipeline	21
Figure 2.8	Operated Pipeline of GTCL	22
Figure 2.9	Marketing Company wise Transmitted Gas by GTCL	23
Figure 2.10	Gas Transmitted by GTCL	24
Figure 2.11	Condensate Transmitted by GTCL	25
Figure 2.12	Present Gas Management Flow System	27
Figure 3.1	Microwave Communications Backbone	30
Figure 3.2	New Telecommunication Tower	31
Figure 3.3	Mast and Monopole	32
Figure 3.4	Screen Shot of the SCADA Network of MCC	34
Figure 3.5	Control Room of SCADA System	35
Figure 3.6	Remote Terminal Unit	36
Figure 3.7	RTU with Solar Panel Array	37
Figure 3.8	Instrumentation Stand	38
Figure 3.9	Screen Shot of Microwave Links and RTU Status	40
Figure 4.1	PABX Network and Interconneeting Trunks	51
Figure 4.2	Trunk Radio System Overview	53
Figure 4.3	System Functional Design	55
Figure 5.1	Flow Diagram of a Part of Grid Line	69
Figure 5.2	Screen Shot of Leak Detection by SCADA System	71
Figure 5.3	Screen Shot of Line Pack by SCADA System	72
Figure 5.4	Screen Shot of Load Balancing by SCADA System	74
Figure 5.5	Screen Shot of Pipeline Efficiency by SCADA System	75

ABBREVIATIONS

AAR	Average Accounting Return
A-B	Ashuganj - Bakhrabad
ACC	Auxiliary Control Centre
AGMS	Ashuganj Gas Manifold Station
A-M	Ashuganj –Monohordi
APS	Ashuganj Power Station
BAPEX	Bangladesh Petroleum Exploration and Production Company limited
B-B	Brahmaputra Basin
BBGF	Beanibazar Gas Field
BCMCL	Boropukuria Coal Mining Company Limited
BCR	Benefit Cost Ratio
BFA	Bakhrabad Franchise Area
BGF	Bibyana Gas Field
BGFCL	Bangladesh Gas Field Company Limited
BGSL	Bakhrabad Gas System Limited
BOGMC	Bangladesh Oil, Gas and Mineral Corporation
CP	Cathodic Protection
CGS	City Gate Station
CNG	Compressed Natural Gas
CUFL	Chittagong Urea Fertilizer Limited
DCS	Distributed Control System
FGF	Fenchuganj Gas Field
GPS	Global Position System
GIDP	Gas Infrastructure Development Project
GIIP	Gas Initially in Place
GTSL	Granger Telecom System Limited
GUFF	Ghorashal Urea Fertilizer Factory
HDD	Hard Disk Drive
HGF	Habiganj Gas Field
IRR	Internal Rate of Return

IOC	International Oil Company
JFA	Jalalabad Franchise Area
JFCL	Jamuna Fertilizer Company Limited
JGF	Jalalabad Gas Field
JGTDSL	Jalalabad Gas Transmission and Distribution System Limited
KAFCO	Karnafully Fertilizer Company Limited
KTL	Kailashtilla
LAN	Local Area Network
LD	Liquidated Damage
MCC	Master Control Centre
MHRCL	Madhyapara Hard Rock Company Limited
MOEMR	Ministry of Energy and Maneral Resources
M&R	Metering and Regulating
MW	Megawatt
MTS	Master Trunk Switch
NGFF	Natural Gas Fertilizer Factory
NMS	Network Management Server
NMT	Network Management Terminal
NPV	Net Present Value
N-S	North -South
OCT	Operating Company Terminal
OD	Outside Diameter
PABX	Private Automatic Branch Exchange
PAS	Pipeline Application Software
PBP	Pay Back Period
PC	Personal Computer
PFA	Pachimanchal Franchise Area
PGCL	Pachimanchal Gas Company Limited
PLC	Programmable Logic Controller
PMR	Private Trunked Mobile Radio
PUFF	Palash Urea Fertilizer Factory

PSC	Production Sharing Contract
RAM	Random Access Memory
RPCL	Rural Power Company Limited
RPGCL	Rupantarita Prakritik Gas Company Limited
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SCX	Serck Controls Ltd. X System
SGFL	Sylhet Gas Field Company Limited
TFA	Titas Franchise Area
TGF	Titas Gas Field
TGTDCL	Titas Gas Transmission and Distribution Company Limited
TSW	Trunk Site Switch
UHF	Ultra High Frequency
VHF	Very High Frequency
VS	Valve Station
WAN	Wide Area Network
ZFCL	Zia Fertilizer and Chemical Complex Limited

UNITS AND SYMBOLS

cum	Cubic Meter
Kg	Kilogram
Kwh	Killo Watt Hour
MHz	Mega Hertz
MMSCFS	Million Standard Cubic Feet per Day
M.Ton	Metric Ton
MW	Mega Watt
TCF	Trillion Cubic Feet
%	Percentage

CURRENCY AND CONVERSION RATE

Bangladeshi Currency	: TK.(Taka)
1 US$	: 70 TK.

CHAPTER 1: INTRODUCTION

Natural gas is considered as a very clean source of energy all around the world, more so after the oil crisis in nineteen seventies and increasing environmental awareness about burning coal (National Committee Report, 2002). Natural gas was first discovered in Bangladesh in 1955 at Haripur (Sylhet Gas Field). Chhatak gas field was discovered in 1959. So far 22 gas fields and one small oil field have been discovered (Saleque, 2001). Gas sector of Bangladesh is primarily controlled by the energy division of the Ministry of Energy and Mineral Resources (MOEMR) of the government through a state owned corporation, Bangladesh Oil, Gas and Mineral Corporation (BOGMC) popularly known as Petrobangla. Petrobangla acts as the holding company for all the other companies in the sector. As of now, the government owned companies operating in the sector include petrobangla as holding company; Gas Transmission Company Limited (GTCL), which is the sole gas transmission company; Bangladesh Petroleum Exploration and Production Company limited (BAPEX), the sole drilling, exploration and production company. There are four gas distribution and marketing companies which are Titas Gas Transmission and Distribution Company Limited (TGTDCL), Bakhrabad Gas System Limited (BGSL); Jalalabad Gas Transmission and Distribution System limited (JGTDSL) and Pachimanchal Gas Company Limited (PGCL). There are two gas production companies which are Sylhet Gas Fields Company Limited (SGFL) and Bangladesh Gas Fields Company Limited (BGFCL). The Government has also promoted companies for alternate use of gas; this is Rupantarita Prakritik Gas Company Limited (RPGCL), which deals with compressed natural gas (CNG) and conversion of natural gas liquids to other usable hydrocarbons. Gas is also produced by 4(four) IOC's (Chevron, Cairn Energy, Niko Resources and Tullow BD Ltd.) under Production Sharing Contracts (PSC). There are also two other companies of Petrobangla working with coal and hard rock, one is Boropukuria Coal Mining Company Limited (BCMCL) and other one is Modhyapara Hard Rock Company Limited (MHRCL).

Gas Transmission Company Ltd. (GTCL) has been incorporated as a limited company under the Company Act in December 1993 with the entrusted responsibility to own, construct, operate and maintain all high pressure natural gas transmission pipelines which operate at a pressure above 900 psig. As per Government decision, Ashuganj – Elenga Pipeline from Titas Gas Transmission and Distribution Company Ltd (TGTDCL) and Bakhrabd-Demra, Bakhrabad- Chittagong gas transmission pipelines from Bakhrabad Gas System Ltd (BGSL) are handed over to GTCL. Eventually all transmission pipelines will be handed over to GTCL. GTCL is also given overall operational control and load despatch responsibility of the national gas grid irrespective of ownership of the pipelines. Among the existing gas transmission pipeline networks of the high pressure trunk gas pipeline, about 833 km pipeline are owned, operated and maintained by GTCL. About 1200 MMSCFD of the total daily produced 1670 MMSCFD gas is transmitted by GTCL pipeline, which is around 72% of total produced gas (Monthly Report, GTCL, 2007).

Supervisory Control and Data Acquisition (SCADA) system was introduced in GTCL in 2004. With this system gas flow, intake and off-take points pressure, valve status (open/close), flow rate and pressure of condensate and quality of gas can be monitored. In this study the existing SCADA system of GTCL is evaluated.

1.1 Objective

The main objectives of this study are:

- Evaluate the benefits and shortcomings of the concerned SCADA system.
- Financial analysis of the SCADA system.

1.2 Methodology

Following methodology is followed for this study:

1. Collecting information by using semi-structured/open/telephonic interview with related departmental officials and personnel.
2. Reviewing secondary information sources/related literature about SCADA system.
3. Collecting information by primary sources / personal visits (observations) of SCADA sites/areas.
4. Financial analysis of the SCADA system, based on financial parameters such as Benefit Cost Ratio (BCR), Net Present Value (NPV), Internal Rate of Return (IRR), Pay Back Period (PBP) etc.

CHAPTER 2: PRESENT STATUS OF GAS SECTOR

This chapter describes present status of reserve, production, transmission and consumption of gas in the country. The amount of gas and condensate transmitted by GTCL pipelines are mentioned here. Present gas management flow system is also discussed here.

2.1 Reserve Scenario

Twenty three gas fields and one oil field have so far been discovered in Bangladesh, nineteen gas fields have so far been developed, seventeen are currently under production. A number of studies were conducted by various agencies/organization in the past. Some of the studies were for limited number of fields, while the others were for countrywide assessment. The national gas reserve committee estimated the gas reserve (proved + probable) between 12.04 and 15.55 TCF (National Committee Report, 2002). From a petrobangla report it is shown that Gas Initially In Place (GIIP) of the discovered gas fields was 20.96 TCF of which 15.19 TCF is the net recoverable proven reserve. Upto December, 2006 around 6.79 TCF has been consumed and the remaining net recoverable reserve (proven) is 8.40 TCF (Petrobangla report, January 2007). The updated gas scenario reserve is shown in Appendix-A, Table-A1.

2.2 Production Scenario

At present gas is produced from state enterprises i.e. companies of petrobangla and international oil companies (IOC). Under Petrobangla three state owned company such as Bangladesh Gas Field Company Ltd. (BGFCL), Sylhet Gas Field Company Ltd. (SGFL) and Bangladesh Exploration and Production Company Ltd. (BAPEX) are producing gas from different fields. BGFCL is producing gas from Titas, Hobiganj, Bakhrabad, Narsingdi and Megna Gas Field. SGFL is producing gas from Kailashtilla (MSTE), Kailashtilla (Silica), Beanibazar, Rashidpur and Horipur Gas Field. BAPEX is producing gas from Salda and Fenchuganj gas field. Four IOC's such as Chevron, Cairn Energy, Tullow BD. Ltd. and Niko Resources are producing gas under Production Sharing Contracts (PSC) from different gas field. The largest IOC Chevron is producing gas from Jalalabad, Moulobibazar and Bibyana gas fields. Cairn Energy is producing gas from the only offshore gas field, Sangu. Tullow BD Ltd. is producing gas from Bangora gas field and Niko Resources is producing gas from Feni gas field. Around 1680 MMSCFD gas is producing from 76 gas well of 18 gas fields. The present production capacity of 18 gas fields is around 1806 MMSCFD. Of the total production of about 1680 MMSCFD about 60% is from the fields owned by the petrobangla and the remaining production comes from the International Oil Companies (IOC's) under Production Sharing Contracts (PSC). The present gas production from different gas fields is shown in table-2.1.

Table-2.1: Present Gas Production

Sl.No.	Gas Fields	No of Wells	Capacity in MMSCFD	Production in MMSCFD
BGFCL				
1	Bakhrabad	4	34	34
2	Hobiganj	9	272	265
3	Meghna	1	2	2
4	Narsingdi	2	35	36
5	Titas	15	435	425
Sub-total		31	778	762
SGFL				
1	Beanibazar	2	18	18
2	Horipur	2	10	9
3	Kailashtilla(MSTE)	4	74	74
4	Kailashtilla(Silica)	1	21	23
5	Rashidpur	6	68	68
Sub-total		15	191	192
BAPEX				
1	Fenchuganj	2	45	39
2	Salda	2	13	12
Sub-total		4	58	51
Chevron				
1	Bibyana	7	250	232
2	Moulovibazar	4	112	106
3	Jalalabad	4	230	160

Table-2.1: Present Gas Production (Contd.)

Sub-total		15	592	498
Cairn Energy				
1	Sangu	6	113	105
Niko Resources				
1	Feni	3	14	12
Tullow BD Ltd				
1	Bangora	2	60	60
Total		76	1806	1680

Source: Daily Gas Report, GTCL, 19th March, 2007

From the above table it is found that the sub-total production of BGFCL, SGFL, BAPEX, Chevron, Cairn Energy, Niko Resources and Tullow BD Ltd. is 762 MMSCFD, 192

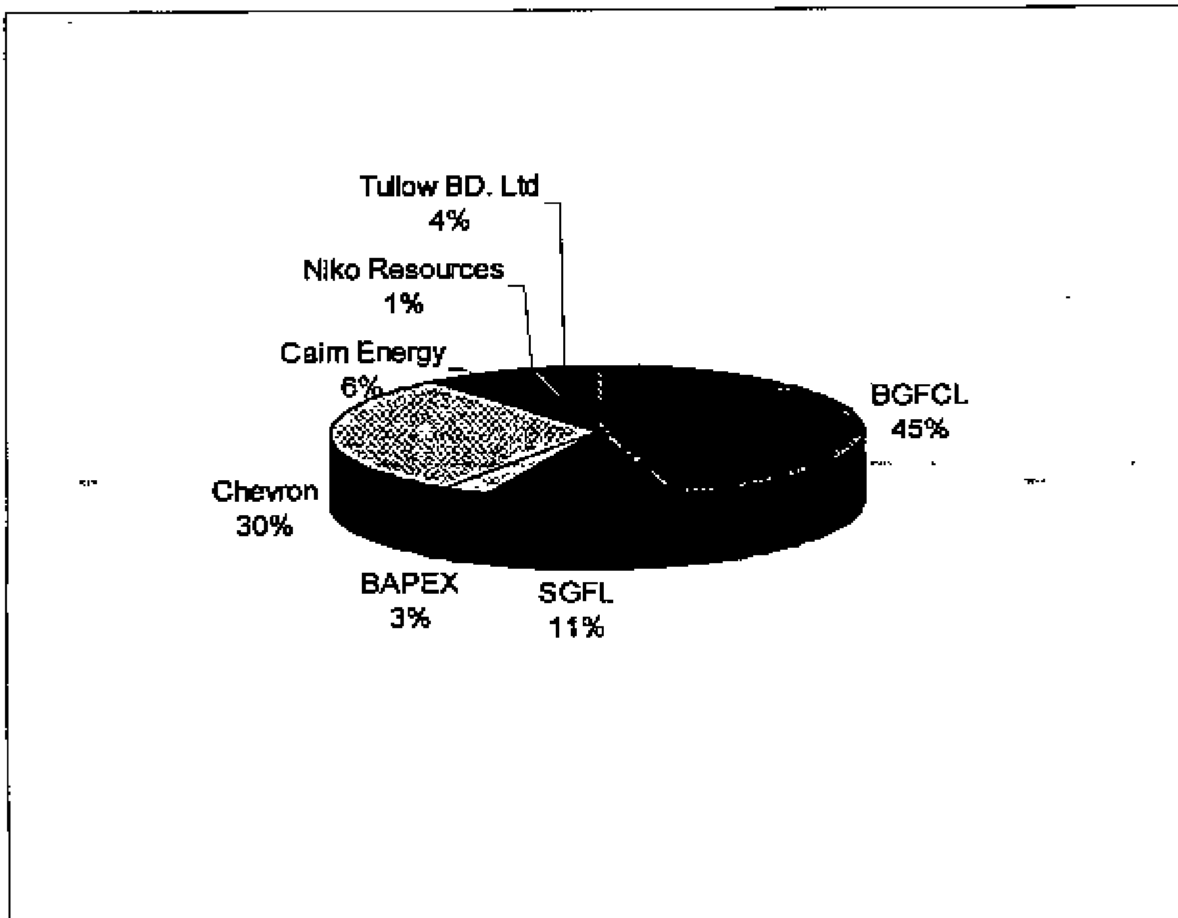


Figure 2.1: Company wise Production

MMSCFD, 51 MMSCFD, 498 MMSCFD, 105 MMSCD, 12 MMSCFD and 60 MMSCFD respectively. The company wise share of production is given in figure 2.1.

From the above figure it is found that most of the production (45%) comes from BGFCL, less than one third (30%) production is from the Chevron, 14% of production comes from the other two state owned company SGFL (11%) & BAPEX (3%). The rest (11%) of the production comes from the three IOC's i.e. Cairn Energy (6%), Niko resources (1%) and Tullow BD. Ltd. (4%).

Three state owned company such as BGFCL, SGFL and BAPEX are producing 1005 MMSCFD. There share are given in figure-2.2.

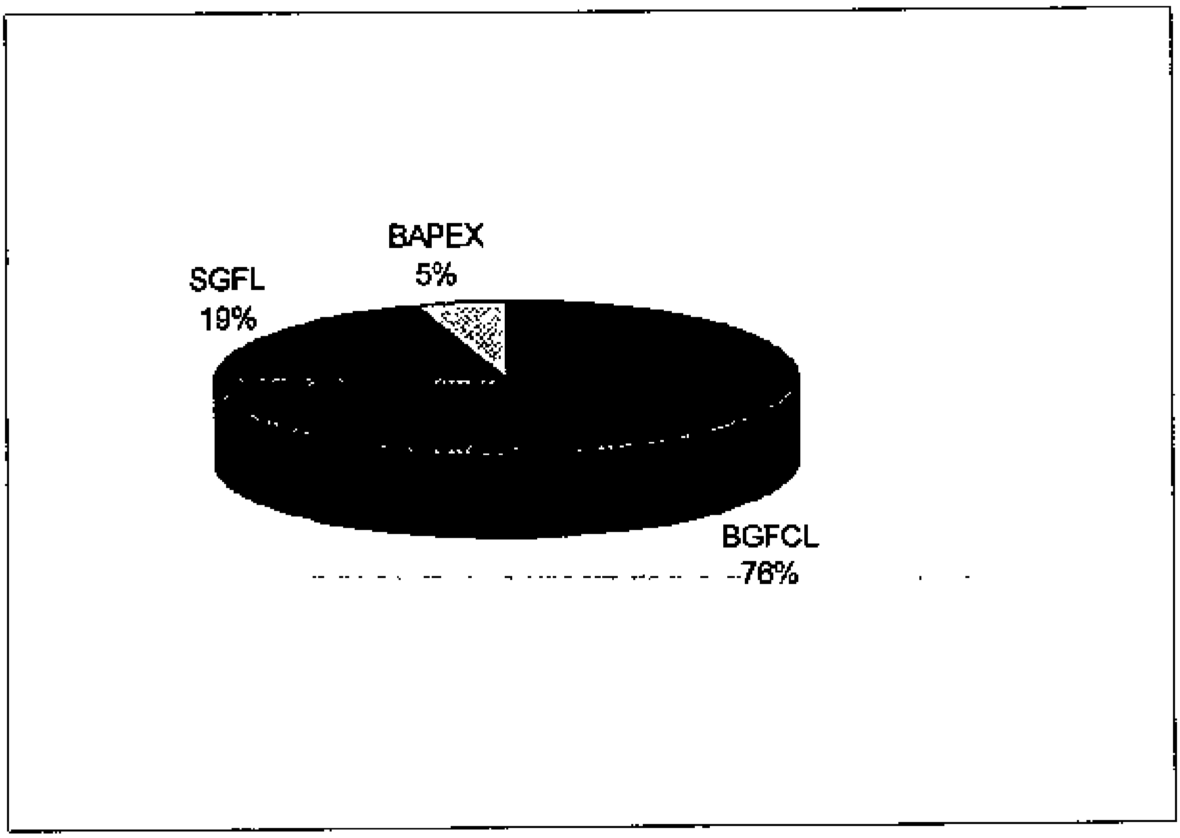


Figure 2.2: State Company wise Production

The above figure shows that more than three fourth (76%) comes from BGFCL. The rest (24%) is from the SGFL (19%) & BAPEX (5%).

Four IOC's such as Chevron, Cairn Energy, Tullow BD. Ltd. and Niko Resources are engaged for producing gas. Their shares are given in figure 2.3.

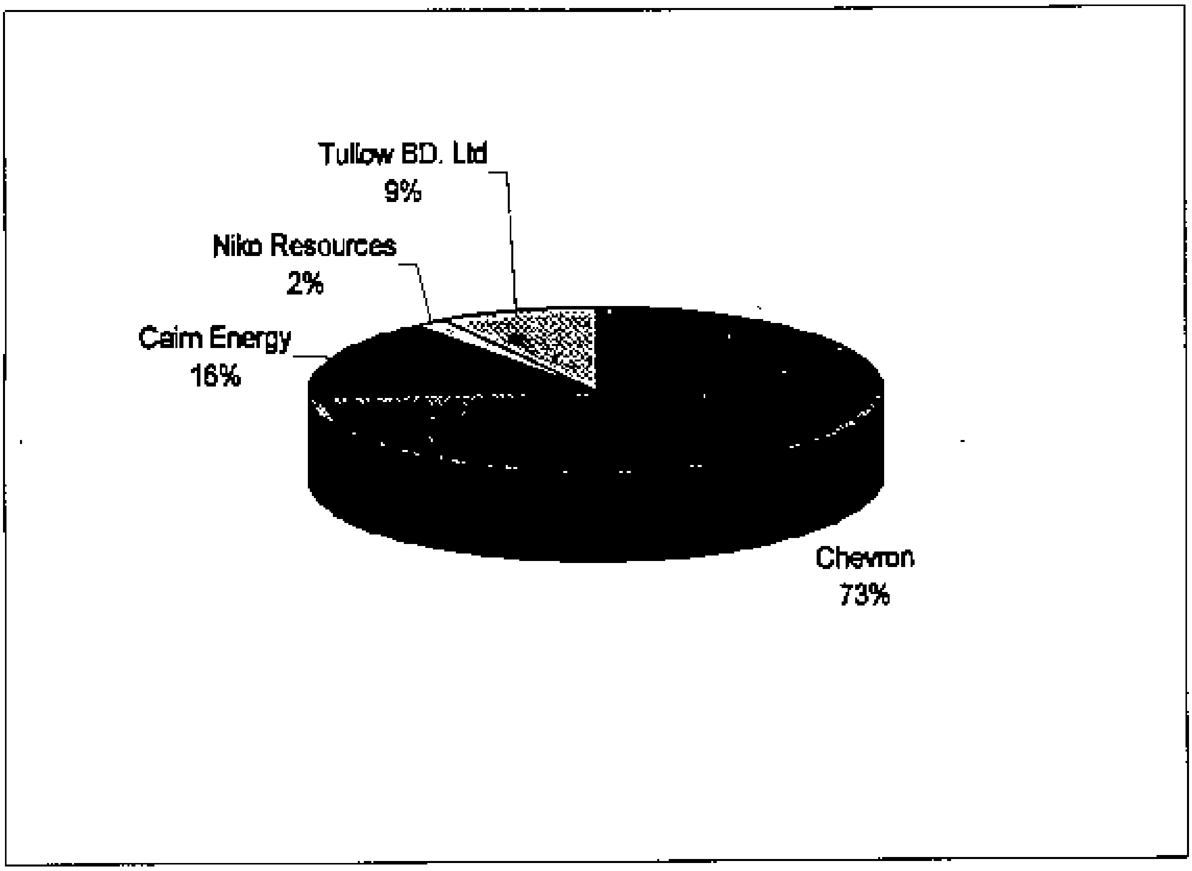


Figure 2.3: IOC wise Production

The above figure reveals that most of the production (73%) comes from Chevron. The rest (27%) is from the Cairn Energy (16%), Tullow BD. Ltd.(9%) and Niko Resources (2%).

2.3 Consumption Scenario

Gas sector contributes to significant revenue earning for the national exchequer. Natural gas is the main natural commodity that ensures regular revenue earning for the government till now.

The bulk of the gas is consumed in the generation of power and in the production of fertilizer, the remainder being used by various small industries, commercial and domestic customers. Currently 4(four) companies of Petrobangla are entrusted with the responsibility of distribution and marketing of natural gas on the regional basis. These are:

a. Titas Gas Transmission and Distribution Company Limited (TGTDCL): Titas Gas Franchise Area (TFA) covers greater Dhaka, grater Mymenshing, Brahmon Baria.

b. Bakhrabad Gas Systems Limited (BGSL): Bakhrabad Franchise Area (BFA) covers Chittagong Division excluding Brahmon Baria.

c. Jalalabad Gas Transmission and Distribution System Limited (JGTDSL): Jalalabad Franchise Area (JFA) covers greater sylhet.

d. Pachimanchal Gas Company Limited (PGCL): Pachimanchal Franchise Area (PFA) covers Rajshahi division.

The area wise consumption of the various category of consumers are provided in table 2.2

Table 2.2: Consumption of Gas

Sl.No.	Consumer	Capacity (MMSCFD)	Consumption (MMSCFD)
A. Titas Franchise Area (TFA)			
i) Power sector			
1	Alpha Power (10 MW)	2	1.5
2	AM Energy Ltd.(10 MW)	2	0.77
3	Ashuganj Power Station (728 MW)	180	105
4	CDC Horipur Power Station (360 MW)	55	51
5	CDC Meghnaghat Power Station (450 MW)	90	69
6	City Sugar Power (10 MW)	2	0.87
7	Ghorashal Power Station (950 MW)	241	153
8	Horipur Power Station (100 MW)	30	0
9	Meghna Energy (10 MW)	2	0.8
10	NEPC (110 MW)	28	16
11	Partex Power (20 MW)	4	0
12	Rahim Energy (30 MW)	7	7
13	REB(Madabdy/Ashulia-37/10 MW)	11	8
14	RPCL(180 MW)	48	23

Table 2.2: Consumption of Gas (Contd.)

15	Shah Cement Power (10 MW)	2.5	1.8
16	Siddirganj 50 MW Power Station	14	7
17	Siddirganj 210 MW Power Station	52	37
18	Tongi Power Station (110 MW)	20	22
19	Unic Power (40 MW)	7	5
Sub-total		797.5	508.74
ii) Fertilizer Sector			
1	Ghorashal Urea Fertilizer Factory (GUFF)	45	44
2	Jamuna Fertilizer Company Limited (JFCL)	50	46
3	Palash Urea Fertilizer Factory (PUFF)	18	14
4	Zia Fertilizer & Chemical Complex Ltd (ZFCL)	50	49
Sub-total		163	153
iii) Other Sector			
1.	Others(Industrial, Commercial & Domestic)	600	565
TFA Total		1560.5	1226.74
B. Bakhrabad Franchise Area (BFA)			
i) Power Sector			
1.	Rauzan Power station (420 MW)	90	72
2.	Shikalbaha Power Station	20	11
Sub-total		110	83
ii) Fertilizer Sector			
1	Chittagong Urea Fertilizer Limited (CUFL)	50	49
2	Karnafully Fertilizer Company Limited (KAFCO)	65	63

Table 2.2: Consumption of Gas (Contd.)

Sub-total		115	112
iii) Other Sectors			
1	Others (Industrial, Commercial & Domestic)	120	118.125
BFA Total		345	313.125
C. Jalalabad Franchise Area (JFA)			
i) Power Sector			
1	Fenchuganj Power station (90 MW)	18	17.6
2	Kumargaon Power station (20 MW)	7	6.8
3	Shahjibazar Power Station (30 MW)	14	5.7
Sub-total		39	30.1
ii) Fertilizer Sector			
1	Natural Gas Fertilizer Factory (NGFF)	18	16.78
iii) Other Sector			
1	Others (Industrial, Commercial & Domestic)	38	20.16
JFA Total		95	67.04
D. Parchimanchal Franchise Area (PFA)			
i) Power Sector			
1	PDB Bagabari Power Station (100+71) MW	50	26.9
2	Westmont Power station (90 MW)	25	23.6
Sub-total		70	50.5
ii) Other Sector			
1	Others (Industrial, Commercial & Domestic)	5	5
PFA Total		78	55.5

Source: Daily Gas Report, GTCL, 19th March, 2007

2.3.1 Daily Consumption by the Marketing Companies

From the table 2.2, the total consumption by TGTDCL, BGSL, JGTDSL and PGCL is 1226.74 MMSCFD, 313.125 MMSCFD, 67.04 MMSCFD and 55.5 MMSCFD respectively. Marketing company wise daily consumption of gas is given in figure 2.4.

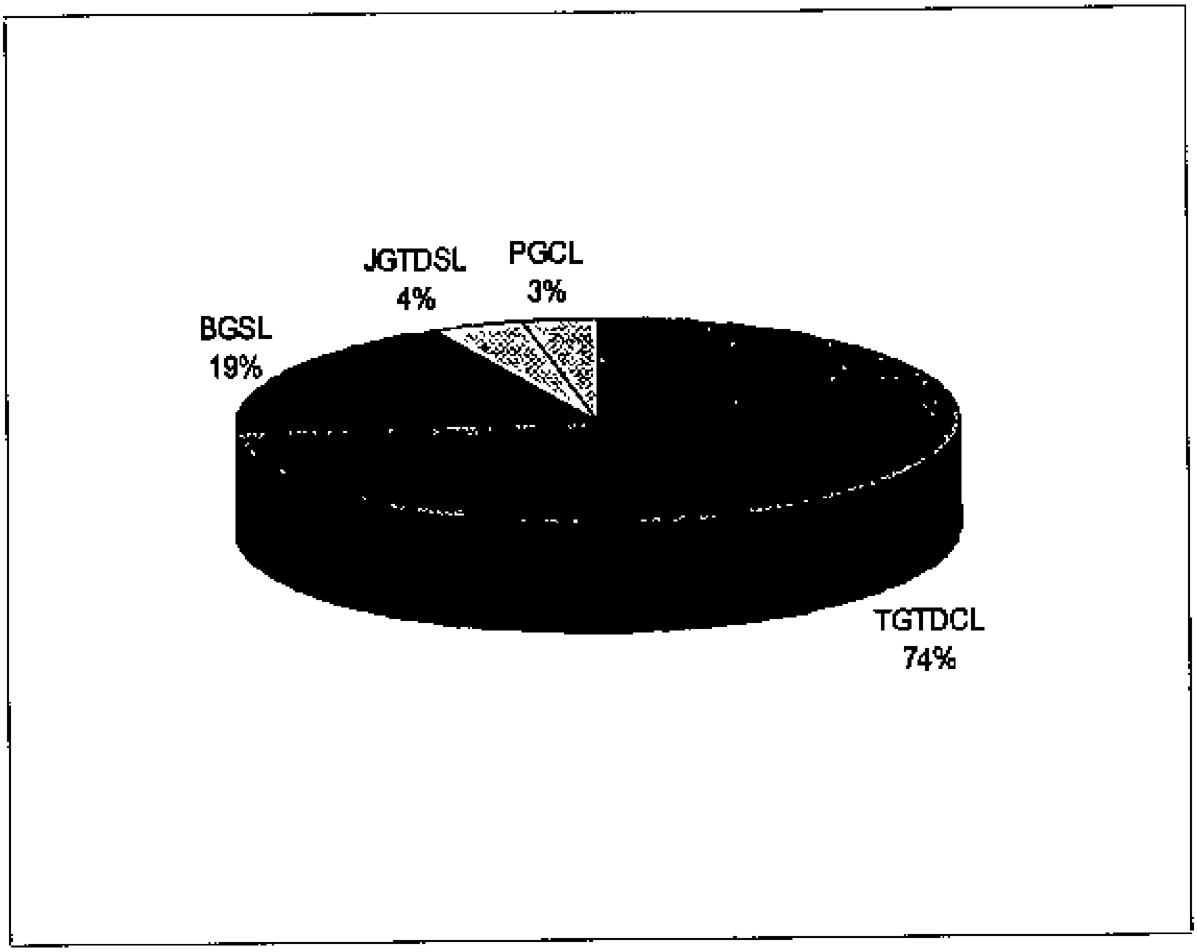


Figure 2.4: Marketing Company wise Daily Consumption of Gas

The above figure reveals that maximum gas around three fourth(74%) of total consumption is consumed by TGTDSL and near about one fifth (19%) of total consumption is consumed by BGSL.A small amount 4% & 3% of total consumption are consumed by JGTDSL & PGCL respectively.

2.3.2 Daily Gas Consumption by Different Sectors

From the table 2.2, consumption of gas by power, fertilizer & others is 672.35 MMSCFD, 281.78 & 708.285 MMSCFD respectively. Sector wise daily consumption of gas is given in figure 2.5.

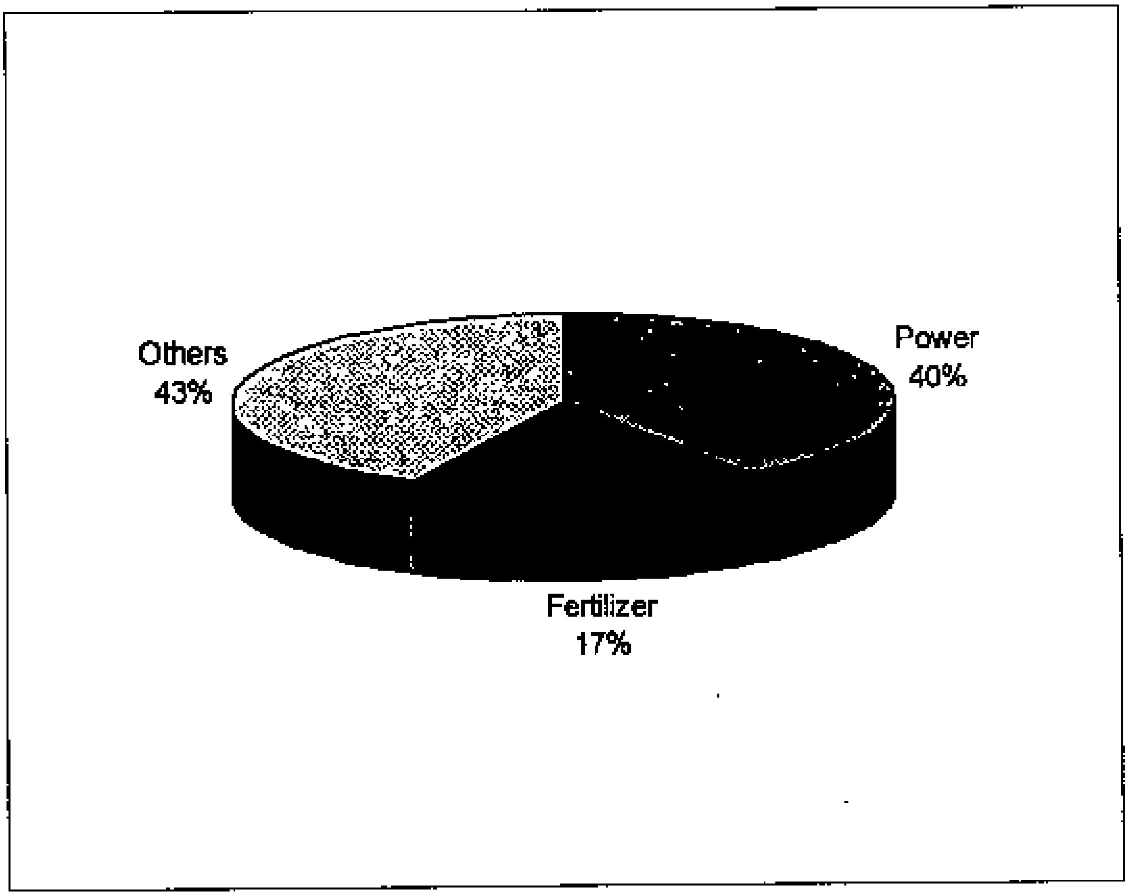


Figure 2.5: Sector wise Daily Consumption of Gas

The above chart shows that 43% of total consumption is consumed by other sectors. Other sectors include industrial, commercial & domestic. The significant amount of gas (40%) is consumed by power sector and the rest 17% is consumed by fertilizer sector.

2.4 Transmission Scenario

The gas transmission pipelines in Bangladesh have been planned and constructed at different stages primarily targeting a particular bulk consumer or potential load centre. In the early stage of development of gas sector the grid concept was possibly not visualized. However, depending on specific requirement over the years, a national gas grid line has been developed and linked to lateral and distribution networks for serving various consumers. Gas transmission Company Limited (GTCL) was incorporated in 1993 in the unbundling process of gas sector restructuring for owning, operating and maintaining the high pressure gas transmission pipelines forming part of the national gas grid. Other companies are also handling some high pressure pipe lines. The ownership of all such existing pipelines is to be handed over to GTCL in phases. However, the following companies are also operating some of the transmission pipelines in their respective franchise areas:

a. Titas Gas Transmission and Distribution company Limited (TGTDCL)

b. Bakhrabad Gas Systems Limited (BGSL)

c. Jalalabad Gas Transmission and Distribution Systems Limited (JGTDSL)

The transmission and distribution system is currently analyzed by utilizing field pressures except Bakhrabad gas field. Recently a compressor station is installed at Bakhrabad Gas Field to boost up line pressure which subsequently increases the production of field. Before installation of the compressor, around 100 MMSCFD of gas were transmitted through Bakhrabad-Chittagong pipeline. But the export pressure of Bakhrabad gas field was 530 psi. So there is a Regulating Metering Station at the Bakhrabad Gas Field to regulate the pressure of the grid line. After installation of compressor station the export pressure of Bakhrabad gas field can be boost up to 800 psi. Now around 200 MMSCFD gas can be transmitted through Bakhrabad-Chittagong pipeline.

A line diagram of existing high pressure gas transmission network is shown in figure 2.6.
The Gas Transmission Pipelines in Bangladesh after or before independence were mostly constructed targeting a particular bulk consumer or potential load centre. Following the discovery of gas at Haripur at Sylhet 8" OD transmission pipeline was constructed from

Haripur to Fenchuganj in the late fifties for supplying gas to Natural Gas Fertilizer Factory (NGFF) at Fenchuganj. Almost simultaneously a 4" OD transmission pipeline was constructed from Tangra Tilla to Chhatak for supplying gas from Chhatak Gas Field to Chhatak Cement Factory. After discovery of Titas Gas Field in Brammanbaria the Titas-Narshindi-Demra 14" OD gas transmission pipeline was constructed in 1967-68 for supplying gas to Dhaka City and Narayangonj area. Based on available gas from the Titas Gas Field important industrial zones were set up in Ashuganj, Gorashal and Shiddirgonj areas. The Gorashal Urea Fertilizer Factory (GUFF), Palash Urea Fertilizer Factory (PUFF), thermal power plants at Ashuganj, Gorashal and Shiddirganj area were based on gas available from Titas Gas Field. Exploitation of gas from Habiganj Gas Field commenced with the supply of gas to Shahjibazar Power Station. A transmission pipeline from this field was build upto Shamshamagar to supply gas to Tea gardens in and around Teliapara, Srimangal and Moulvibazar areas. In 12" OD gas transmission pipeline was constructed from Habiganj Gas Field to Ashuganj for supplying gas to Zia Fertilizer Factory in Ashuganj. However, the most significant development after independence in gas sector was the creation of Bakhrabad Gas Systems Limited (BGSL) which successfully implemented the following projects:

- Development of Bakhrabad Gas Field (in 1980-1982). Drilling of 4 (four) deviation wells and work over of Bk1 at BK1 Culmination with financial assistance of OECF, Japan.
- Installation of 60 MMCFD capacity Glycol De-hydration Plant.
- Construction of 175 km long Bakhrabad-Chittagong Gas Transmission Pipeline and 35 km 24"/20"/16" OD Chittagong City Ring main pipeline (1982-1983).
- Latetal pipelines for supplying gas to Comilla, Chandpur, feni, Maijdee and Kaptai.
- 78 km, 20" OD Bakhrabad-Demra gas Transmission pipeline.
- Installation of City Gate Stations at Foujderhat, Chittagong and Demra, Dhaka.
- Gas distribution network for Chittagong, Comillla, Chandpur, Feni, Maijdee and Kaptai i.e. in entire south eastern zone of Bangladesh.

The development of Kailashtilla Gas Field in early eighties opened avenues for expansion of gas transmission network in the Sylhet area. A pipeline was built from Kailashtilla Gas Field to Chhatak for meeting the demand of that area.

Two more important gas transmission networks were developed simultaneously following the drilling of 11 wells in Beanibazar, Kailashtilla, Rashidpur, Habiganj. Titas, Belabo and Meghna Gas Field under second development project which are given below:

- 174 km 24" OD North-South (N-S) pipeline from Kailashtilla to Ashuganj with a Parallel 6" OD condensate/NGL pipeline (1991-1993).
- 117 km 24" OD Brahmaputra Basin pipeline from Ashuganj to Elenga for delivering gas to greater Mymensing areas, Jamuna Fertilizer Factory at Tarakandi with a future provision for gas supply to the Western Zone of Bangladesh (1990-1991).

The emergence of Bakhrabad Gas System Limited (BGSL) created revolutionary changes in the economic development activities of South-East. The power plants, fertilizer factories, paper mill, refinery, steel mill and various other industries of Chittagong region started using gas available from Bakhrabad as well as Feni gas fields. But unfortunately injudicious production strategy led to the dramatic decline of gas production from Bakhrabad Gas Field and suspension of gas supply from Feni Gas Field. Under compelling situation due to alarming sand flow and water production, the gas flow was drastically reduced causing suspension of production of Chittagong Urea Fertilizer Factory, Karnafully Fertilizer Company Limited and some power plants. This resulted in country wide load shedding. The situation was partially overcome by expediting construction of the 58 km 30" OD Ashuganj to Bakhrabad (A-B) gas transmission pipeline commissioned in 1997 for diverting the surplus gas from the northern gas fields to the south-east. Subsequently transmission pipelines were also constructed from Meghna Gas Field to Bakhrabad and Salda Gas Field to Bakhrabad for augmenting the supply gas to the south-east. For flexibility of gas transmission 20" OD gas transmission lateral has been built from Monohordi-Narshindi-Siddhirgonj. GTCL constructed 82 km 30" OD Rashidpur –Ashgonj gas transmission loopline parallel to the N-S pipeline to increase the transmission capacity (2002-2005). The line's maximum capacity is 500 MMSCFD. GTCL constructed another 37 km, 30" OD Ashuganj-Monohordi gas transmission loop line parallel to Brahmaputra Basin (B-B) pipeline to increase the flow and pressure at the down stream i.e. Dhaka, Narayangonj, Elenga, Joydebpur, Mymensingh and Bagabari. GTCL also constructed a 36 km, 20" OD Dhanua to Aminbazar pipeline under the

Dhaka Clean Fuel Project (2005-2007). Due to this line, the pressure of Dhaka and and CNG station is improved.

If the transmission network is carefully analyzed it appears that Ashugonj is the focal point of the national gas grid. Two key locations of Ashugonj are Mainline Valve Station-3 of Titas-Narshingdi-demra transmission pipeline and Gas Manifold station of GTCL. Gas from the north-eastern gas fields (Beanibazar, Jalalabad, Kailastilla, Fenchuganj, Moulbibazxar, Bibyana, Rashidpur , Habiganj and Titas) are being transmitted through North-south and Rashidpur-ashuganj loopline to Ashuganj Manifold Station of GTCL from where is further transmitted to Titas Franchise Area (TFA), Bakhrabad Franchise Area (BFA) and Pachimanchal Franchise Area (PFA) through valve station -3, Brahmaputra Basin (B-B), Ashuganj to Bakhrabad (A-B) and Asuganj to Monohordi (A-M) pipeline. N-S and R-A loopline are currently transporting around 60% of national gas demand. From Bakhrabad Gas Field, Bakhrabad –Chittagong pipeline transmit part of the required gas from national gas grid to Chittagong. The remaining gas for Cittagong is supplied from Salda, Meghna and Sangu Gas Fields. After AGMS, Bakhrabad is another key transmission hub in Bangladesh.

The following pipelines/compressor stations are under construction of GTCL:

i). Dhanua- Kodda (20" OD, 35 Km), gas transmission pipeline.

ii) Monohordi-Dhanua-Elenga-Eastern Side of Jamuna Bridge (30" OD, 103 Km) gas transmission pipeline and Compressor Station at Ashuganj & Elenga.

iii) Bonapara-Rajshahi (12" OD, 53 Km) gas transmission pipeline.

iv) Westero side of Jamuna Bridge-Nalka-Hatikumrul-Ishwardi-Bheramara (30" OD, 101 Km), gas transmission pipeline.

v) Berhamara-Jessore-Kulna (20" OD, 165 Km) gas transmission pipeline.

vi) Compressor Stations at Muchai & Ashuganj.

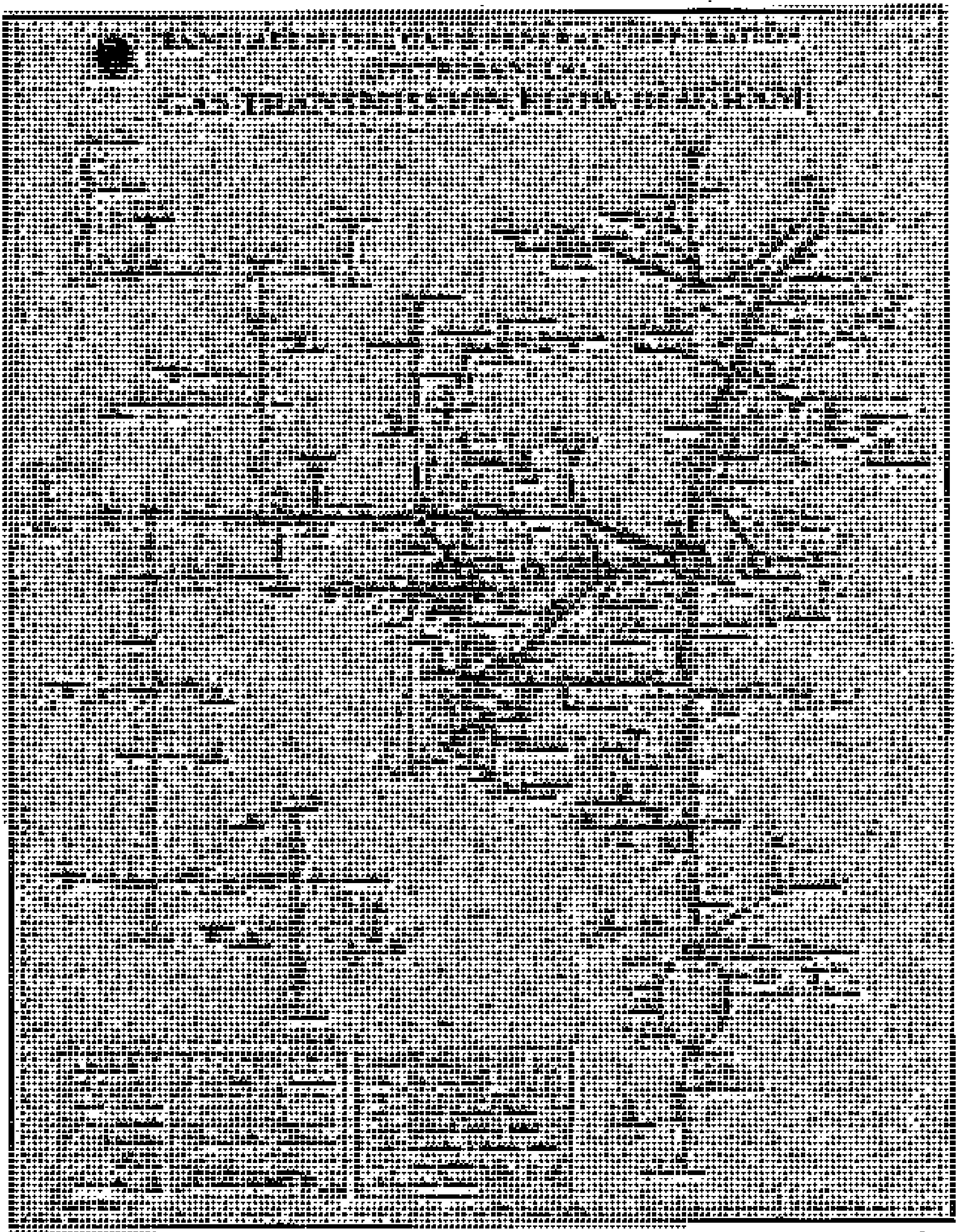


Figure 2.6: A line Diagram of a National Gas Grid Line (Petrobangla, 2007)

The reliability and security of gas supply in the national gas grid is largely dependent on the following pipelines:

Table 2.3: Transmission Pipelines of Different Companies

Name of Pipeline	Diameter (inch)	Length (Km)	Operating Pressure (PSIG)
A. GTCL Transmission Pipelines			
Ashuganj-Bakhrabad (A-B) pipeline	30	58	1000
Ashuganj-Elenga	24	124	1000
Ashuganj-Monohordi	30	37	1000
Bakhrabad-Chittagong	24	175	960
Bakhrabad-demra	20	69	1000
Beanibazar-Kailashtilla	20	18	1000
Dhaka Clean Fuel Project	20	60	1000
Elenga-Eastern side of Jamuna River	24	14	1000
Gas Pipeline over Jamuna Bridge	30	9	1000
Nalka-Bagabari	20	35	1000
Nalka-Bogra	20/30	60	1000
North-South (N-S) Pipeline	24	175	1000
Rashidpur-Ashuganj Loop Line	30	82	1000
Western Side of Jamuna Bridge-Nalka	24	15	1000
Sub-Total (A)		931	
B. TGTDCL Transmission Pipelines			
Ashuganj VS 3-APS Complex	10	0.69	1000
Ashuganj VS 3-ZFCL Complex	10	3.43	1000
Belabo Gas Field – Narsingdi VS 11	8	13	1000
Dewanbagh – Horipur Power Station RMS	14	1.58	1000
Dhanua – Mymensingh	12	56.00	1000
Elenga – Tarakandi	12	43	1000
Ghatura M & R Station-Narsingdi VS 12	14	49.39	1000

Table 2.3: Transmission Pipelines of Different Companies (Contd.)

Ghorashal – Joydebpur CGS	14	24.5	1000
Habiganj Gas Field – Ashuganj VS 3	12	57.75	1000
Jamalpur – Sherpur	4	16	1000
Kamta Gas Field – Joydebpur CGS	6	19.32	1000
Monohordi – Kishoreganj	4	35	1000
Monohordi- Narsingdi	20	25	1000
Mymensingh – Netrakuna	8/6	40	1000
Mymensingh-RPCL Complex	8	5	1000
Narsingdi VS 12-Demra CGS	14	32.41	1000
Narsingdi VS 12-Ghorashal	14	23.31	1000
Narsingdi- Ghorashal, Third Parallel Line	16	12	1000
Narsingdi- Siddirganj	20	41	1000
Tarakandi-Sarishabari-Jamalpur	8/6	31	1000
Titas Gas Field – Ghatura M & R Station	12	1.07	1000
Titas Gas Field-Narsingdi VS 12	16	46.31	1000
Sub-total (B)		577	
C. JGTDSL Transmission Pipelines			
Habigong Gas Field – Shajibazar Power Station	8	2	1000
Haripur – NGFF	8	43	1000
KTL II – KTL I	14	3	1000
KTL – Kuchai – Chatak	8/6	52	1000
Sub-Total (C)		100	
D. BGSL Transmission Pipelines			
Meghna - Bakhrabad	8	28	1000
Salda - Bakhrabad	10	40	1000
Sub – total (D)		68	

Table 2.3: Transmission Pipelines of Different Companies (Contd.)

E. IOC Transmission Pipelines			
Bibiyana Gas Field - Muchai	30	43	1000
Moulvibazar Gas Field - Muchai	14	27	1000
Jalalabad Gas Field – KTL II	14	15	1135
Sangu Gas Transmission Line(Offshore)	20	48	1135
Sub-total (E)		133	
Grand Total (A+B+C+D+E)		1809	

Source: GTCL & TGTDCL, 2007

The total transmission pipeline of different company is 1809 km. Companywise share of pipeline is shown in figure 2.7.

The figure 2.7 reveals that more than fifty percent (51%) of pipeline are operated by GTCL. Less than one third (32%) pipeline is operated by TGTDCL. The IOC's operate 7% pipeline which include Chevron & Cairn Energy. The rest 6% and 4% pipelines are operated by JGTDSL & BGSL respectively.

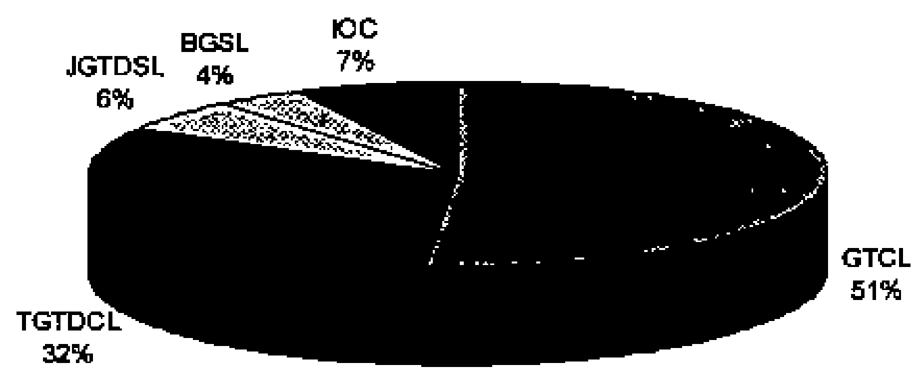


Figure 2.7: Company wise Operated Pipeline

2.4.1 Operated Pipeline of GTCL

GTCL started its operation by North – South (N-S) pipeline that was constructed in 1994. The cumulative operating pipeline of GTCL is increasing with the time. In 2003-2004, the operating pipelines were increased significantly than previous year as three major pipe lines i.e. Ashuganj-Elenga, from TGTDCL, BKB-CTG & BKB –Demra from BGSL were handed over to GTCL. Now the cumulative pipeline of GTCL is 913 km which is 51% of total transmission pipelines. Operating pipeline of GTCL is shown in figure 2.8.

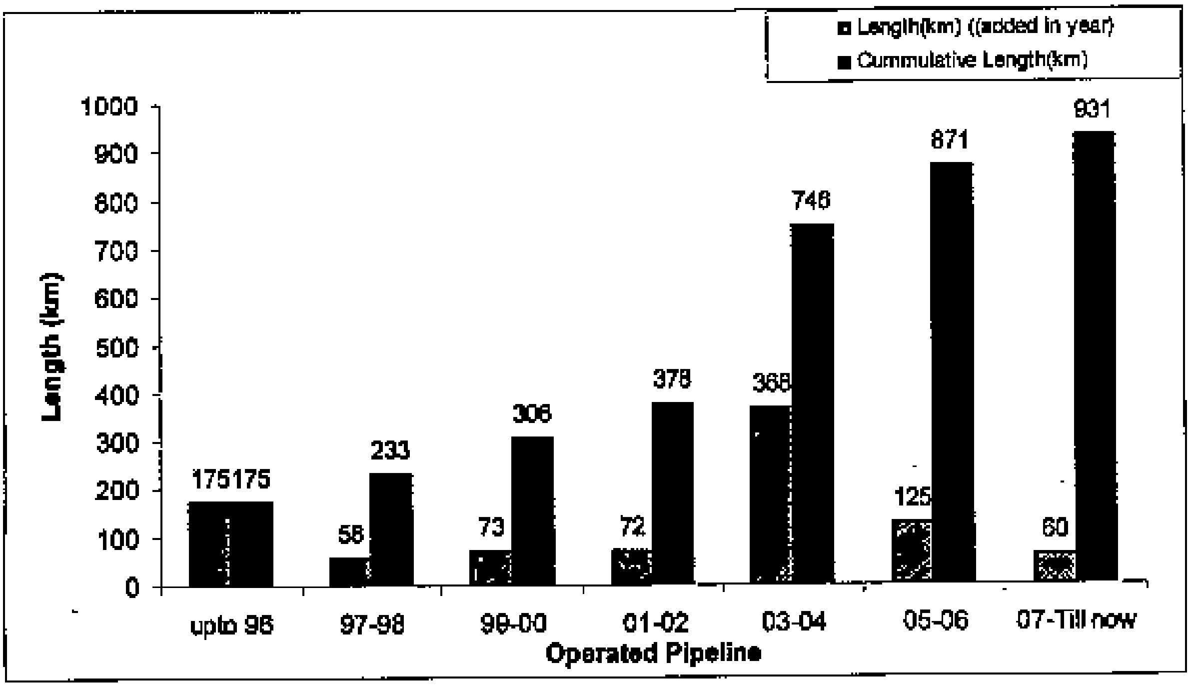


Figure 2.8: Operated Pipeline of GTCL (Monthly progress report, GTCL, December 06).

Beside the above high pressure (900psig) gas transmission line there are also some spur lines which are also operating at high pressure. The capacity of some spur lines which originates from the terminal stations or off-takes of major trunk lines are given in table 2.4.

Table 2.4: Spur Pipe Lines

Spur Pipe lines	Diameter X Length (Inch X Km)	Designed Operating Pressure (Psi)	Designed Capacity (MMSCFD)	Controlling Company
Chittagong City Ring Main	24/20/16x35	350	420	BGSL
Chandpur Lateral Pipeline	8 x 42	960	30	BGSL
Comilla Lateral Pipeline	10x30	350	20	BGSL
Kaptai Lateral Pipeline	8 x 32	350	20	BGSL
Narshingdi Gas Field-Titas Trunk line	8 x 16	1000	30	TGTDSL
Raujan Lateral Pipeline	20x18	350	120	BGSL

Source: Saleque, 2002

2.4.2 Gas Transmitted by GTCL

The production company's supply their gas to the nearest transmission line. GTCL transmits the gas through its transmission lines to the four marketing companies. GTCL gets wheeling charge of the transmitted gas from the marketing companies. The amount of gas is transmitted by GTCL to the four marketing companies in 2005-2006 is shown in figure 2.9.

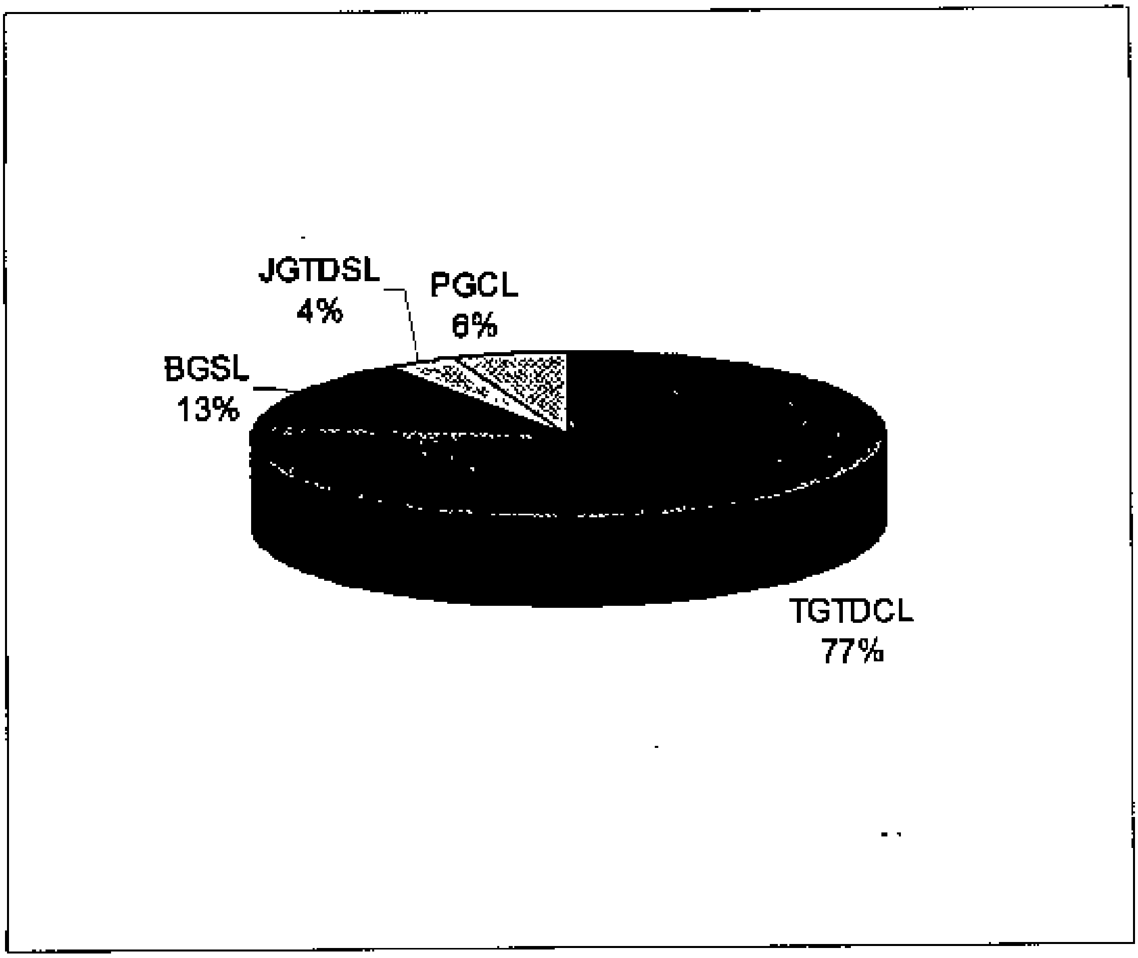


Figure 2.9: Marketing Company wise Transmitted Gas by GTCL
(Monthly progress report, GTCL, December 06)

The above figure shows that maximum of the gas (77%) is transmitted to the largest marketing company (TGTDCL).13% of gas is transmitted to the second largest marketing company (BGSL). The remaining 10% gas is transmitted to PGCL (6%) and JGTDSL (4%).

2.4.3 Year wise Gas Transmitted by GTCL

Gas transmission through GTCL pipelines is started from 1993-1994. With the time new pipeline is added to the existing system that results the increase of GTCL network. The demand of gas is also increased with time. So the amount of transmitted gas is also increased significantly by GTCL pipelines. Consequently the wheeling charge is also increased. Year wise gas transmitted by GTCL pipelines is shown in figure 2.10.

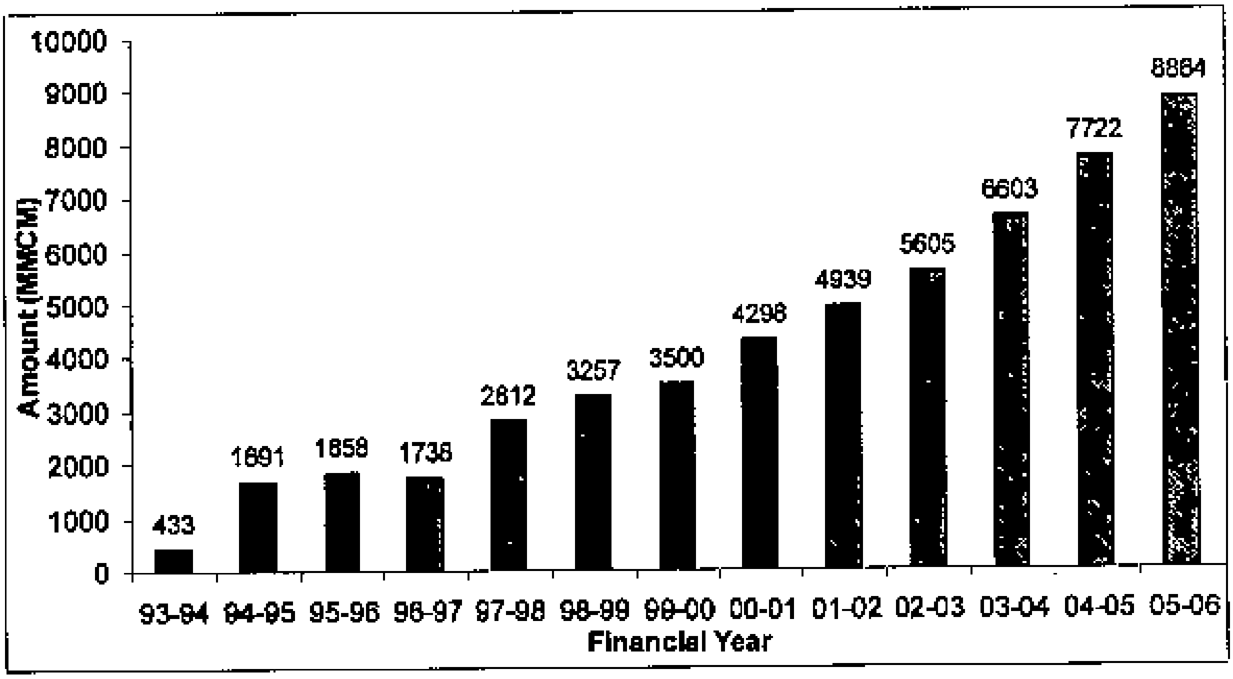


Figure 2.10: Gas Transmitted by GTCL (Monthly progress report, GTCL, December 06)

From the above figure it is found that the amount of gas is increased with the financial year. But in financial year 96-97 the amount of transmitted gas is decreased comparing to previous year. It may be shut down of any bulk customer (power/fertilizer).

2.4.4 Condensate Transmission Pipeline of GTCL

Two condensate pipelines were installed by GTCL which are parallel to N-S gas pipelines. Condensate from different gas fields in Sylhet region are fed to condensate lines. The condensate lines are shown in table 2.5.

Table 2.5: Condensate Pipelines of GTCL

SI No	Name of Pipeline	Length(Km)	Diameter (Inch)	Operating pressure(PSIG)	Capacity (Barrel)
1	N-S Pipeline	175	6.625	150-250	5000.00
2	Beanibazar-Kailashtilla	18	4	250	2000.00

Source: Monthly progress report, GTCL, December 06

2.4.5 Year wise Condensate Transmitted by GTCL pipelines

Condensate transmission was started from 1995-1996, although gas transmission was started from 1993-1994. Year wise condensate transmission is shown in figure 2.11.

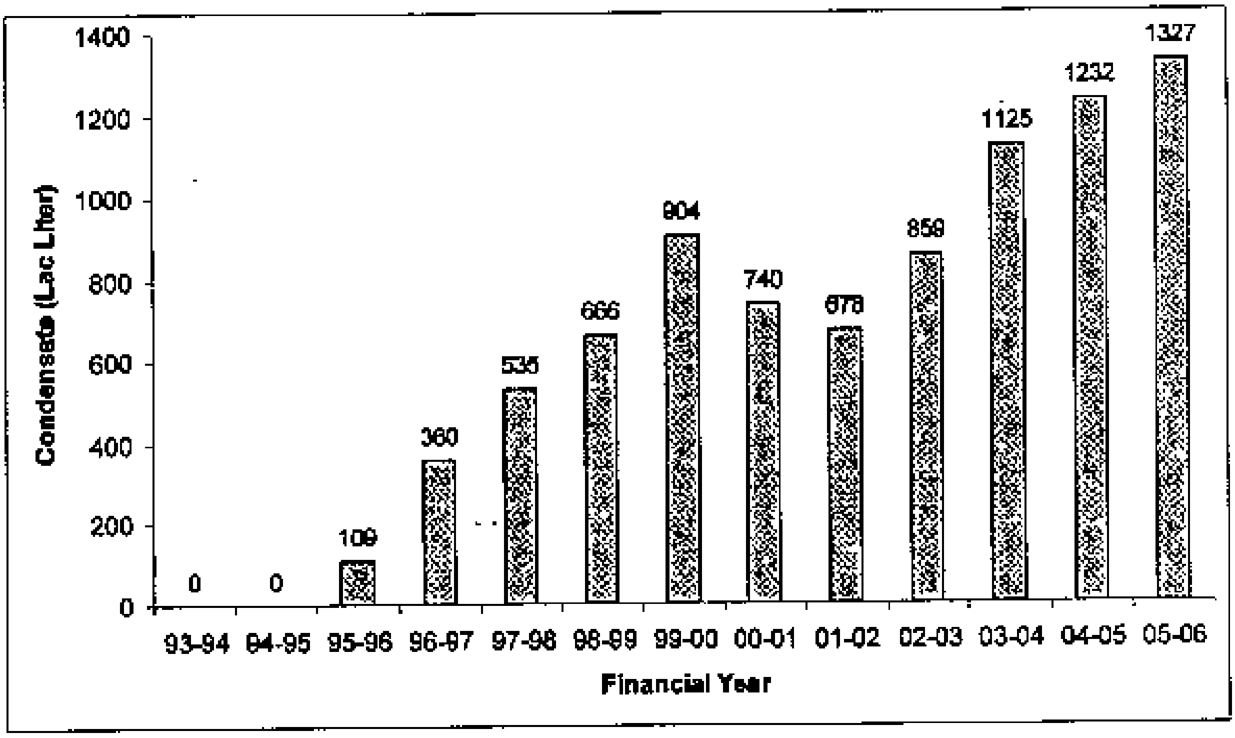


Figure 2.11: Condensate Transmitted by GTCL

(Monthly progress report, GTCL, December 06)

2.5 Present Gas Management Flow System

The Present Gas Management Flow System (Figure-2.12) states that four production companies among seven, such as Bangladesh Exploration and Production Company Limited (BAPEX), Chevron Bangladesh Ltd., Niko Resources and Tullow BD. Ltd. feed their produced gas to GTCL. Two production companies such as Bangladesh Gas Field Company Limited (BGFCL) and Sylhet Gas Field Limited (SGFL) feed their gas to GTCL and two marketing companies which are Titas Gas Transmission and Distribution Company Limited (TGTDCL) & Jalalabad Gas Transmission and Distribution System Limited (JGTDSL). Cairn Energy feed their gas directly to the ring main of Bakhrad Gas System Limited (BGSL). GTCL transmits the gas to four marketing companies such as TGTDCL, JGTDSL, BGSL and Pachimanchal Gas Company Limited (PGCL).The marketing companies supply the gas to consumers of their respective franchise area.

According to decision of Bangladesh government, GTCL in 2003, TGTDCL and RPGCL operate as autonomous bodies to be commercially viable. Managing Director, General Manager (Operation) and General Manager (Finance) are being recruited on contract basis. It is also planned to divide TGTDCL and implementing three independent companies comprising Dhaka-Gazipur-Manikganj zone (Titas Gas Distribution Company), Naryanganj-Munshiganj-Narshindi zone (Sythalakha Gas Distribution Company) and greater Mymensingh-Bhoyrab zone (Bramaputra Gas Distribution Company). A separate distribution company is also planned for Chittagong area (Karnafully Distribution Company Limited) by re-arranging BGSL for efficient management.

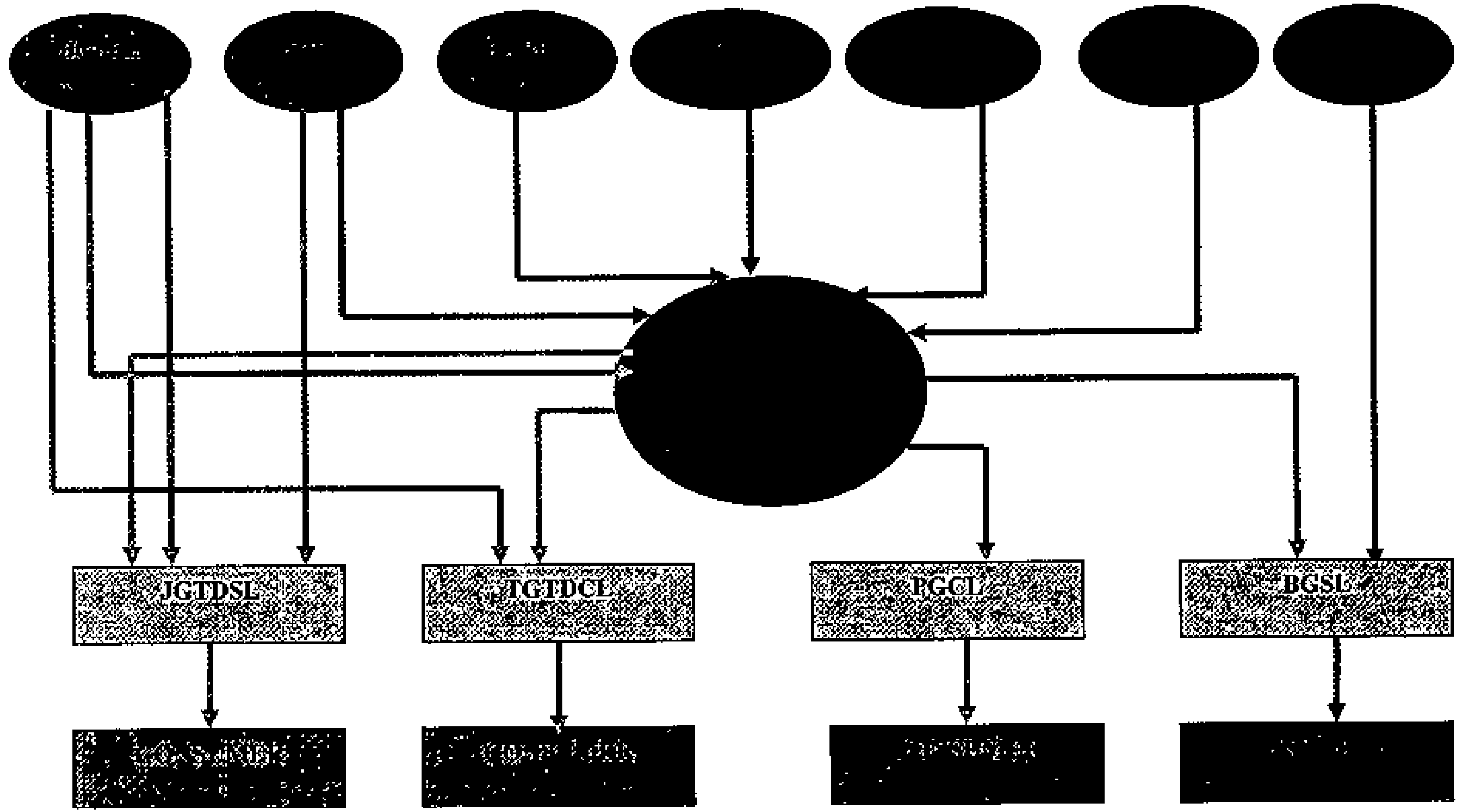


Figure 2.12: Present Gas Management Flow System

CHAPTER 3: OVERVIEW OF SCADA SYSTEM

Supervisory Control and Data Acquisition (SCADA) is a process control system that enables a site engineer/operator to monitor and control processes distributed among various remote sites. Such systems can be used to monitor and control land, air or water pollution control equipment, or just about any manufacturing process. A properly designed SCADA system saves time and money by eliminating the need for service personnel to visit each site for inspection, data collection/logging or make adjustments.

Real-time monitoring, system modifications, troubleshooting, increased equipment life and automatic report generating are the benefits that come with today's SCADA System.

By the late 1980s, SCADA systems were in wide use on pipeline networks. It was estimated in 1991 that natural gas pipelines and utilities in the United States for instances, had plans to install 159 complete SCADA systems during the 30-month period beginning in October 1990. Also planned was the installation of 90 Remote Terminal Units (RTUs) on existing SCADA systems. These estimates were based on research by CSR, Roseville, California, which maintains a data base on gas utility and pipeline companies.

SCADA systems are computerized hardware and software systems that perform a set of monitoring and control functions. In gas and oil companies, the systems can also provide batch tracking, leak detection and flow information.

RTUs at compressor and pump stations and at other remote sites measure operating conditions and transmit the data to a central computer. Programmable logic controllers act as RTUs, but can also perform local logging and control functions at the remote sites.

In general, modern computer –based pipeline control systems consist of the following components:

i) The computer complex includes computers, computer peripherals and interfacing equipment for the man/machine system and remote stations.

ii) The man/machine system includes devices necessary for the operator to communicate with the computer, such as the video display unit, keyboards and loggers.

iii) Remote stations are connected to the computer complex via a communication channel-microwave, telephone, radio or other means.

iv) Field devices such as pumps and motor operated valves are controlled and monitored by the remote station. Field instrumentation includes pressure and temperature transmitters, tank gauges and similar components (Kennedy, 1993).

3.1 SCADA System in GTCL

Supervisory Control and Data Acquisition (SCADA) system was introduced in GTCL in 2004. Under this system, two identical control centers were built, one is Master Control Centre (MCC) which is located at Demra and another one is Auxiliary Control Centre (ACC) which is located at Ashuganj. With this system gas flow, intake and off-take points pressure, valve status (open/close), flow rate and pressure of condensate and quality of gas can be monitored. The components of the SCADA system are discussed below.

3.1.1 The Telecommunications System

The Microwave Communications Backbone (Figure 3.1) comprises a dual redundant, hot standby microwave radio system which generally follows the same routes in the eastern half of Bangladesh as the main gas pipelines and provides the SCADA system with a transparent transmission medium for all communications. The microwave radio system supports the SCADA telemetry communications system, an integrated telephone system via Private Automatic Branch Exchange (PABX's) and a private trunked mobile radio (PMR) system to assist maintenance crews working in the vicinity of the pipelines. PABX equipment at two new Control Centres located at Demra and Ashuganj, together with inter-PABX trunks to the Head Offices of the gas operating companies forms an integrated telephone network. The result is an overall telecommunications system which provides voice and data facilities to support gas transmission and operations throughout the National Gas Grid (Serck Controls, 2004).

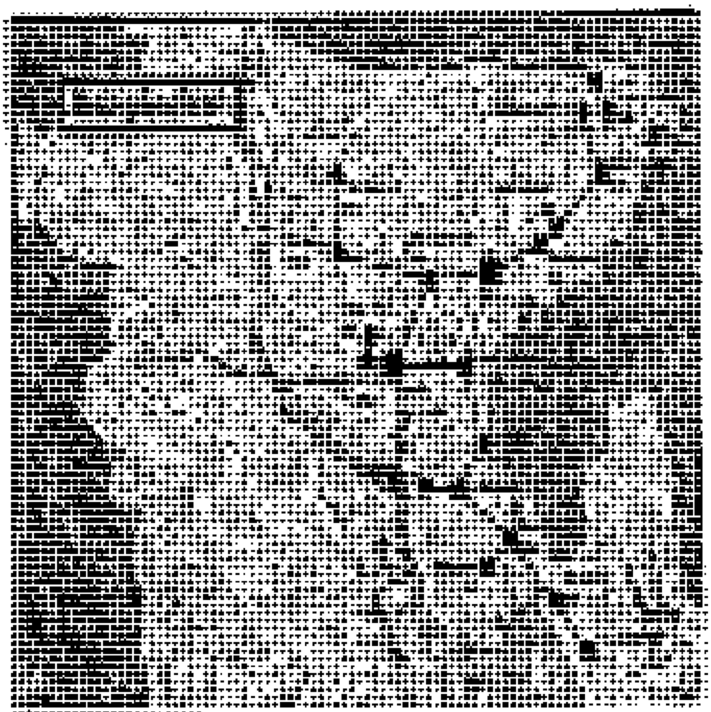


Figure 3.1: Microwave Communications Backbone

3.1.2 Radio Rooms, Telecommunications Towers, Masts and Monopoles

Radio Building: Nine new radio buildings have been built along the northern section of the pipeline from Horipur down to Bakhrabad and nine existing radio buildings have been completely renovated along the southern section of the pipeline from Demra down to Faujdarhat. The radio buildings house the new microwave, SCADA telemetry and PMR equipment plus battery back up and standby generator systems to ensure uninterrupted operation during public supply power interruptions and voltage fluctuations.

Telecommunication Tower: The channel capacity of the existing analogue microwave system equipment is being expanded and upgraded along with the addition of SCADA telemetry and PMR equipment within the TITAS franchise area from Tarakandi down to Ashuganj and Demra. Microwave, SCADA telemetry (UHF) and private mobile radio (VHF) antennas are mounted on a series of new/existing, self-supporting towers

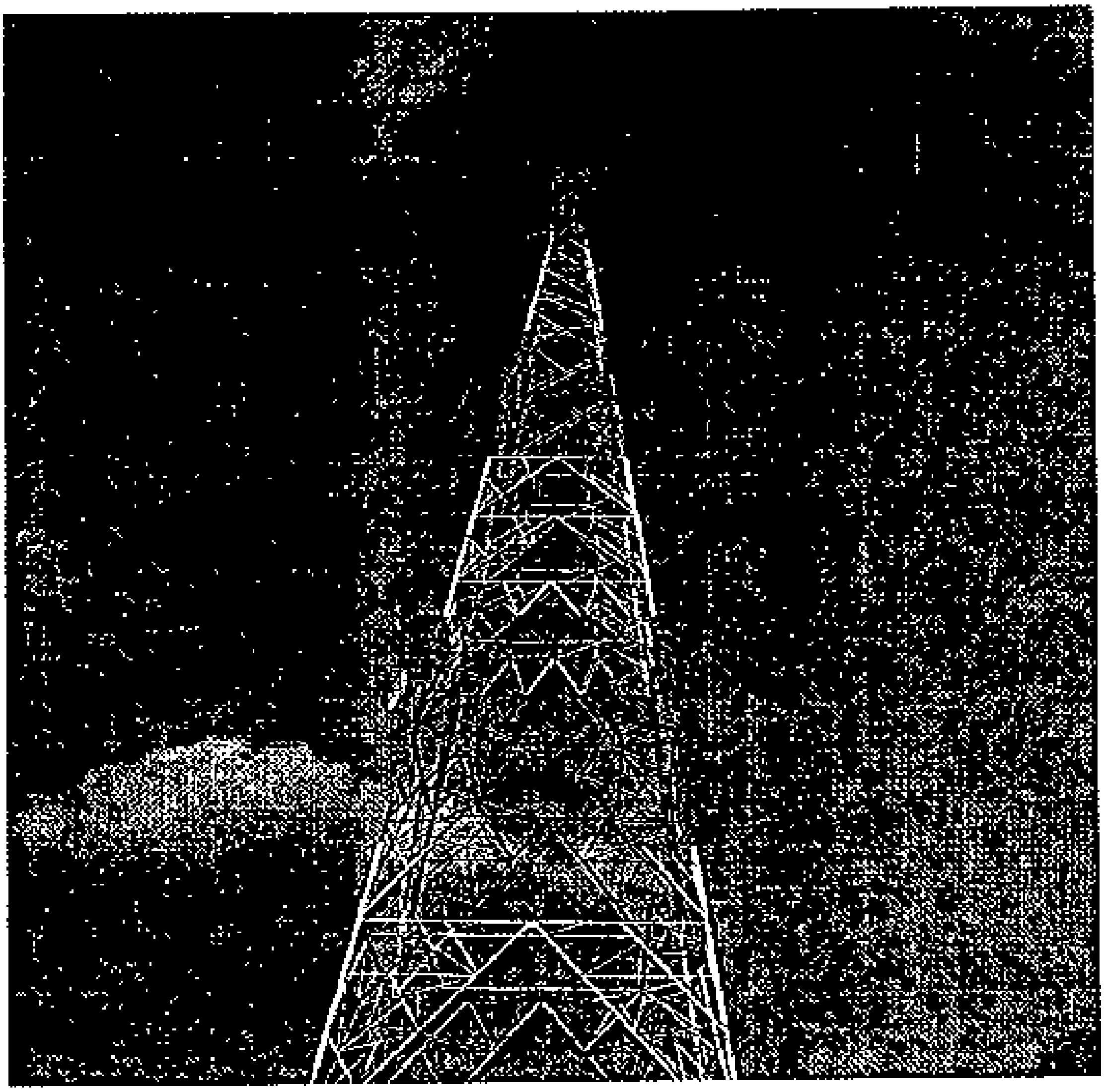


Figure 3.2: New Telecommunication Tower

(Figure-3.2) along the northern and TITAS franchise route of the pipeline and existing guyed masts along the southern route of the pipeline (Serck Controls, 2004). The towers and masts (Figure 3.3) are located adjacent to the new and existing radio buildings. Seven new towers ranging from thirty four to one hundred metres in height along the northern route and two new stub towers on top of the Petrobangla and Jalalabad Head Offices have been provided.

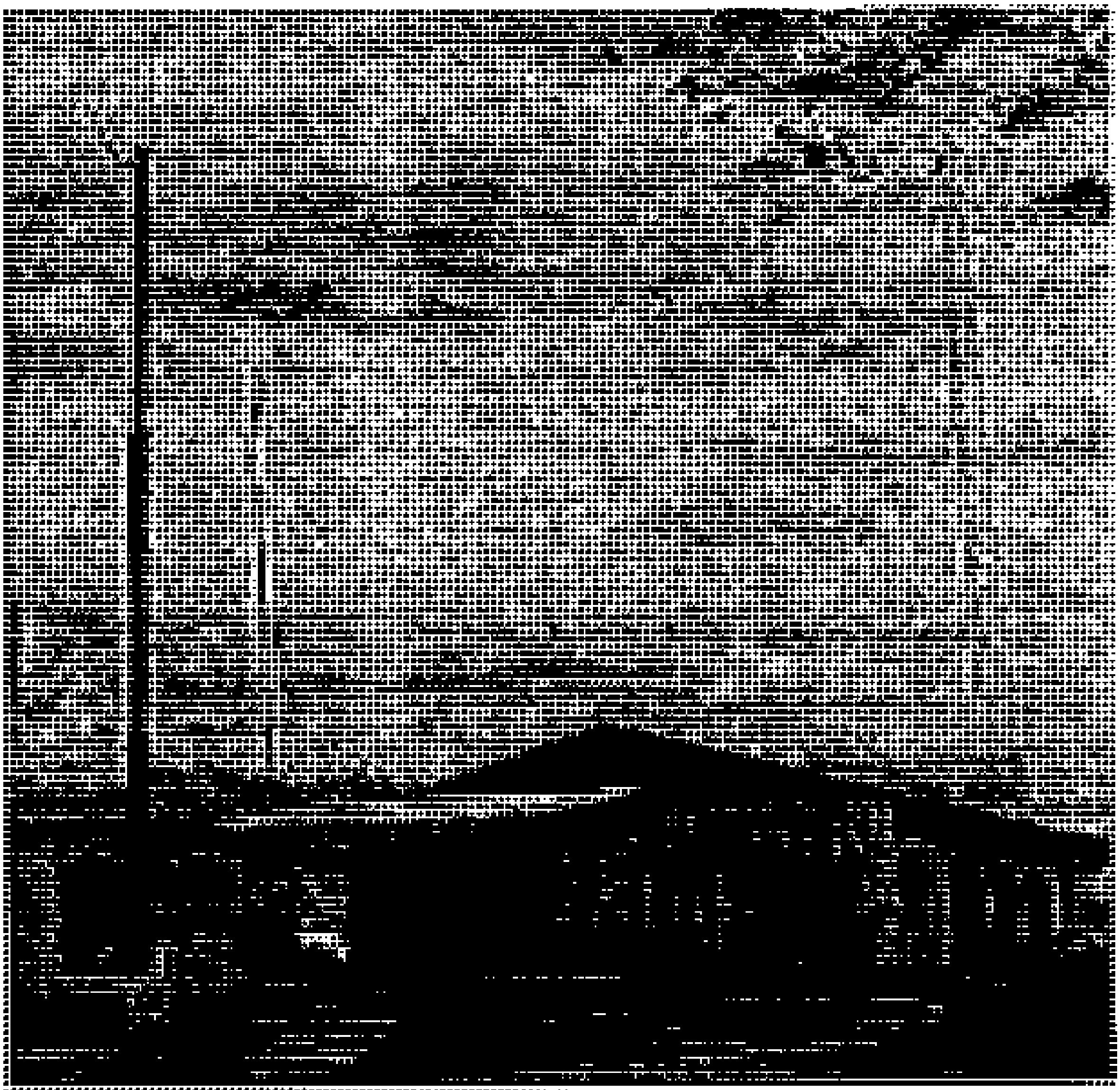


Figure 3.3: Mast and Monopole

The project includeed inspection, repainting and refurbishing of the existing masts. SCADA telemetry antennas, mounted on monopoles interface to Remote Terminal Units (RTUs) located at over sixty gas sites to provide monitoring and control facilities over the full extent of the pipeline at the two new Control Centres at Demra and Ashuganj.

3.1.3 The SCADA System

In Master Control Center (MCC), Demra, (Figure 3.4) there are three computers (MCC4, MCC5, MCC6) called control room workstation in the control room which display the flow parameters, open/close status of valves, overview of all major pipelines etc. There is one computer for pipeline application (MCC1) which main use is to configure and run Pipeline Application Software (PAS) enabling load balancing & scheduling, leak detection, line pack calculation etc. Another computer (MCC2) is for SCADA management which main use is to configure/re-configure various parameters of SCADA database. There are three printers in the system, one is for alarm and events printing, another one (MCCP2) is for report printing and the rest one (MCCP1) is for color printing. SCADA servers are located at each control centre and operate in a main/standby configuration. The servers communicate via a dual 256kbit/s extended LAN (WAN) link between the MCC and ACC. CC1 & CC2 are the communication controllers which are used to relieve the SCADA servers of the telemetry load. All compnters, printers etc. in the system are connected by hub. Under wide area network (WAN), six Operating Company Terminals (OCT's), ACC, MCC and Petrobangla are connected through router. Device Masters are 32-port bridging unit which holds point to point connection from each telemetry master station via sentinel panel. Device masters are connected to the communication controllers via Ethernet link. After a certain interval, server request for getting data from outstation via sentinel panel.

After getting request, RTU sends the requested data to communication switch in the radio room via UHF/cable link. The communication switch test which one (MCC/ACC) is ready to get the data. If there is no problem of MCC to get the data then RTU sends data to MCC. If MCC is not ready then RTU will send data to ACC. As there is a link of 128 kbps between ACC and MCC, the acquired data is updated automatically between two control centres. Pipeline Application Workstation (MCC1) will take data from server. The user will also insert the required data to run the software. After running the software, the results will be sent to server. From the server, the results are available to the computers of control room, OCT,s and petobangla as well.

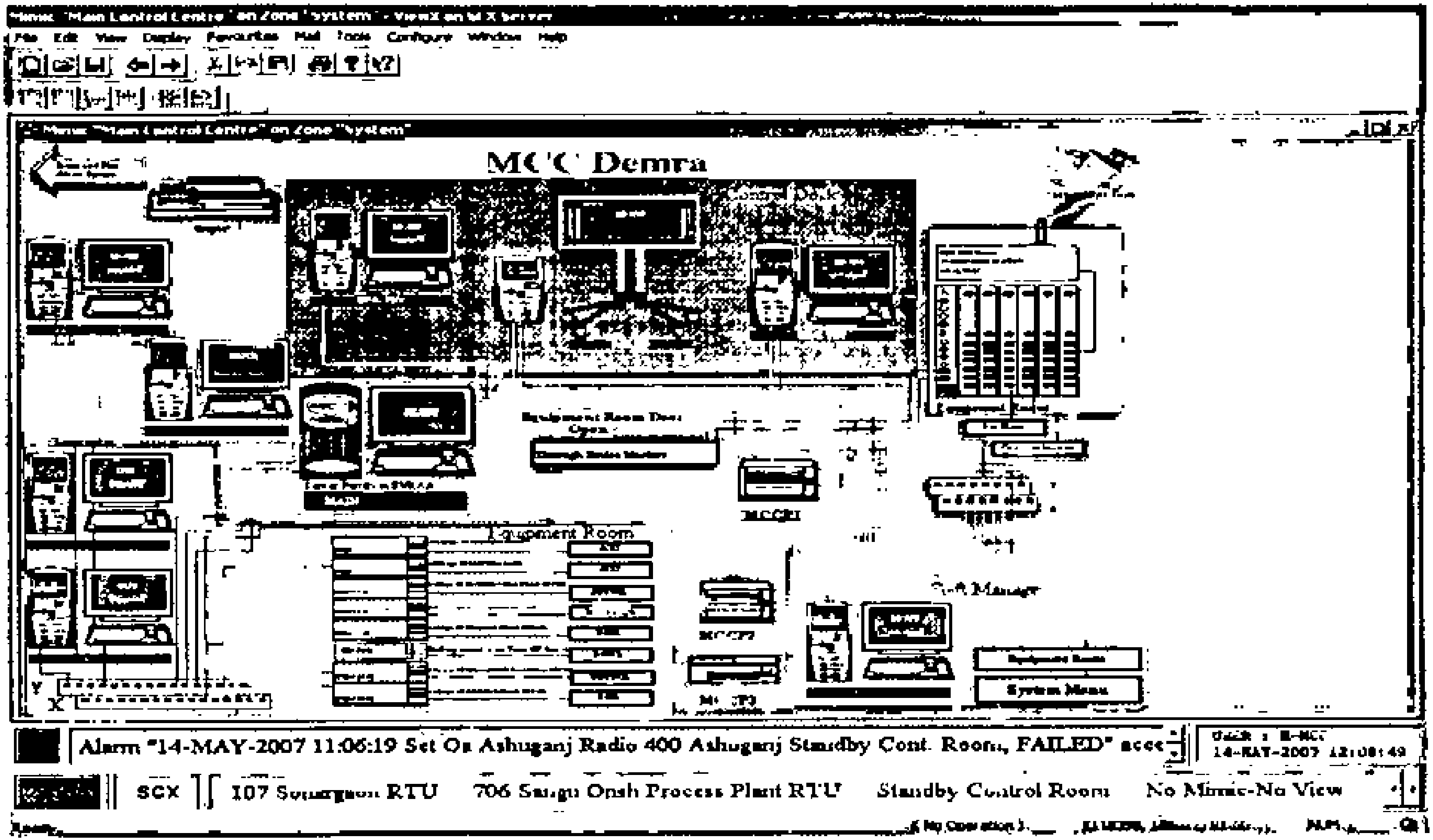


Figure 3.4: Screen Shot of the SCADA Network of MCC

3.1.4 The Control Centres and Gas Operating Company Terminals (OCTs)

The system is based around two geographically separated Control Centres offering, for security purposes, identical facilities, with a dual processor server configuration for resilience

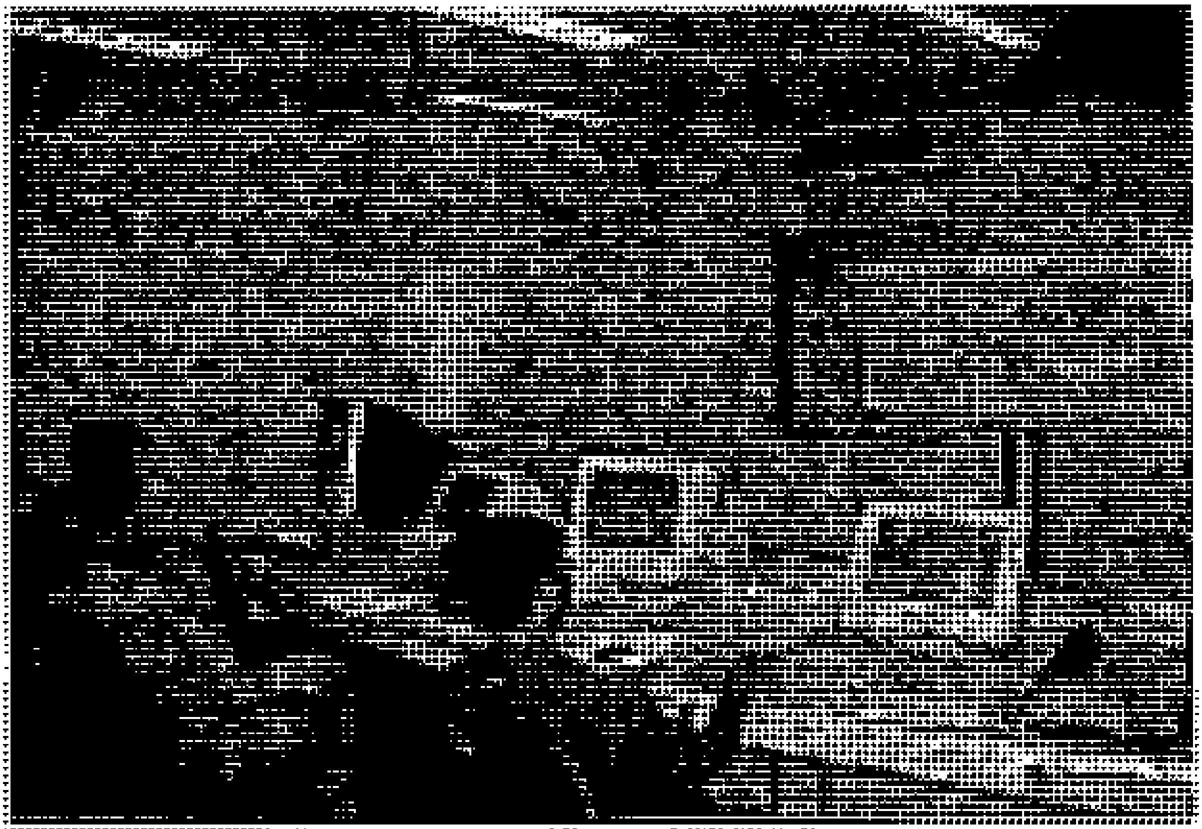


Figure 3.4: Control Room of SCADA System

and additional security. The Main Control Centre (MCC) is located at Demra, 12 Km South East of Dhaka and the Auxiliary Control Centre (ACC) at Ashuganj, 85 Km North East of Dhaka (Figure 3.5). Database transfers via high-speed links between the servers provide main/standby functionality across the system. The servers support PC based workstations in the Control Rooms and Operating Company Terminals (OCTs) installed in the Gas Operating Company Head Offices throughout Bangladesh to provide the facilities of Gas Plant monitoring and control, pipeline operations management, maintenance dispatch, production planning and training. Large, high-resolution rear projection system screens provide an overview of operations as part of an integrated Control Room design.

An on-line mathematical modeling package is incorporated into the SCADA system to improve the detection/location of leaks, monitoring of under/over pressure, pig tracking, demand prediction and where necessary to simulate parts of the gas network. Both Control Centres are provided with duty/standby gas powered generators, each capable of supporting the full building power load to cater for interruptions or voltage fluctuations in the public supply. Battery back up facilities which can maintain the power supply to the system for up to four hours are also provided to ensure a seamless changeover between the public and standby generator supplies.

3.1.5 Remote Terminal Units (RTUs), Instrumentation and Metering Skids

RTUs have been installed at sixty sevens sites throughout the existing national gas network, to interface to the pipeline instrumentation, retrieve data and transmit it back via the Microwave backbone to the MCC and ACC and to transmit control signals to the plant (Serck Controls, 2004). A typical RTU is shown in figure 3.6.

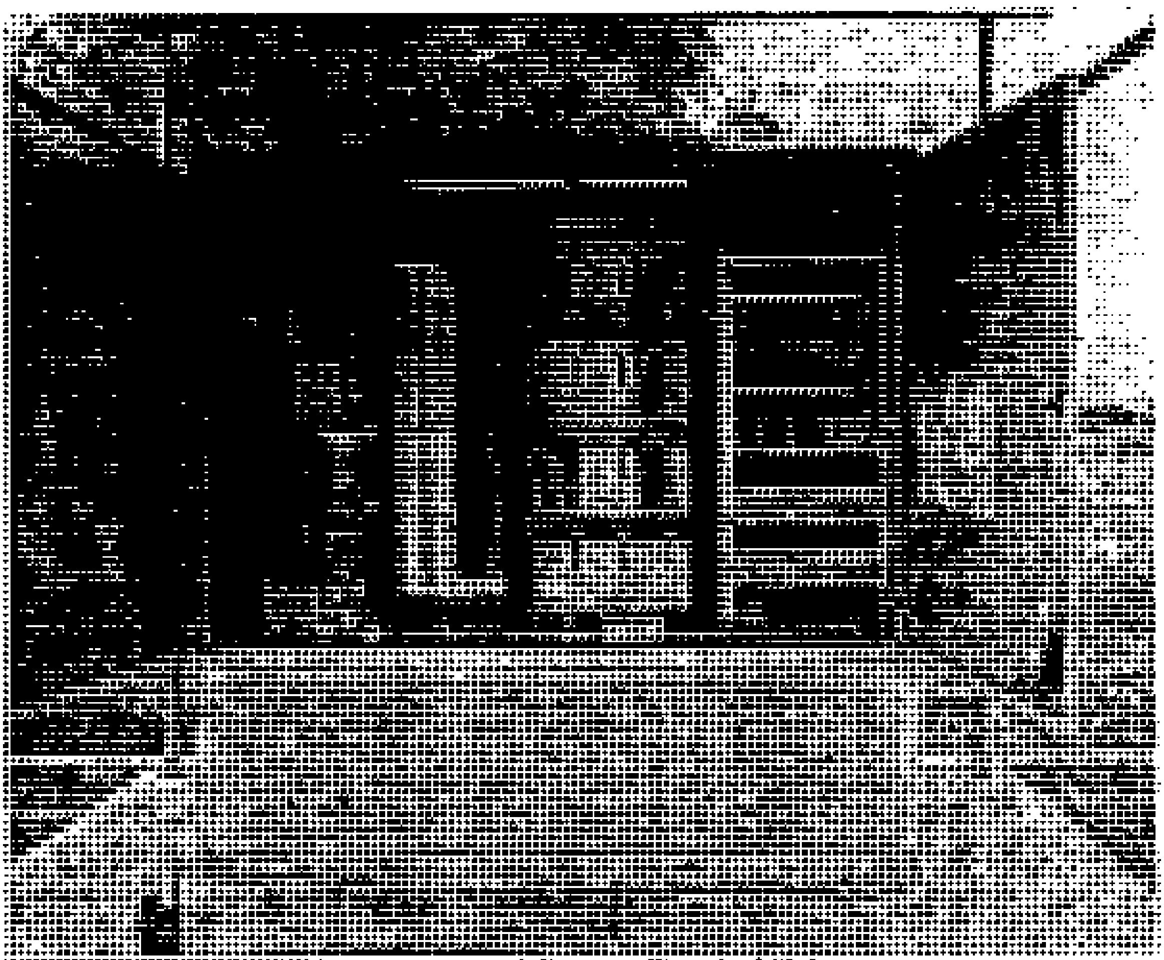


Figure 3.6: Remote Terminal Unit

The RTU cabinets need to be capable of withstanding the harsh environmental climate of Bangladesh and typically must endure monsoon rains, cyclones, flooding high temperatures and humidity. Raised concrete platforms to a height above the worst known flood level and galvanised steel shelters have also been constructed to offer additional protection. Batteries are installed in the bottom section of the RTU cabinet to provide power back up facilities and maintain equipment operation for a full twenty-four hours, on loss of the public electricity supply.

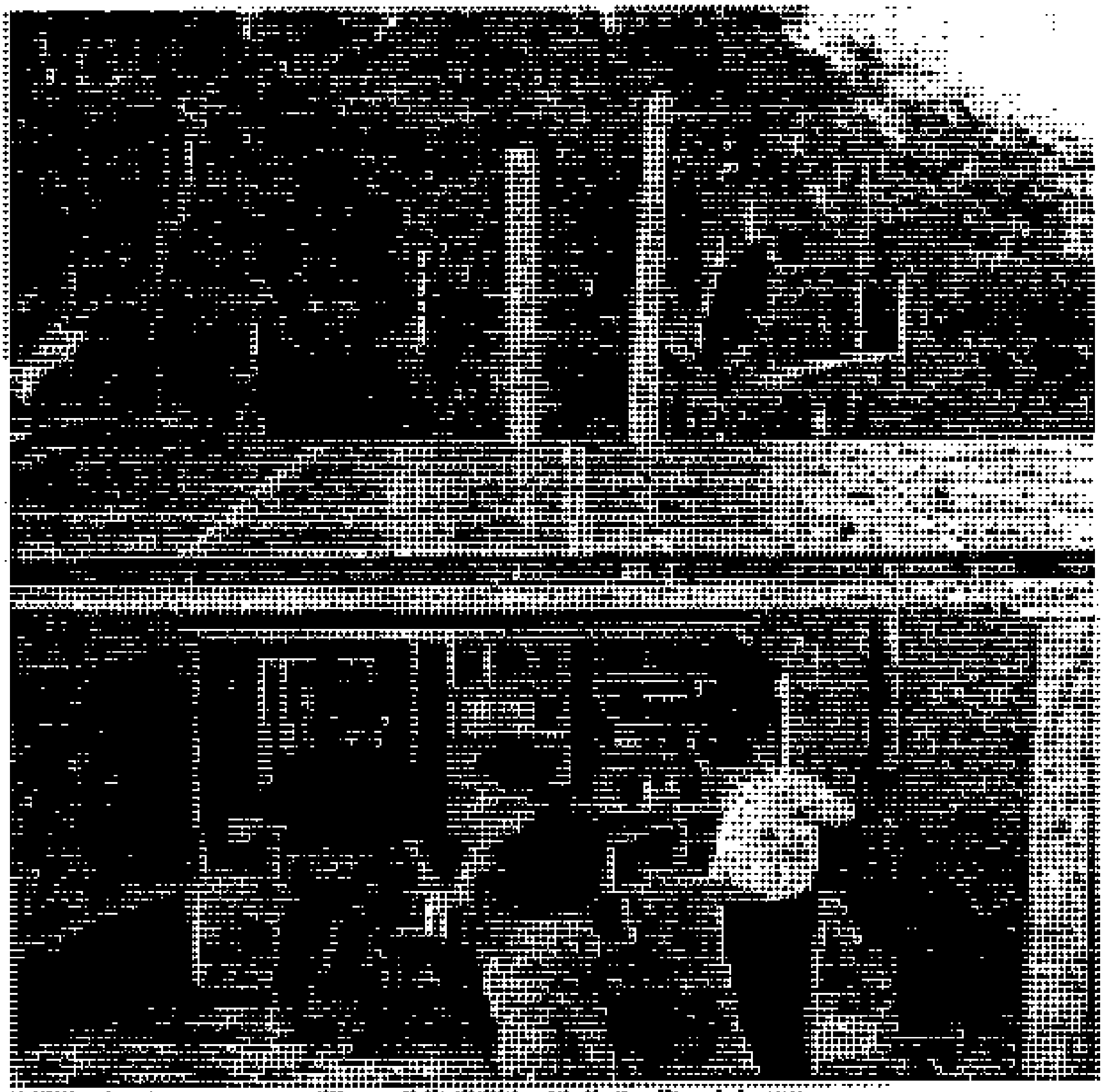


Figure 2.1: RTU with Solar Panel Array

Many of the gas sites are in remote locations without any public electricity supply. In these instances, solar panels have been installed on the RTU shelter roofs to provide the power necessary to energise the RTU equipment and pipeline instrumentation (Serck Controls, 2004). The RTU with solar panel array is shown in figure 3.7.

Instrumentation: Typically, at each site, new intelligent gas pressure, temperature and flow monitoring instrumentation has been installed on the pipeline itself and adjacent to the pipeline on new instrumentation stands. The instrumentation stand is shown in figure 3.8.

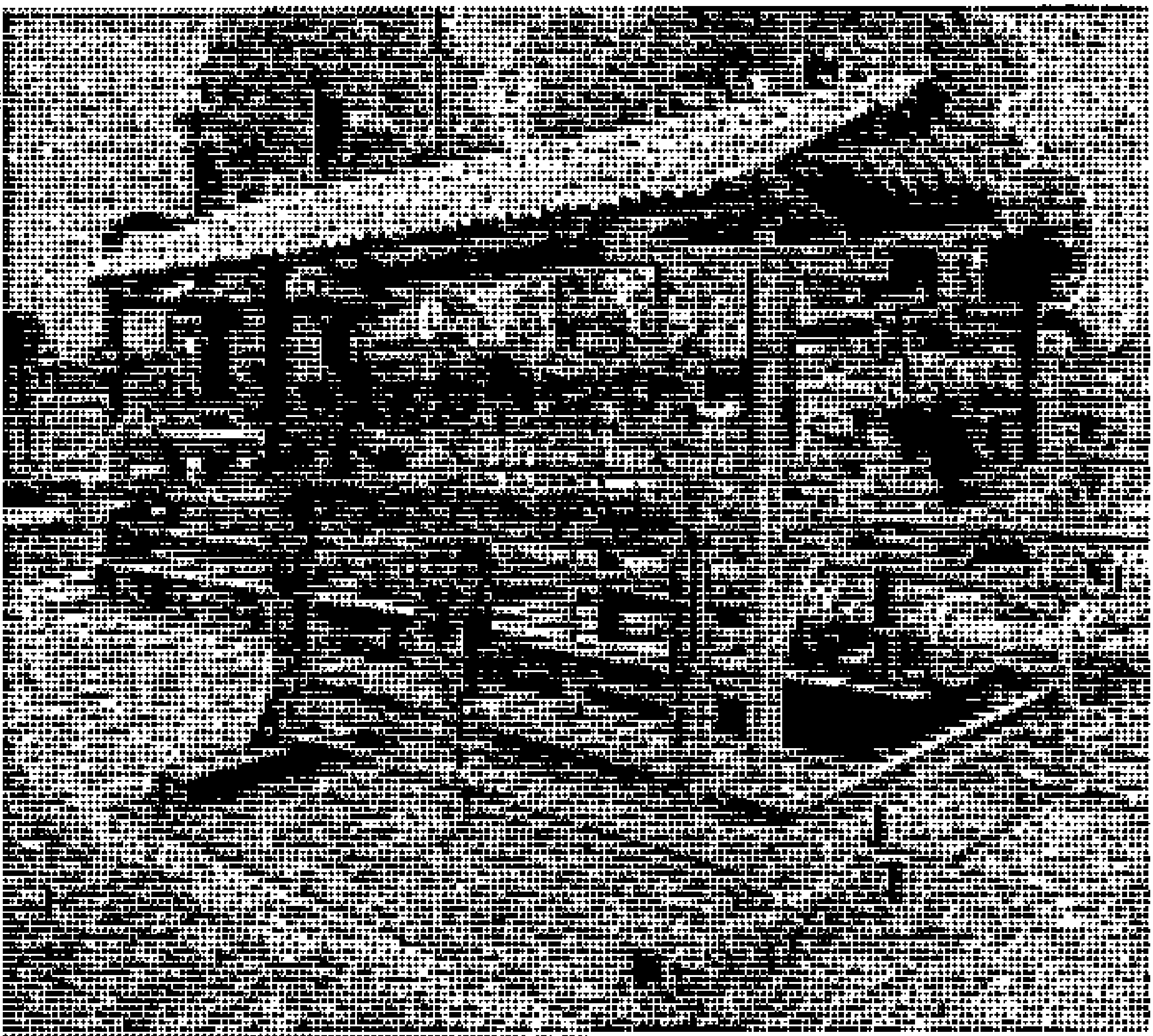


Figure 3.8: Instrumentation Stand

The data signals are then taken back to the site RTU via cables, fed into a flow computer which accurately calculates the true gas flow which is then transmitted to the Control Centres. At two locations, Elenga and Monohordi new metering skids have been installed. Each skid is about twenty-one by nine metres in size and weighs around fifty tonnes. The installation required an excavation the size of a basket ball court to be dug by hand to expose the existing twenty-four inch pipeline (GIDP, SCADA Component, 2002).

A section of the pipeline was cut away, valves inserted and pipe work modified to allow the flow of gas to pass via the new skid. The gas passes through gas filters, scrubbers and dual chamber orifices before returning to the main pipeline.

3.1.6 Microwave Links and RTU Status

There are 23 nos. towers and 67 nos. out stations (RTU) under the SCADA system. Amoug 23 nos towers, 9 new towers are installed and the rest of the towers are modified and interfaced with the new towers. Two control centers, one is Master Control centre (MCC) located at Demra and another oue is Auxiliary Control Centre (ACC) located at Ashuganj. From two identical control centres the microwave link and RTU status can be monitored.

Figure 3.9 shows the microwave link and RTU status. If any problems occur in any outstation or microwave link, the corresponding outstation and microwave link will show red color in the SCADA system. There are many outstations under one microwave site and the radio room is located near the tower. The nearest outstation is connected by cable link with the radio room and the remote outstations are connected by UHF/laser communication with the radio room via tower. Between towers there is a link of microwave communication. RTU collects data from plant and sends data to control centre by microwave link.

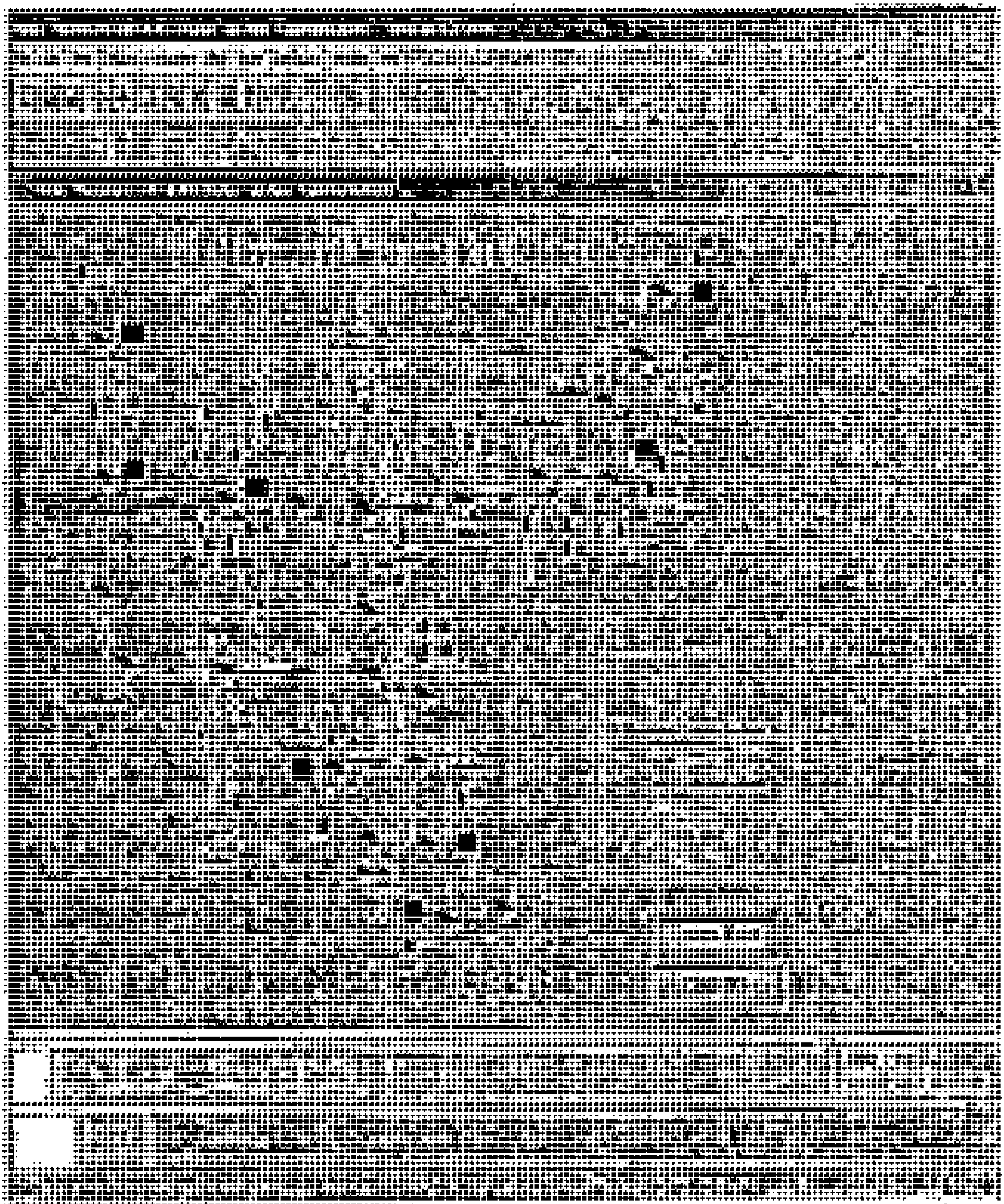


Figure 3.9: Screen Shot of Microwave Link and RTU Status

CHAPTER 4: TECHNICAL SPECIFICATION OF SCADA SYSTEM IN GTCL

SCADA system consists of control centre hardware, head office hardware, Remote Terminal Unit (RTU), Telecommunication system and Instrumentation. There are many components of this system. The technical specification of this system is discussed here.

4.1 Control Centre Hardware

There are two control centres:

- Main Control Centre (MCC) at Demra
- Auxiliary Control Centre (ACC) at Ashuganj

Each control centre contains the following components:

- SCADA server
- Telemetry
- SCADA Management Workstation
- Pipeline Applications Workstations
- Control Room Workstation
- Large Screen Display
- Printers
- LAN Equipment
- GPS Clock
- Remote Access Modem

Brief discussion of the components is given below.

4.1.1 SCADA Server

SCADA server is located at each control centre and operates servers in a main/standby configuration. The servers communicate via a dual 256kbit/s extended LAN (WAN) link between the MCC and ACC.

Each SCADA server is connected to a SCADA management workstation and a pipeline applications workstation via a dual LAN. The dual LAN also connects each SCADA server to two Communication Controllers. The Communication Controllers operate in dual mode under the control of the main/standby SCADA servers (Lewin, 2002).

4.1.2 Telemetry

Telemetry means remote measuring device. It describes any system using electronic communications for measurement. It can also be used for systems with control functions and to highlight wide area rather than plant based system. The telemetry system consists of the following components.

Communication controllers: Each control centre has two Communication Controllers. The Communication Controllers are used to relieve the SCADA servers of the telemetry load. The Communication Controllers provide a set of 9.6kbit/s communication channels from each control centre via a sentinel changeover panel.

Each Communication Controllers consists of a kayak XU PC Pentium II 400 MHz 128 Mb RAM and a 4.2 GB HDD. The Communication Controllers are connected to the Sentinel Panel via two 32 port Device Masters accommodating the single communications channel from each control centre to the RTU's over the radio system.

Under normal operating conditions, one control centre communications channel is used to poll the Remote Terminal Units (RTUs) at any one time. Switching within the telecommunications system ensures the RTUs are connected to the polling control centre.

When there is a fault on a particular channel, polling for that channel is automatically switched to the other Communication Controllers. The Communication Controllers output a serial control signal to their local sentinel panel-the control signal is used to direct the sentinel to switch to the appropriate Communication Controller.

Data exchange between RTUs and Communication Controllers is at 9600bps over multi-drop RS-232 virtual channels, providing a point to point connection to each microwave telecommunications site from ACC and MCC (Lewin, 2002).

Sentinel Panels: The sentinel panels are control units based on Serck Controls' Proteus 2000 hardware. The sentinel Panels monitor the main and standby computer system to detect hardware or software malfunction and announce the failure to the other system.

If the main system fails, the standby system instructs the changeover panel to transfer control to the standby system. The transfer is performed by magnetically latched relays controlled by the processor in changeover panel.

When control is transferred, the standby system takes control of the peripherals and communication lines normally dedicated to the main system (Lewin, 2002)

Device Masters: Device Masters are 32-port bridging unit which holds point to point connection from each telemetry master station via sentinel panel. Device masters are connected to the communication controllers via Ethernet link.

4.1.3 SCADA Management Workstation

The SCADA system management workstation consists of a HP kayak XU Pentium iv, 1.8GHz PC fitted with 128Mb memory, a 40 Gb hard disk drive, keyboard, mouse and a 17" colour monitor. Its main use is to configure/re-configure various parameters of SCADA database.

4.1.4 Pipeline Applications Workstation

The pipeline applications workstation consists of a HP kayak XU Pentium iv, 1.8 GHz PC fitted with 128Mb memory, a 40 Gb FastRAID hard disk drive, keyboard, mouse and a 17" colour monitor. Its main use is to configure and run Pipeline Application Software (PAS) enabling load balancing & scheduling, leak detection, line pack calculation etc.

4.1.5 Control Room Workstations

The control room workstations consist of a HP kayak XU Pentium iv, 1.8 GHz PC fitted with 128 Mb memory, a 40 Gb hard disk drive, keyboard, mouse and a 21" colour monitor. The various flow parameters data of gas and condensate are monitored in the control room workstations.

4.1.6 Large Screen Display

Each control room has a Barco RetroGraphics 808s high resolution rear screen projection system. The Fresnel/Lenticular Blackstripe screen measures 50" across the diagonal and is controlled by a Pentium iv, 1.8 GHz PC fitted with 128 Mb memory, 40 Gb hard disk drive, CD-ROM, keyboard and mouse. It displays the flow parameters i.e. static pressure, flow rate, differential pressure and temperature.

The Pentium iv, 1.8 GHz PC supplies a SCADA display to the screen and runs the Searck Controls Ltd X System (SCX) client software. The video output of the PC is connected to the screen system. Only one PC can remotely control the screen at any one time. If a control room PC has not requested control of the screen, the screen displays the windows that were selected by the previous user.

The RetroGraphics 808s display has a multi-standard video input to allow data input from sources other than the control room workstations. The video standards included are PAL, NTSC3.58, NTSC4.43 and SECAM.

An orbitor card is used in the projector to avoid burn-in on the screen. The graphics card used in the display control PC and the display itself, including the interconnections, provides a screen resolution of 1600x1200, ensuring a sharp display. An automatic convergence adjustment feature is included in the display to avoid the requirement for manual screen adjustment (Domjan and Parkes, 2002).

4.1.7 Printers

There are three types of printer of the SCADA system which are used for various purposes. The types are given below:

Alarm/Event Printer: For smooth operation of the system, alarm/event printer is used. When an alarm or event is generated in the system, it prints out automatically. Dot Matrix printers are configured as alarm and event printers. The printer groups are configured so that alarms and events print out at both the MCC and ACC.

Report Printer: For convenience of the system report printer is used. This printer is dedicated for report. Laser printers are configured as report printers. Each laser printer, across the system, including OCTs, is configured as an individual print group. The reports can be printed at a specific location.

Screen Dump Printer: HP 1600C colour printers are configured as individual printer groups. The printer group is selected when a screen dump is initiated. Screen dumps can be sent to any screen dump printer on the system.

4.1.8 LAN Equipment

The Local Area Network (LAN) at the MCC and ACC is duplicated for security. Each LAN consists of a 16 port 10 base-T Ethernet hub, and an 8 port 10 base –T Ethernet hub. The server and workstations are connected to both LANs that share the network load under normal operating conditions.

If a LAN fails, the other LAN takes over the full load of that site. Connection to the Wide Area Network (WAN) is via routers connected to the microwave backbone.

The Local Area Network equipment consists of:

Hubs: The system uses two types of hub:

- 3 Com OfficeConnect Hub 8/TPO (10 BASE –T Hub)

- Office Connect Hub TP 16C(10 BASE-T Hub)

Routers: Network routing topologies enable an OCT to connect to either an ACC or an MCC LAN. Client workstation software retrieves data from the main or standby SCADA server depending on proximity/WAN speed and determined on installation. Client software always writes data to the Main SCADA server.

The system uses two types of router:

- Cisco 1601
- 3 com officeconnect Remote 531 Model

(Lewin, 2002).

4.1.9 GPS Clock

A Global Position System (GPS) clock, with a suitable externally mounted antenna, is connected to each SCADA server in MCC and ACC. The GPS clock is connected to the SCADA servers via the Sentinel panel, Device Masters and the Communication Controllers.

The GPS clock is used to synchronize time stamping of alarms and events across all Serck Proteus RTU's to 1 second. Syncronisation is achieved by means of a broadcast from the master station to all RTU's. The GPS clock is used as the system clock for the master station (Lewin, 2002).

4.1.10 Remote Access Modem

Remote Access Modems are connected directly into the COM port of Pipeline Applications Workstation. The PC anywhere software package is used to log into the servers to provide remote support for the system. The system uses the multitech MT5600ZDX Remote Access Modem (Lewin, 2002).

4.2 Head Office Hardware

Workstations are installed at operating company head offices to provide operational data such as gas production and consumption and generate customized reports but they do not provide control facilities. Three workstations are installed in the head offices of the three distribution companies (TGTDSL, BGSL, JGTDSL). Two workstations are installed in the head offices of two production companies (BGFCL, SGFL). One workstation is installed at petrobangla. The operational data of the whole SCADA system is monitored from petrohangla workstation. In the other workstations, the operational data of their respective franchise area is monitored.

The equipment at each head office is identical and provides workstation access (with printing facilities) to the SCADA system via 64Kbit/s WAN links to each control centre.

Each head office has:

- A workstation based on Pentium iv, 1.8 GHz PC fitted with 128 Mb memory, a 40 Gb hard disk drive, keyboard mouse and a 21" colour monitor.
- A HP Laser Jet 4000N printer.
- A HP 1600C colour printer (connected to the 3 com officeconnect 8 port 10 BASE –T Hub based LAN).

Each head office is connected to the WAN via a pair of office Connect remote routers at 64 kbps (Domjan and Parkes, 2002).

4.3 Remote Terminal Units (RTU's)

Remote Terminal Unit's (RTU's) gather data from measuring device points and send instructions to controllable device points. RTU's are usually positioned some distance away from the master station network. The RTU's communicate with the master station network via the telemetry channels and use the same protocol.

The main components of the RTU are given below:

- Heater
- Thermostat
- Hydrostat
- Processor card (PR3)
- TM-1 Communications Terminal Module
- GE2/4 Back Plane
- UB7 Termination Module
- PR13/PM13 Switching Card
- Serial Interface Card (PR27)
- Optically Isolated Digital Input Card (PR28)
- Analogue Input Card (PR36, PR37)
- Digital Output Card (PR64)
- Analogue Output Card (PR71)
- Power Card (PR82)
- Termination with SE cards
- Flow Computer
- Inverter
- Rectifier
- Lightning Arrestor
- Relay
- Barriers

(Domjan and Parkes, 2002).

4.4 Telecommunication System

The telecommunication system provides the SCADA system with a transparent transmission medium for all communications. It also provides voice and data facilities to support the GTCL's and the operating companies operations through the national grid.

The main function of the telecommunication system is given below:

- The communications medium through which the national gas grid data acquisition element of the SCADA system is implemented.
- The telephone links between the PABX equipment (MCC & ACC) and the sites.
- The trunk interconnections between the PABX at the various control center sites.
- The trunk interconnections between the trunk radio base stations and the central trunk switches located at the main control centers.
- The trunk interconnections between the three central trunk switches of the trunk radio system and the master trunk switch.
- The WAN network linking the operating company offices with the main control center servers.

In addition to these main functions, the system is equipped with a separate PC9010 network manager system for the configuration of the control and alarm monitoring of the telecommunications system equipment located at each microwave site in the system.

The main components of the telecommunication system are given below:

- Microwave Tower
- Microwave Dish Antenna
- Lighting Rod
- Light
- Aircraft Warning Light

- Microwave Radio
- SAGEM Multiplexur
- PMR Master Station
- Telemetry Radio
- PC9010 RTU
- PS21 RTU
- Rectifier
- Inverter
- Lightning Arrestor
- Relay

(Brown, 2003).

4.4.1 Communication Systems

The backbone communications system consists of a digital line of site microwave bearer system with digital multiplexers at each site. This extends voice and data communications facilities throughout the national gas grid. This provides data communications between adjacent microwave sites to create a complete communication pathway from the MCC/ACC through the complete chain of microwave sites.

4.4.2 PABX Network

Two Mitel 2000 digital PABX's provide voice communication service for the national gas grid. These are located at the MCC and the ACC. Interconnecting trunks are connected between the existing stand alone PABX at each operating company head office and the new PABX to form a PABX network covering the main sites in the field. PABX Network and Interconnecting Trunks are shown in figure 4.1 (Brown, 2003).

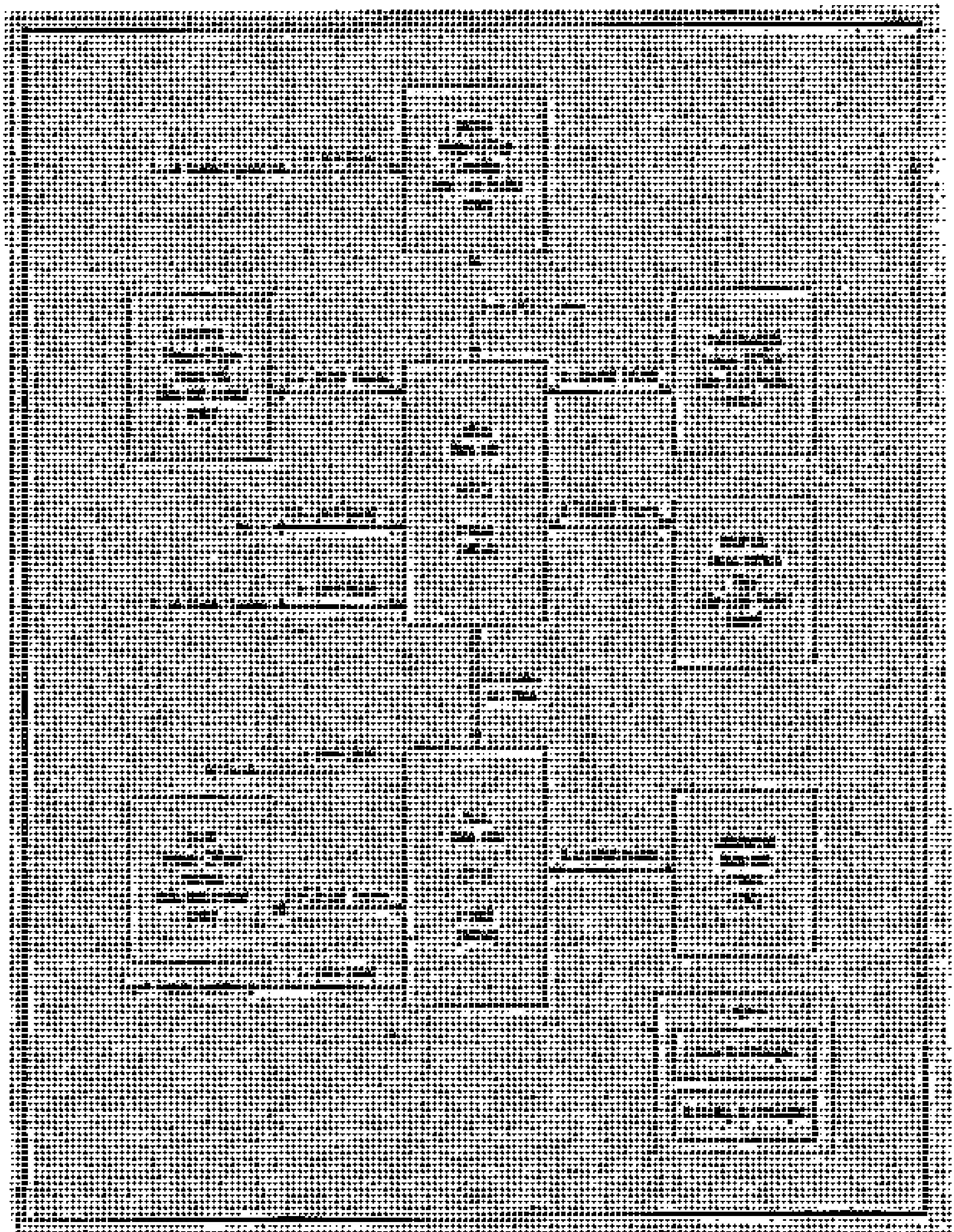


Figure 4.1: PABX Network and Interconnecting Trunks

In addition, access to the PSTN is provided by the inclusion of five PSTN connections to the ACC and six to the MCC, the sixth line at the MCC being an international line.

The PABX at the MCC, the ACC and at BGSL each have two 4W Ear & Mouth (E&M) trunks connected to the trunk radio system to permit calls to be set up between these operating company PABX extensions and the mobile radios serving the Trunk Radio System (TRS).

4.4.3 Trunk Radio System

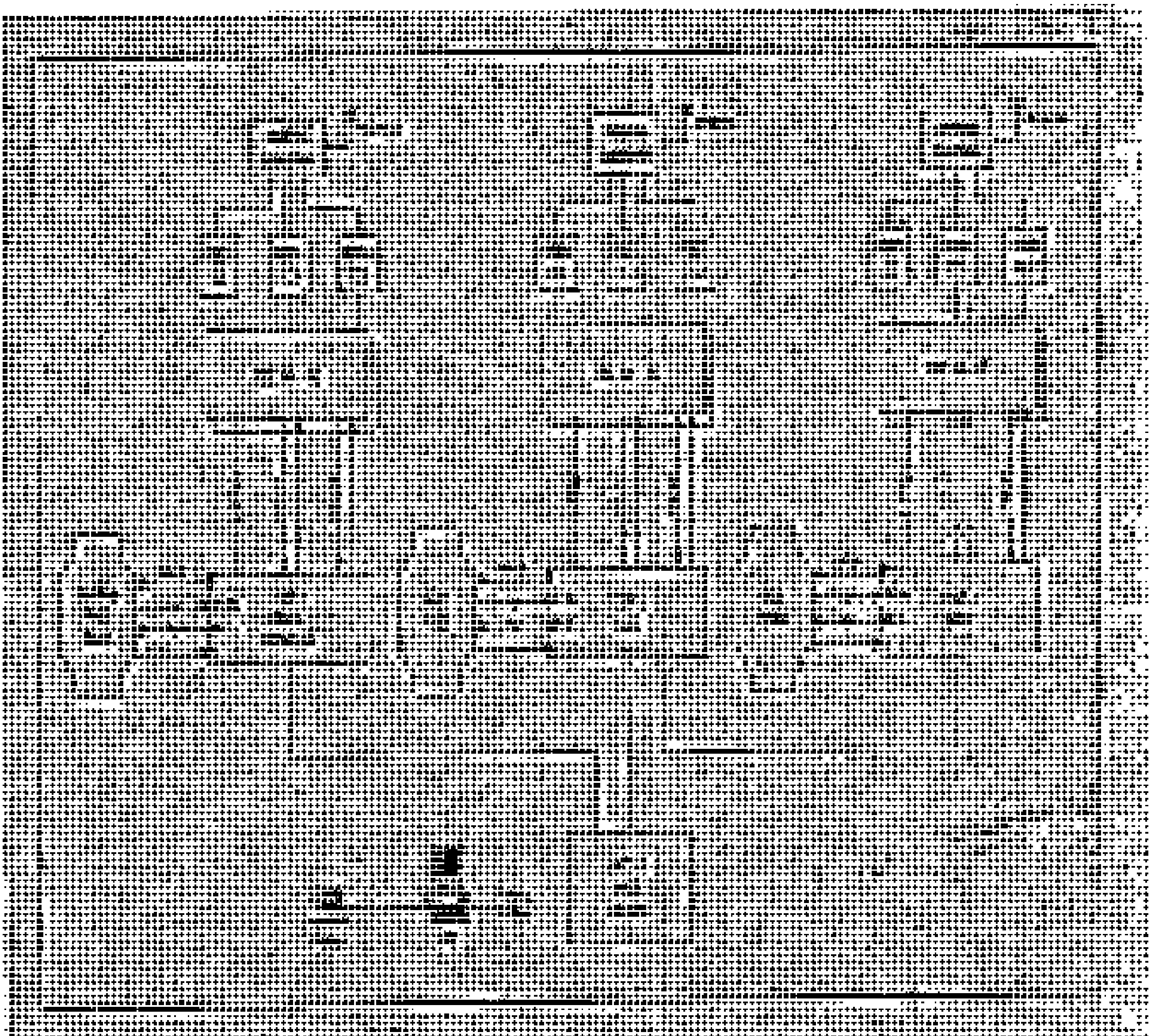
The trunk radio system is a voice and data communications network that operates in the 80 Mhz VHF band which allows field staff working on the main transmission lines and at sites on the national gas grid to communicate with the MCC/ACC or with each other.

The network is a modular hierarchical infrastructure with Trunk Site Switches (TSW) at MCC, ACC and BGSL (Comilla) controlling 19 VHF base stations located at the microwave sites. The three TSW switches are controlled by a single Master Trunk Switch (MTS) located at the MCC.

The system is configured as a 3 channel trunked scheme with one dedicated control channel base station and two traffic channel base stations at each site. Calls may be made from the MCC/ACC or BGSL at Comilla to single portables, groups of portable or all hand portables. The signaling system used conforms to MPT 1327 specifications allowing hand portables to be uniquely identified by means of user name, unit number or group name.

The system is equipped with interfaces to the GTCL PABX network at the MCC, ACC and the BGSL PABX at comilla to facilitate communication between the mobile radios and PABX estensions or the PABX operator.

Hand held radio terminals can establish calls to the MCC, ACC or BGSL Comilla by means of a simple key press operation. Handhelds can be configured for calls to home or "prime" dispatcher locations. Speech calls from portable radios can be assigned with normal, priority or emergency call status. In addition, simple status signaling can be used on the system control channel which allows simple massages to be transmitted to the dispatcher or hand portables without the need for the allocation of a traffic channel. Simple stacked dipole antennas are used at the VHF base stations to give omni directional coverage. The trunk radio system is provided with a Network Management Terminal (NMT) for configuration and fault reporting. The trunk radio system overview is shown in figure 4.2 (Brown, 2003).



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4.4.4 Communications Management System

A Communication Management System is provided to allow operators to assess the performance of the telecommunications system and reconfigure or control it as appropriate.

The PC9010 Communications Management System provides a management function for:

- Remotely monitoring the configuration and alarm status of the equipment at each microwave site
- Remotely reconfiguring microwave site equipment
- Remotely monitoring the multiplex equipment at each site
- Remotely reconfiguring the multiplex equipment at each site

The PC9010 is a data communications network that uses a combination of interconnecting cables and microwave transmission links to transmit data frames containing management commands to the microwave site equipment

Data frames containing equipment address, equipment status/configuration read commands or configuration control commands, are issued by the Network Management Server (NMS) at the MCC and are transmitted around the system at a data rate of 9600kb/s.

Equipment configuration and alarm status read from each site is inserted into the respective data frames for transmission back to the NMS (Brown, 2003).

4.4.5 Gas Data Acquisition Control

Each of the two control centres; the MCC and ACC, are equipped with dual redundant communication controllers for controlling the gas data acquisition element of the SCADA system. Each communication controller is identical and is loaded with the same software. Each communication controller has a separate V24 interface to each microwave radio site in the system through which the poll and gas data gathering process is executed to that particular site. The V24 interfaces in figure 4.3 are numbered V24(102), V24(105)..........and so on to V24(702) following the site numbering scheme (Brown, 2003).

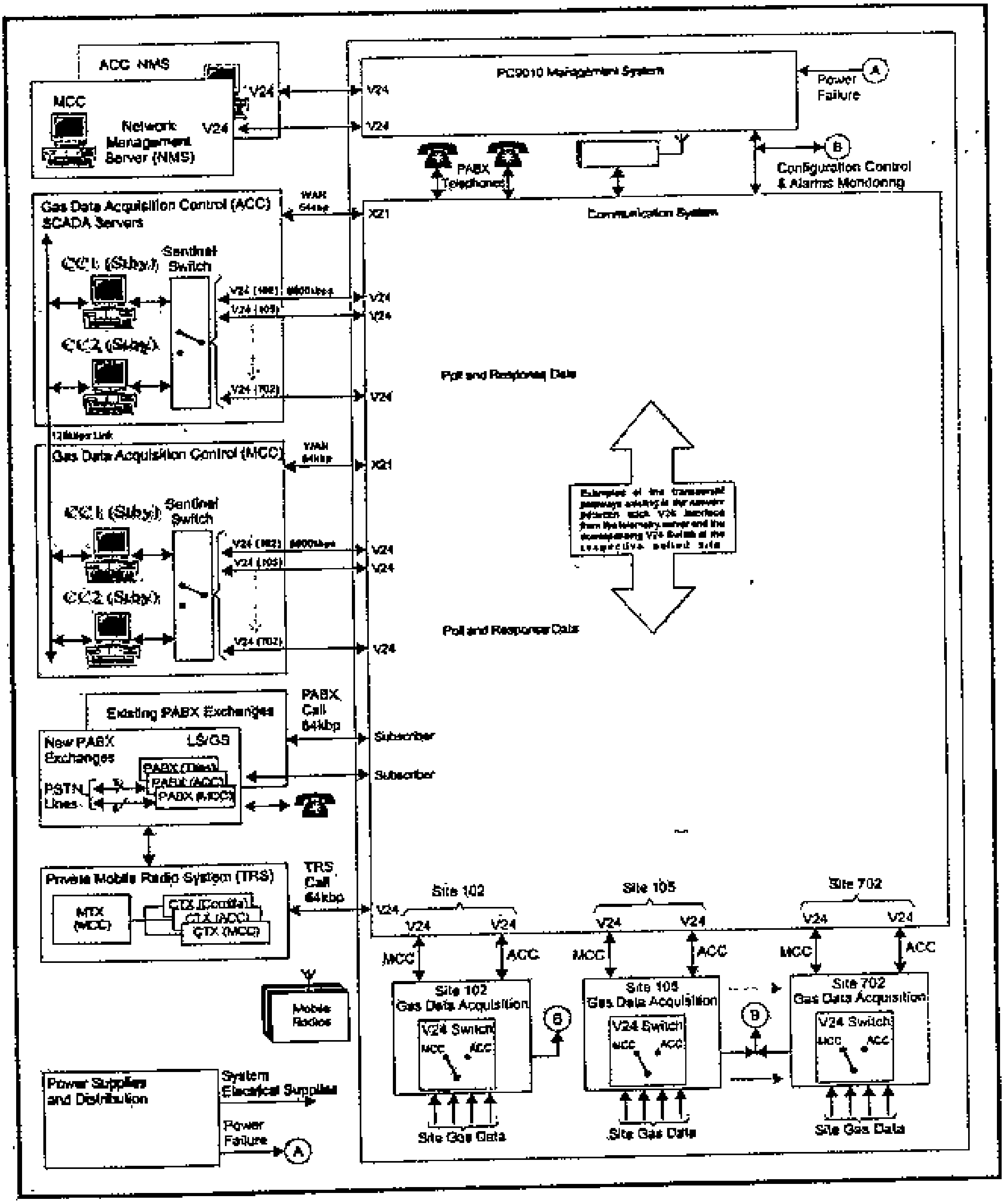


Figure 4.3: System Functional Design

The main and standby communication controllers V24 interfaces at the MCC and ACC are each connected to a sentinel switch to ensure that only the V24 interfaces from one of the communication controllers at each control site is applied to the system. The V24 interfaces of just two communication controllers are thus normally connected through the sentinel switches.

The four communication controllers operate in tandem. Therefore when a poll is made, all four communication controllers output a poll procedure on their respective group of V24 interfaces. Consequently, the group of V24 interfaces from the MCC duty server, all initiate the poll request simultaneous with the ACC. Normally, the Microwave and Multiplex system only use the poll commands from the MCC. In the event of failure of V24 signaling, the Microwave and Multiplex system automatically switches over to using the ACC main server as its source of poll command and as its destination for the response data. The V24 data rate is set at 9600bps.

The database of gas grid data built up by the duty server is shared with the other servers by periodic updates via a 256kbps high speed data link. Thus if another server has to take over control, it will have the same database. The poll and response process have the flexibility to initiate a poll from the duty server (at the MCC) and in the case of an immediately following fault or loss communications, to accept the response data at the ACC server. If the main server at a control site fails, the Sentinel Switch automatically disconnects the V24 interfaces of the failed server from the system and connects the V24 interfaces from the standby server through the switch instead (Brown, 2003).

4.4.6 Site Data Acquisition

The poll signals originated at the MCC and ACC are received from the microwave and multiplex system via a V24 switch. This may be connected to either the MCC or ACC V24 channel. If communication is lost, the switch is toggled alternately between the MCC and ACC position for a set time-out period until communication is reestablished. The time-out period is dependent upon the type of communication loss. When communication with a communication controller is achieved, the switch stops toggling between the MCC and ACC and stays in the selected position.

In response to a poll command, the function gathers gas data from all outstations that are monitored by the site and sends the data back to the servers. If the V24 switch is at the MCC position, the data will go to the MCC, if it is in the ACC position, then it will go to the ACC server. The function forms part of an integrated data communications system together with the communications system and the Remote Terminal Units (RTU's). Gas parameters, pressure, temperature and flow rate, collected from the gas grid, are inserted into a data string containing gas grid source address, parameter identification codes, gas parameter magnitude and transmission error control codes. The string is transmitted back to the relevant server via the transparent microwave and multiplex system.

All data interfaces at the periphery of the Microwave and Multiplex system that are associated with the process of gas data acquisition are V24. Each V24 interface from the Sentinel Switch is site specific programmed. When a poll signal is initiated on one of these V24 interfaces, a set pathway is automatically through the Microwave and Multiplex system to the input of a V24 switch at the corresponding site. This pathway becomes transparent to V24 signaling and can be viewed as a virtual V24 circuit. For example, in figure 4.3, the V24 (102) interface from the communication controller at the MCC is linked to the MCC input of the V24 switch at site 702. Similarly, the V24 (102) interface from the communication controller at the ACC is linked to the ACC input of the V24 switch at site 102 and so on.

The poll commands generated on each V24 interface by the duty server are therefore input to the respective site V24 switch. Normally, with the MCC acting as the duty server, the command is applied to the MCC input of each switch. Gas data received from the site Gas Data Acquisition function in response to the poll is fed back via the V24 switch and the virtual V24 circuit on the communication system to the relevant V24 interface of the polling server (Brown, 2003).

4.5 Instrumentation

Different types of instrumentation are used in the SCADA system. The details of these instrumentation are given here.

4.5.1 Differential Pressure Transmitter

Differential pressure transmitters are grouped and mounted on instrument supports, and are protected by sunshades. Transmitters are direct mounted 3 valve manifold and are connected to existing spare tapping points at the orifice fittings using 12mm OD 316 stainless steel tubing and stainless steel compression fittings. The transmitters conform to the HART protocol and have an integral local indicator.

Instrument stands are located so as to minimize the length of the impulse lines.

Transmitter 4 to 20 mA output signals are cabled to the local junction box for retransmission to the marshalling cabinet (Domjan and Parkes, 2002).

4.5.2 Pressure Transmitter

Pressure transmitters are installed on the instrument stands, and are grouped together with other instrumentation. The transmitters conform to the HART protocol and have an integral local indicator.

Process impulse piping is 12 mm OD 316 stainless steel tubing and compression fittings. Each transmitter is supplied complete with a 2 valve manifold and connect to the process via an existing spare screw in an isolated boss on the pipeline, or in specified instances by tapping into an existing pressure gauge installation.

Transmitter 4 to 20 mA output signals are cabled to the local junction box for retransmission to the marshalling cabinet via multipair cable (Domjan and Parkes, 2002).

4.5.3 Temperature Transmitter

Temperature transmitters are direct mounted on Resistance Temperature Detector (RTD), and are direct mounted with screwed thermowell into an existing spare boss on the pipeline. Temperature transmitters conform to HART protocol and have an integral local indicator.

Output signals from the transmitters are cabled to the local junction box for retransmission to the marshalling cabinet via multipair cable (Domjan and Parkes, 2002).

4.5.4 Turbine Meter

Where turbine meters (that are to be incorporated into the system) already have signal cables connected, the existing single output pulse meter is changed to a dual pulse output to accommodate the additional signal requirement.

GTSL have included for the supply of new turbine meters at two sites Dewanbagh (108) and Ashuganj (400).

Output signals from the turbine meters are cabled to the locally installed junction box for retransmission to the marshalling cabinet via multipair cable (Domjan and Parkes, 2002).

4.5.5 Main Line Valve (MLV) Solenoid Valves

Two 3 way solenoid valves are installed at each MLV actuator as required. Cabling to solenoid valves from the RTU cabinet is via multipair cables to the local junction box and then via local cabling to the MLV actuator. The solenoid valves are actuated by relays installed in the marshalling cabinet and activated via the RTU. Limit switches are cabled back to the RTU via the local junction box (Domjan and Parkes, 2002).

4.5.6 Level Instruments

Level transmitters to measure and transmit levels in the condensate tanks are provided at:

- Kailashtilla Gas Field
- Ashuganj standby control room

Transmitters are installed at access flanges. Output signals from the transmitters are cabled to the RTU via the junction box and multipair cable (Domjan and Parkes, 2002).

CHAPTER 5: EVALUATION OF THE SCADA SYSTEM

SCADA system was implemented to control and monitor of all the transmission pipeline network parameters such as gas flow at supply and off-take points, current line pressures through the network, movement of gas and condensate volumes and quality of gas being supplied to the system by the producing companies. Furthermore, the SCADA would provide pipeline integrity monitoring, leak detection, line pack, movement of pig along the pipeline, load balancing, load scheduling and efficiency of pipeline. But the SCADA system is not functioning fully. This chapter describes the benefits of pre and post SCADA and also the shortcomings of the SCADA system.

5.1 Benefits

The benefits of pre and post SCADA system are discussed below.

5.1.1 Response Time

Before SCADA system, it was difficult to get the information. Getting the flow data was time consuming. More time was required to get the valve status of pipeline.

After SCADA system, real time flow data, open/close status of valves, flow and pressure of condensate can be monitored instantaneously.

The length of time required to get the flow data at pre and post SCADA system is quantifiable.

5.1.2 Man Power

During pre SCADA system, a large number of manpower was engaged at different regulating and valve station. They would collect the pressure and flow data after a certain period and they would deliver the collected data to the head office. GTCL would pay a lot of money for this manpower.

After SCADA system, the flow and pressure data are monitored in the SCADA system. So manpower is reduced significantly due to SCADA system and GTCL is saving money for this system.

The number of manpower saved due to SCADA system is quantifiable.

5.1.3 Liquidated Damages

Before SCADA system, it was difficult to maintain the load in the system. So bulk consumers especially power and fertilizers were faced problems due to gas crisis. At that time many power stations and fertilizer factories were out of generation/production due to cut of gas. Many power and fertilizer factories claimed Liquidated Damages (LD) from Gas Company according to gas supply agreement.

After SCADA system, load dispatch is properly done. So the bulk consumer is facing fewer problems. Liquidated Damages are very less due to SCADA system.

The number of days that were out of production/generation of fertilizer factories & power stations due to gas crisis is quantifiable.

5.1.4 Condensate Loss

The condensate line is a separate line in which the production companies feed the condensate at a certain rate. A gang of miscreants is pilferrnging condensate from the condensate line. Before SCADA system, it was not possible to monitor the flow parameters of condensate properly. It was difficult to detect the purging point. So huge amount of condensate was lost. GTCL would require a lot of money to repair the purging.

After SCADA system, the real time data of flow rate and pressure are monitored instantaneously. When the flow rate decreases significantly, it is considered that condensate is being pilfered. Thus concerned people check the line and find out leakage. Loss of condensate by pilferage is checked.
The amount of condensate loss saved due to SCADA system is quantifiable.

5.1.5 Voice Communication

Voice communication was done by T & T and mobile phone systems within companies and among different companies during pre SCADA system. GTCL spent huge money for this communication.

After SCADA system, voice communication is done by the SCADA system within companies; inter companies and with petrobangla as well. It also provides fax facilities.

The amount of money thus saved is quantifiable.

5.1.6 Decision Making

It was very difficult to record the all data. Due to lack of data it was not possible to get the flow and pressure profile. So management faced problems for planning and forecasting for constructing a new pipeline.

After SCADA system, all real time flow and pressure data are monitored instantaneously in the system. All pressure and flow data are stored in the computer. One or two year back flow data can be delivered from the system within short time. The pressure and flow profile can be monitored in the system. So the management can do analysis easily with these data and reach a decision quickly.

Decision making is intangible benefit. How much decision making is improved due to SCADA system, is difficult to quantify.

5.1.7 Accuracy of Data

The operators manually would collect the field data during pre SCADA system. When they would take readings there would be wrong. At the time of recording the readings in the log book, there was a possibility of mistake. So every stage there was a possibility of mistake. After SCADA system, all field data are sent to control centre by microwave backbone. The real time data are viewed in the system. So the accuracy of the monitored data is high.

Accuracy of data is intangible benefit. How much accuracy of data is improved due to SCADA system is not quantifiable.

5.1.8 Billing Period

Before SCADA system, billing was done manually. Without use of SCADA system, marketing companies have to insert and withdraw chart recorder on daily basis and consumption data at flowing temperature and pressure are taken. From these pressure and temperature data, pressure and temperature factors are calculated. By multiplying the daily consumption with pressure and temperature factors, consumption will be found at standard condition. The daily consumptions are then added to calculate the monthly consumption for billing of bulk customers and the total process is very time consuming.

After SCADA system, the consumptions of bulk customers are monitored instantaneously. So marketing companies can prepare bill for bulk customers within short time by taking the consumption report from SCADA control room.

The amount of billing period saved due to SCADA system is quantifiable.

5.1.9 Gas Compositions

Gas compositions data were not always available during pre SCADA system. Jalalabad gas field and Sangu gas field would send their gas composition report at the end of every month. In Ashuganj there is also a gas Chromatograph; GTCL would prepare a gas composition report once per month.

All Chromatographs are interfaced with the SCADA system, so the real time data of gas compositions are monitored instantaneously. Now all company can monitor the gas compositions from their Operating Company Terminal (OCT). So the transferency of the quality of gas is increased. Now the gas compositions report can be delivered within a short time.

The level of quality increased due to SCADA system is difficult to quantify.

5.1.10 Daily Gas Report

Daily gas report is automatically generated from the SCADA system that contains daily gas intake, off-take and dispatch scenario of different pipelines.

Before SCADA system, there was no daily gas report. So it was difficult to know the intake, offtake and dispatch status of different pipelines.

Under SCADA system, a daily gas report is automatically generated everyday in the morning. So the intake, off take and dispatch status for 24 hours are found from this report.

The benefit derived from crystal report due to SCADA system is not quantifiable.

5.1.11 Operational Capacity

During pre SCADA system, operational capacity was less due to lack of improved information. More time was required to get the response of any problems. It was also difficult to maintain the load of different pipelines.

After SCADA system, operational capacity increases due to available of improved information. The real time flow and pressure data of gas and condensate are monitored instantaneously.

How much operational capacity is increased due to SCADA system is not quantifiable.

5.1.12 Cathodic Protection

Before SCADA, the reading of Pipe to Soil Potential (PSP) of cathodic protection system was collected manually. So many operators were engaged to collect these data. GTCL also spent a lot of money for this purpose.
Cathodic protection system is connected with the SCADA. Now the real time reading of pipe to soil potential (PSP) of cataodic protection system is monitored instantaneously. By monitoring the real time data of CP one can understand the status of the pipeline and take remedial measures quickly in case of abnormal protection.

The number of manpower saved from Cathodic protection due to SCADA system is quantifiable.

Table 5.1 is a summary of the points discussed in this section.

Table 5.1: Comparative Statement of Benefits of Pre and Post SCADA System

Sl No	Particulars	Pre SCADA	Post SCADA	Remarks
1	Response time	It took more time to get response of readings of flow parameters.	It takes less time to monitor the readings.	Quantifiable
2	Operational Capacity	Less operational capacity due to lack of improved information of flow parameters.	High operational capacity for improved information of flow parameters.	Not quantifiable
3	Manpower	A large number of manpower is required to collect the information.	Less manpower is required to collect the information.	Quantifiable
4	Liquidated Damages	Liquidated Damages were claimed due to gas crisis.	Liquidated Damages are not claimed.	Quantifiable
5	Condensate Loss	Condensate loss was high due to lack of information.	Condensate loss is lees due to improved information.	Quantifiable
6	Voice Communication	Voice communication was done by T&T, Mobile within companies and inter companies which was very expensive.	Voice communication is done by SCADA system within companies, inter companies and Petrobangla as well.	Quantifiable
7	Decision Making	To reach a decision is difficult in this system.	Decision making is easy in this system. Different types of data are required for planning and forecasting.	Not Quantifiable
8	Accuracy of data	Instantaneous flow parameters are not found. Different types of data are collected manually that results less accuracy of data.	Real time data are monitored in the system that results high accuracy of data.	Not Quantifiable

Table 5.1: Comparative Statement of Benefits of Pre and Post SCADA System (Contd.)

9	Billing Period	The data was collected manually so more time was required for billing especially for major power and fertilizer customers.	The data is generated automatically in the system so more rapid billing can be done especially for power and fertilizer customers.	Quantifiable
10	Gas Compositions	Gas compositions are not always available.	Gas compositions are known instantaneously.	Not quantifiable
11	Daily Gas Reports	No daily gas reports.	Daily gas reports containing data of hourly basis of gas intake, off take and despatch of high pressure lines are automatically generated everyday in the morning from the system.	Not quantifiable
12	Cathodic Protection	Pipe to Soil Potential (PSP) reading is collected manually. So more time is needed to collect the data.	Cathodic protection system is connected with SCADA system. So real time data is monitored that results saving of manpower.	Quantifiable

The quantifiable items are explained in more details in chapter-6. These are used in the financial analysis.

5.2 Shortcomings of the System

SCADA system was not implemented fully. Some measuring parameters are not monitored/controlled due to lack of infrastructure of grid line. Only GTCL high pressure lines are covered by the SCADA system. But some high pressure pipelines owned by the distribution companies are not covered by the SCADA system that creates problem for proper load management. Before going to shortcoming of the SCADA system a brief discussion of the infrastructure of part of grid line is given below.

From the figure 5.1, it is shown that gas from Kailashtill Gas Field (KTL GF), Beanibazar Gas Field (BBGF) and Jalalabad Gas Field (JBGF) is added to the North-South (N-S) pipeline. At intake points of N-S pipeline, there are no meters, how much gas is added to the line is not known. Gas is supplying to 90 MW power station from N-S pipeline. How much gas is withdrawing is not known as there is no meter at off take points. After off take of 90 MW how much gas is remaining, is not known. Fenchuganj Gas Field (FGF) is adding gas to N-S. There is no meter at intake point of N-S. So how much is adding from FGF is not known. Same incident is occurring for the case of Rashidpur Gas Field (RGF) and Moulvibazar Gas Field (MGF). At Muchai manifold the event is very difficult. There is a Rashidpur-Ashuganj loop line. At Muchai, gas from Bibyana Gas Field (BGF) is added. At Muchai, there is a valve connecting between N-S and loop line. After Muchai manifold how much gas is flowing through N-S and loop line is not known. Same event is occurring for the case of Habiganj Gas Field (HGF) and Titas Gas Field (TGF). There is also a connecting line between the N-S & loop line. The valve of connecting line is always opened and there is no meter. So how much gas is flowing through N-S & Loop line is not known. Gas from N-S pipeline and part of gas from loop line enters into Ashuganj Manifold Station (AGMS) without metering. A part of loop line goes to the B-B2 by metering. The remaining of the loop line gas flows through the A-M line without metering. After AGMS gas delivers through A-B, B-B1 & VS3 lines by metering. Total intakes of AGMS are calculated by summing up all production of the gas field connecting with the N-S & loop line. Total off takes are calculated by summing up all consumption of the customers connecting with the N-S & loop line. Net Intake of AGMS is calculated as deducting total off take from total intake.

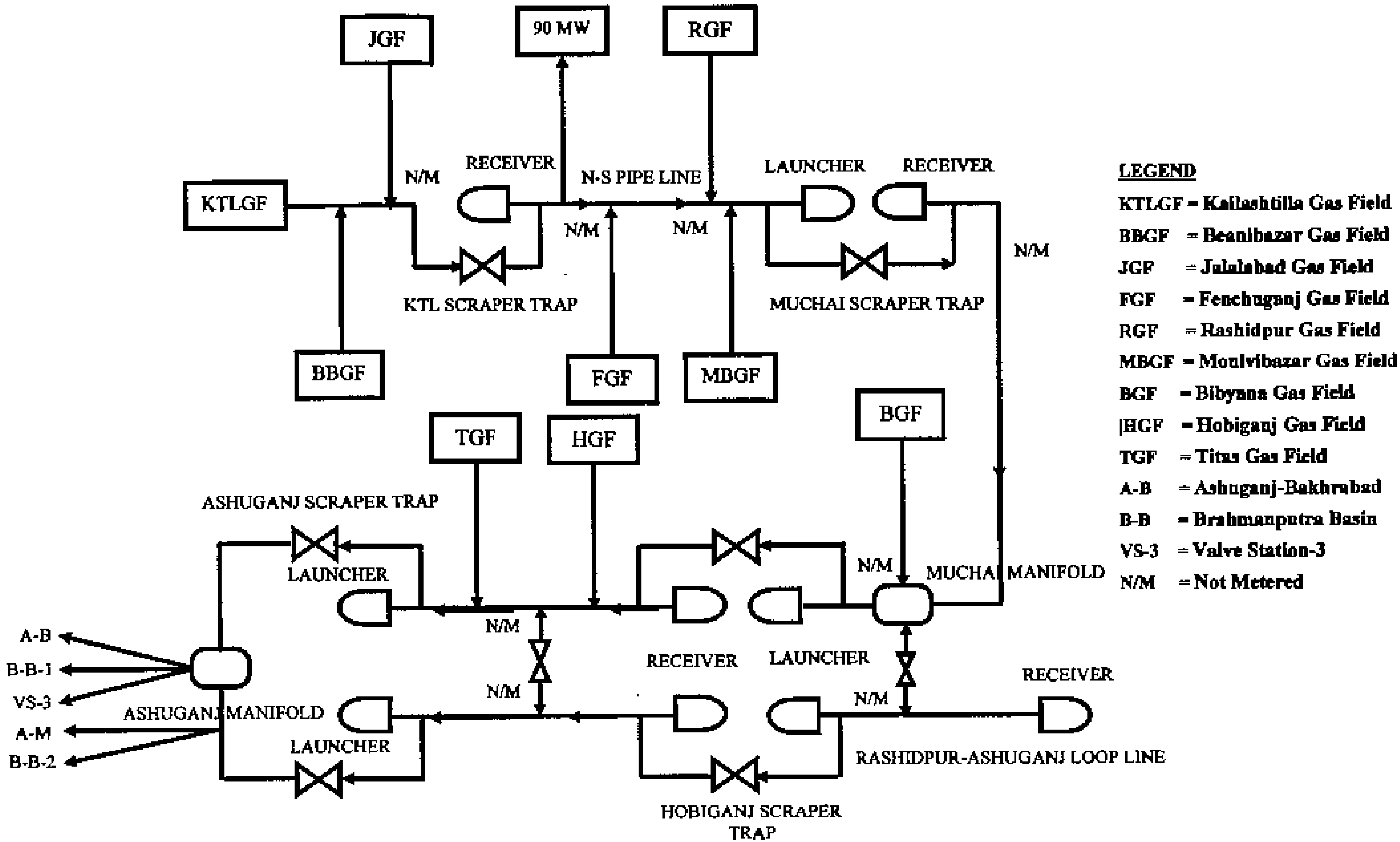


Figure 5.1: Flow Diagram of a Part of Grid Line

The shortcomings of the SCADA system installed in GTCL are discussed below.

5.2.1 Remote Control Valve

SCADA means supervisory control and data acquisition. In SCADA system of GTCL there is no supervisory control. Only monitoring is done. Actually, the actuators are not yet tested whether it is functioning or not by giving command from the control room of SCADA. The high authority advised not to control the valves remotely. They think that if the actuators are controlled by SCADA system, unwanted situation may occur. As for example, if a command is given from the control room to actuator to open 50%, but it does not function accordingly, the demand of the customers will not be served. To avoid this type of problem the actuators are not yet controlled by SCADA system.

The actuator can be tested in a dummy or parallel line by SCADA system. If it works successfully, then actuators can be run in live pipe line by SCADA system.

If the actuators are controlled by SCADA system, the system will be implemented fully and the proper load management will be ensured.

5.2.2 Leak Detection

Leak detection software calculates and determines the presence of leak and determines the corresponding size of the leak under flowing condition. Leak location at various points i.e. leak location minimum, leak location average and leak location maximum are provided. Updating of leak size and location takes place once every 30 seconds during leak situations. The results are only presented to the operator after a leak warning.

The Pipeline Application Software (PAS) for leak detection shown in the figure 5.2 is not working in the SCADA system due to problem of national gas grid. To find ont the leak of a pipeline the pressure of upstream and downstream and flow rate of that line are needed. But there are no meters at the most of the intake and off take points. Meter should be installed at the intake and off take points to get the data. If the data are available, the software will run. If the leak is detected easily by this software, the loss of gas will be less and saves the pipeline from accident such as fire.

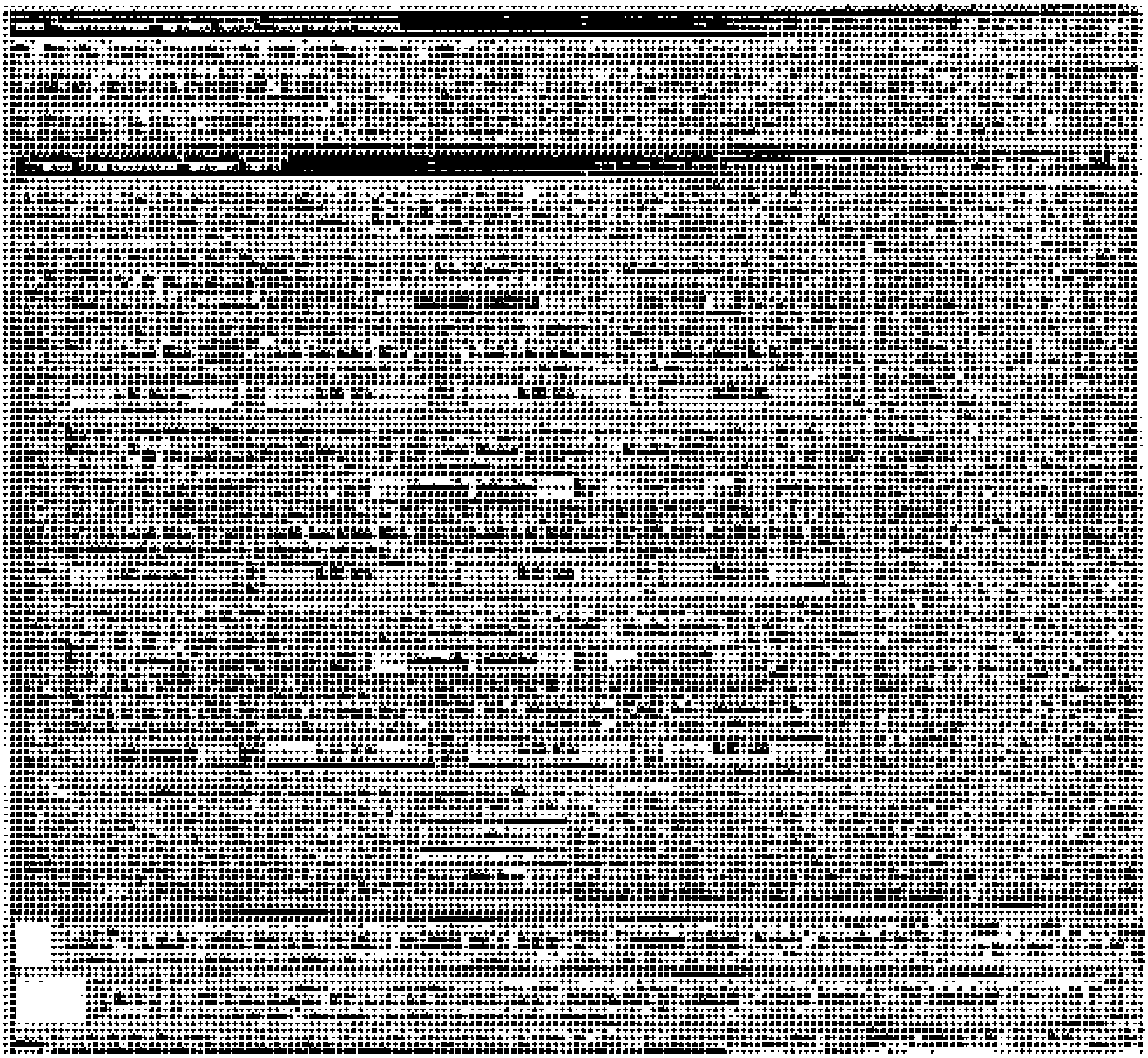


Figure 5.2: Screen Shot of Leak Detection by SCADA System

5.2.3 Line Pack

Line Pack is the amount of gas that always remains in the pipeline from the purchase figure. With the build up line pressure the amount of gas packed increases in the pipeline. As pressure is always changing in the pipeline and pressure is higher in the lean hour than the peak hour. Thus line pack is higher in the lean hour. Line pack is always changing. There is software of line pack in the SCADA system which is not working shown in the figure 5.3 as most of the intake and off-take points there are no meters. So it is not possible to find out the upstream and downstream pressure of every pipeline.

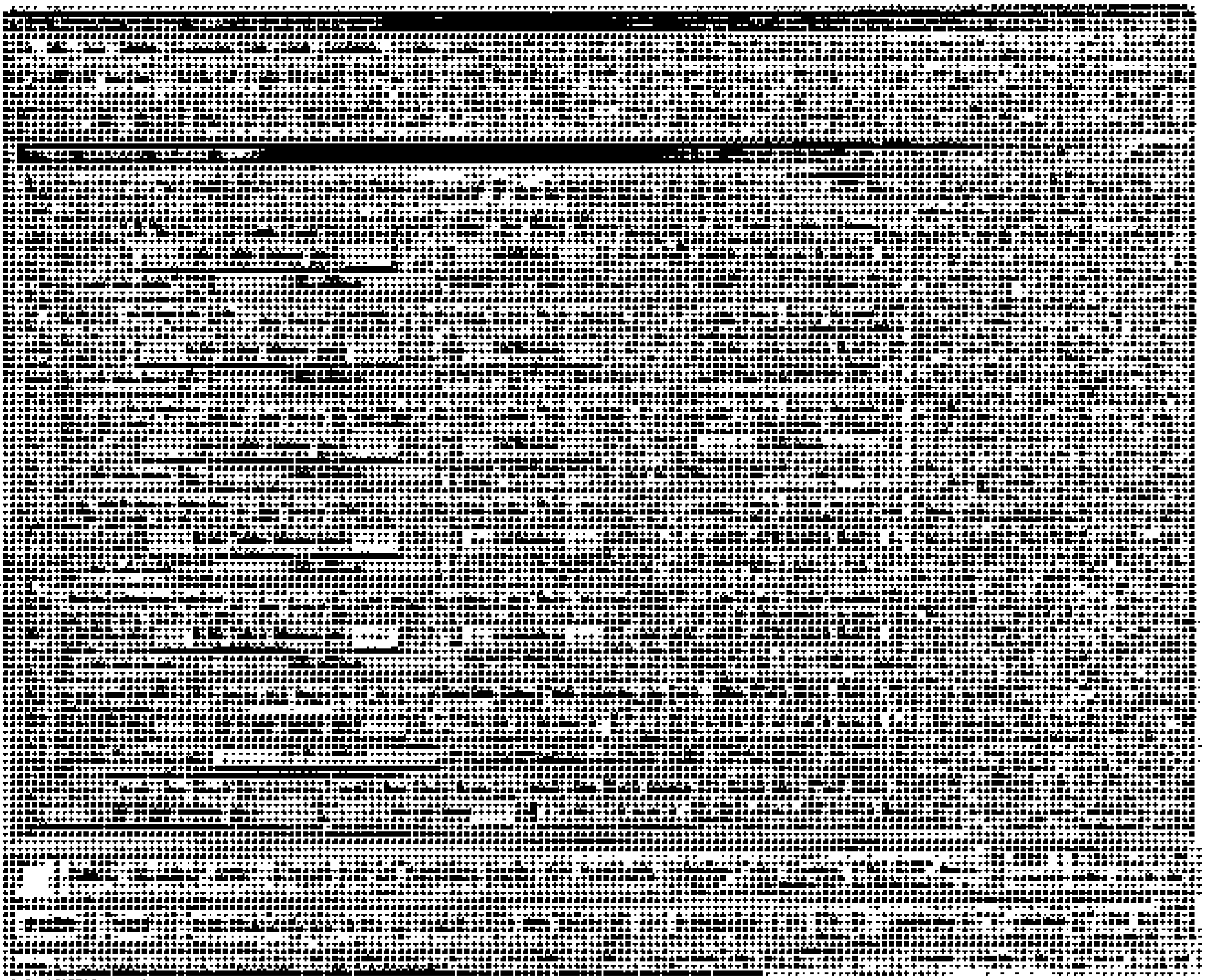


Figure 5.3: Screen Shot of Line Pack by SCADA System

Meter should be installed at the intake and off take points of the pipelines. If the software for line pack works, the line pack, line pack rate of a section in a pipe line will be known and excess line peck of pipe line will be diverted into the other pipeline where there is demand of gas. Moreover, the pipelines will be saved from over pressurized by diverting gas.

5.2.4 Load Scheduling

The load scheduling tool is a predictive analysis running with flow control at all inlets and outlets in order to predict any violations of pre-defined limits on inventory or pressure.

The load-scheduling models initially copy the state of the real time model. All boundary conditions are taken from the nomination time series. The load scheduling model runs ahead of real time completing a 24 hours calculation of the entire network in a matter of minutes. If there is any alarms, load of different customers will have to be revised and will run for 24 hours. If everything is ok, it will show normal.

In the SCADA system the software for the load scheduling is ok. But the problem is in the national gas grid. Meters are not available at the most of the intake and off-take points that results non-functioning of the software for load scheduling.

Meters at intake and off take points should be installed to run the software of the load scheduling. If the software works, the customers will know how much load and pressure they will get and they also take action accordingly.

5.2.5 Load Balancing

Load Balancing is configured to run cyclically. It is a predictive analysis with flow control at all boundaries. The flow readings are copied from real time and are maintained throughout the run. It is initially suggested that this is once per hour, running for maximum 4 hours. The boundaries for load balancing are maximum/minimum pressures and maximum/minimum inventories for all pipelines.

If the current operation of the network leads to a violation of pre-defined limits on inventory or pressure at any of the joints within the 4 hours period, this is highlighted to the operator and information about location and type of violation are provided. Information regarding the load balancing is to be transferred to the SCADA as described above for load scheduling.

In the SCADA system the software for the load balancing is ok which is shown in the figure 5.4. But the problem is in the national gas grid. Meters are not available at the most of the intake and off-take points that results non-functioning of the software for load balancing.

This enables the operator to take preventive action before any critical situation arises or depending upon the severity creates the need to reschedule the nominations for remainder of the day.

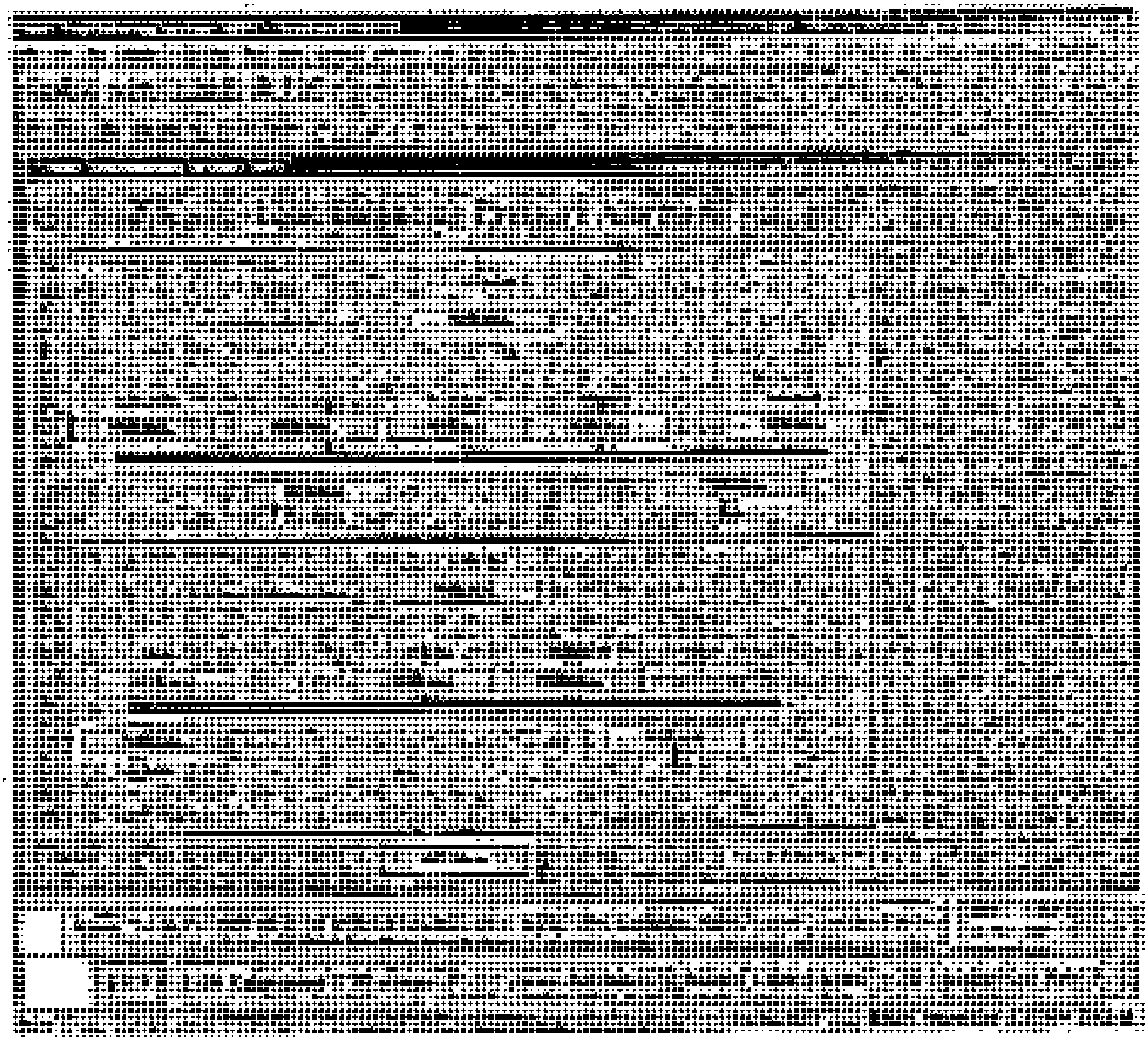


Figure 5.4: Screen Shot of Load Balancing by SCADA System

5.2.6 Pigging

Pigging is done before and after commissioning of the pipeline to clean the inside of the pipeline. In pipeline, different foreign matters, dust etc may accumulate.

As a result, the flow capacity of pipeline decreases. To avoid this problem and supply clean fuel, pigging is undertaken in pipelines. Different types of pigs such as foam, brush and cup are used in the pipeline. When the pig moves along the pipeline, status of pig i.e. its departure from the pig launcher, possible location of the pig based on different input parameters and arrival at receiver, are monitored in the SCADA system.

In GTCL on line pigging has not yet been done. So the pigging is not tested till now.

5.2.7 Pipeline Efficiency

The purpose of this function is to detect whether the pipeline friction losses in any particular section have exceeded defined limits. This then gives an indication as to when "pigging" of the pipeline may be required in order to increase through put and reduce transportation cost.

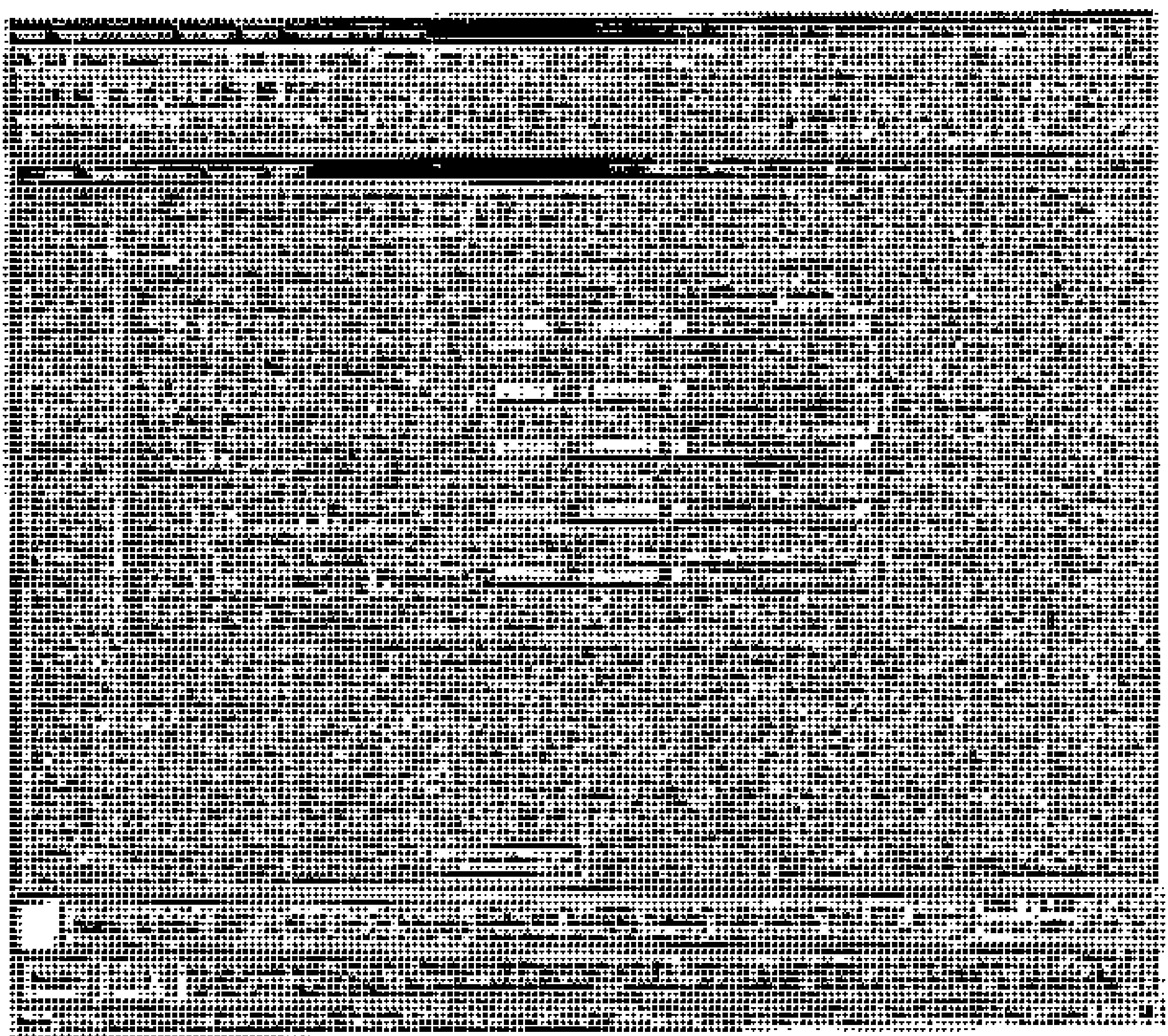


Figure 5.5: Screen Shot of Pipeline Efficiency by SCADA System

The function calculates the ratio between the actual friction factor and the 'theoretical' friction factor (Colebrook-White) to derive the 'pipeline efficiency factor'. The calculation of the actual friction factor is based upon the flow and pressure measurements at the end points of the pipeline section. The figure 5.5 shows the pipeline efficiency.

The software for pipeline efficiency is not working as the flow data at the end points of the pipeline section are not available.

To run the software of pipeline efficiency, meter at intake and off take points of the pipeline should be installed.
If the software runs, the status of the pipeline will be known which will be helpful in determining the necessity of pigging.

5.2.8 Trained Manpower

SCADA is a sophisticated technology. There is a lack of trained personnel in GTCL who are expert or well conversant with this technology. Due to this reason some technical parts of the SCADA system are not run.

Extensive training of GTCL personnel in different stages is necessary to derive full advantages of the SCADA system by keeping all the options and facilities in operation.

CHAPTER 6: FINANCIAL ANALYSIS

GTCL introduced SCADA system in 2004 with an initial investment of around US$ 27 million. No financial analysis was done before implementing the SCADA system and no such evaluation has been carried in this regard till now. This study aims at evaluating the financial aspects of the SCADA system. To find out the financial parameters, a cash flow analysis is carried out. The calculation details of this analysis are given below.

6.1 Calculation of Cash Outflow

A. Investment Cost

Many items are included in the investment. The items and their cost are given in the following table 6.1

Table 6.1: Investment Cost

Sl No	Items	Investment Cost (in Lakh Taka)		
		Local	Foreign	Total
1	Land Acquistion	0.00	0.00	0.00
2	Land Requisition	0.00	0.00	0.00
3	Soil & Sub-surface Investigation	0.00	0.00	0.00
4	Civil construction	0.00	0.00	0.00
5	Mechinery and Equipment	0.00	6219.45	6219.45
6	Transport Vehicles	3.75	0.00	3.75
7	Manpower	130.00	0.00	130.00
8	Cost of Engineering Design and construction supervision Consultancy	0.00	2967.75	2967.75
9	Installation of SCADA Telecom system	1228.00	6887.79	8115.79
10	Office Rent, Electricity, Telephone, Water Supply, Office Stationeries, Printing and other miscellaneous	85.00	0.00	85.00
11	Interest during construction	175.00	0.00	175.00
12	Allowance for unforeseen	0.00	0.00	0.00
13	Cost Escalation	100.00	0.00	100.00
14	CD-VAT/Tax	1175.00	0.00	1175.00
15	**Total:**	**2,896.75**	**16,074.99**	**18,971.74**

US$ 27,102,485.71

Source: Project Proforma, SCADA Project, 2003

B. Operating cost

There are so many items under operating/running cost which are given in the table 6.2.

Table 6.2: Operating Cost

Sl No	Particulars	Amount Per Year (US$)
1	Services and maintenance	315,714.29
2	Utility expenses	27,565.71
3	Salaries and wages	61,200.00
4	Administrative overhead	5,142.86
	Total	**409,622.86**

Source: Project Proforma, SCADA Project, 2003, & Salary Statement, GTCL, 2006

Break up of operational cost is given below:

Service and maintenance cost are $315714.29 (As per PP, 2003). Utility expenses include bill of mobile phone, land phone (T&T), electricity, Octane, Gas which are shown in the following table 6.3

Table 6.3: Utility Expenses

Sl No	Particulars	Amount Per Year(US$)
1	Mobile Phone	2057.14
2	Electricity	10285.71
3	Land Phone (T&T)	5485.71
4	Octane	9051.43
5	Gas	685.71
Total		**27565.71**

Source: Bill of Utility, GTCL, 2006

Different types of personnel are engaged to run the SCADA system. Salary and wages of the employees engaged in the SCADA system are given in the table 6.4.

Table 6.4: Salary and Wages of the Personnel

Sl No	Type of Personnel	No	Monthly Salary (Tk)	Total Monthly Salary (Tk)
1	Manager	2	25,000.00	50,000.00
2	Deputy Manager	5	20,000.00	100,000.00
3	Assistant Engineer	7	15,000.00	105,000.00
4	Assistant Technical Officer/Telecom Operator	6	12,000.00	72,000.00
5	Cleaner/Attendants	10	3000.00	30,000.00
Total Monthly Salary (Tk)			357,000.00	
Total yearly salary(US$)			61,200.00	

Administrative overhead is assumed to be Tk 30,000.00 per month.

6.2 Calculation of Cash Inflow

After implementation of the SCADA system, manpower is reduced significantly. The rate of shutdown of bulk customers is decreased that results savings from liquidated damages. The pilferage of the condensate is decreased due to SCADA system. These are the savings for the SCADA system, which are discussed below.

6.2.1 Savings from Site Offices

Due to implementation of SCADA system different types of data i.e. pressure at inlet and outlet, flow rate of gas, flow rate of condensate, condensate pressure and temperature of gas and Pipe to Soil Potential (PSP) are monitored in the SCADA system. Valve status i.e. open or close status of valves can be monitored from SCADA system. The flow parameters are updated in every hour. Before implementing of SCADA system, the flow parameters of gas and condensate and Pipe to Soil Potential (PSP) were collected by mobile/T&T, from 67 metering/valve stations. To collect flow & PSP data, four operators and four cleaners/attendants were engaged at every metering/valve station. The amount of cost to be required to collect flow parameters from 67 metering/valve stations which are monitored in the SCADA system is shown below. After implementation of SCADA the amount that is saving from the site offices is given in the table 6.5.

Table 6.5: Savings from site offices

Sl No	Particulars	Per Year (US$)
1	Manpower (skilled), 4 nos.	4,63,104.00
2	Manpower (unskilled), 4 nos.	2,31,552.00
3	Mobile call for data collection	92,268.57
4	House Rent	2,29,714.29
5	Utility Expenses	57,428.57
6	Administrative Overhead	57,428.57
	Total	**1,131,496.00**

Average salary for each operator (skilled) = Tk. 10,000.00/month

Average salary for each cleaner (unskilled) = Tk. 5,000.00/month

Flow parameters will be collected at every hour from 67 metering/valve station. It is assumed that 5 minutes will be required at every time to collect flow data. The rate of mobile call is 2 Tk/minute.

The amount of cost required at every station = 5x2 Tk/hr

= 5x2x24x30x12 Tk/year

= 86400 Tk/year

Cost required for 67 stations = 5788800Tk/Year

The cost of each mobile set = 10,000 Tk

Total cost including set = 6458800 Tk/year

= 92268.57 $/year

House rent for each station is assumed Tk 20,000.00/month.

Utility expenses include electricity, land phone (T&T) and gas bill which are assumed Tk.5,000.00/month for each station. Administrative overhead is also assumed Tk.5000.00/month for each station.

6.2.2 Savings from Liquidated Damages

There are gas supply agreements with the government fertilizer factories, multinational fertilizer company (Karnafully Fertilizer Company limited) and the multinational power company, CDC Meghnaghat/ CDC Horipur. There is no gas supply agreement with Power Development Board (PDB). In gas supply agreement there is a Liquidated Damages (LD) clause. If the seller fails to supply gas to the buyer for five (5) days or less per year, the seller shall not be liable to pay any compensation. If failure days are more than five (5) days per year, the seller shall have to pay. The particulars of Liquidated Damages (LD) clause with the different companies are given in the table 6.6

Table 6.6: Particulars of Liquidated Damages with Different Companies

Particulars	Fertilizer Factory	KAFCO	CDC Meghnaghat/ CDC Horipur	PDB
No Compensation	Up to 5 days per year	Up to 5 days per year	Up to 4 days per year	No Sales agreement between gas company and PDB
Penalties	60,000/- (Sixty Thousand per day)	10 (Ten) hours average supply of gas at the floor price per commenced day of failure to supply starting on the sixth(6) day and for any subsequent day of failure to supply	US$ 3.00/Kw/month	

Source: Gas Supply Agreement between TGTDCL & CDC Meghnaghat, BGSL & KAFCO

Savings in Liquidated Damages from Fertilizer: Gas from Sangu Gas Field is fed to Chittagong region. Only Sangu gas is not sufficient to fulfill the demand of Chittagong region. So the significant amount of gas is supplied to the Chittagong region through national gas grid. During pre SCADA system, when the production of Sangu Gas Field remained suspended, the production of CUFL was also suspended for most of the time due to gas crisis. It happened because efficient load management was not possible at that time. After implementation of the SCADA system, the real time flow data of the bulk customers and the gas fields are monitored. If the production of Sangu Gas Field is suspended the significant amount of gas is diverted quickly to Chittagong region through the national gas grid by proper load management through SCADA system. Thus most of the time, CUFL is in running condition although the production of Sangu Gas Field is suspended. At pre and post SCADA system the shut down status of Chittagong Urea Fertilizer Factory Limited (CUFL) is given in the table 6.7.

Table 6.7: Shutdown Status of CUFL at Pre & Post SCADA

Sl No.	Particulars	Shutdown Period (Day)	
		Pre SCADA (2002&2003)	Post SCADA (2005&2006)
1	Maintenance shutdown	50	40
2	Mechanical fault	15	11
3	Gas crisis due to operational problem of gas field	12	4
4	Shut down due to lack of load management	34	8

Source: BGSL, 2005-2006 & GTCL, 2002-2003

At post SCADA the load management is done efficiently. So the rate of shutdown at post SCADA is less than that of pre SCADA. During pre SCADA (2002 & 2003) and post SCADA (2005 & 2006), the rate of shutdown was 34 and 8 days respectively. So the savings of shut down period are = 34-8 = 26 days for two years. The annual savings of shut down period is 13 days.

According to gas supply agreement up to 5 days of failure per year due to gas crisis, there is no compensation. So the seller has to pay the compensation for = 13-5= 8 days per year.

So the amount of Liquidated Damages (LD) : Tk 60,000x 8 /year

= 4, 80,000 Tk/year

= US$6,857.14 /year

There are also four other government fertilizer factories such as Gorashal Urea Fertilizer Factory Limited (GUFFL), Zia Fertilizer Factory Limited (ZFCL), Jamuna Fertilizer Factory Limited (JFFL) and Polash Urea Fertilizer Factory Limited (PUFFL). These fertilizer factories were out of production due to gas crisis before SCADA system. So savings of 8 days shut down are assumed for each of the fertilizer factories.

The amount of LD for other 4 fertilizer factories = 4,80,000x4 Tk/year

= 1,920,000 Tk/year

= 27,428.57 US$/year

Total Liquidated Damages of fertilizer factories are given in the table 6.8

Table 6.8: Liquidated Damages of Fertilizer Factories

Sl No.	Name of Factory	Per Year (US$)
1	CUFL	6,857.14
2	ZFCL, JFCL, PUFFL, GUFFL	27,428.57
	Total	34,285.71

Savings from Liquidated Damages in Power Station: Raujan Power Station is the largest power station in Chittagong region. It consumes around one third of total gas demand in Chittagong. When the production of Sangu Gas Field is suspended, there is a shortage of gas in Raujan Power Station. During pre SCADA system, efficient load management was not possible. So the Raujan Power Station would go to shut down fully or partially when there was an operational problem of Sangu Gas Field. After implementation of the SCADA all real time pressure and flow data are monitored. If the production of Sangu Gas Field is suspended the gas from national grid is supplied to Chittagong region to run the Raujan Power station partially during post SCADA system. So the rate of shutdown at post SCADA is less than that of pre SCADA.

There is a gas supply agreement with the Independent Power Producer (IPP) i.e. CDC Meghnaghat and CDC Horipur. Gas Supply Company gives priority to supply gas to IPP to avoid Liquidated Damages. If there is crisis of gas they stop to supply gas to government sector and try to supply gas to private sector. Till now CDC Meghnaghat/CDC Horipur did not claim any Liquidated Damages from the gas supplier. There is no gas supply agreement with PDB. Most of the power stations of PDB were out of generation due to gas crisis at pre SCADA. PDB is privatizing now so there will be gas supply agreement like IPP. Applying IPP's LD clause for PDB, the calculation of LD is given below. The shutdown status at pre and post SCADA of Raujan Power Station is given in table 6.9.

During pre SCADA (2002 & 2003) and post SCADA (2005 & 2006), the rate of shutdown was 42 and 10 days respectively. So the savings of shut down period are = 42-10 = 32 days for two years. The annual savings of shut down period is 16 days.

Table 6.9: Shutdown Status of Raujan Power Station at Pre & Post SCADA

Sl No.	Particulars	Shutdown Period (Day)	
		Pre SCADA (2002&2003)	Post SCDA (2005&2006)
1	Maintenance shutdown	45	50
2	Mechanical fault	15	12
3	Gas crisis due to operational problem of gas field	10	6
4	Shut down due to lack of load management	42	10

Source: BGSL, 2005-2006 & GTCL, 2002-2003

According to gas supply agreement there is no compensation up to 4 days failure per year. So the seller has to pay the compensation for = 16-4= 12 days.

The capacity of Raujan Power Station: 360 MW

So the amount of Liquidated Damages: US$ 3.00/kw/month (As per Contract)

= US$ 3.00x360x1000x12/30/ year

= US$ 432000/year

So the other power stations of PDB were out of generation due to gas crisis. Assuming 12 days savings of shutdown for other power station, the calculation of Liquidated Damages is given here.

Liquidated Damages for rest of the power station of PDB (2200 MW)

= US$ 3.00x2200x1000x12/30/year

= US$ 2,640,000/year

Total Liquidated Damages for PDB are given in the table 6.10

Table 6.10: Liquidated Damages of PDB

Sl.No	Name of Power Station	Per Year (US$)
1	Raujan Power Station (360MW)	432,000.00
2	PDB (Others-2200 MW)	2,640,000.00
	Total	3,072,000.00

6.2.3 Savings from Condensate

Before implementation of SCADA system, the flow rate and pressure of condensate was not monitored properly. So there was a lot of condensate pilferage through purging of condensate line at that time. At the purging point, huge amount of condensate as well as wheeling charge were lost. Moreover GTCL required a lot of money to repair the purging. There were total 14 purging points in 2003. So the amount required due to purging is given in the table 6.11

Table 6.11: Total Cost due to Purging of Condensate Line in 2003

Sl.No of Purging Points	Loss of Condensate (Liter)	Value of Condensate (Tk)	Wheeling Charge (Tk)	Cost of Repair Clamp (Tk)	Repair Cost (Tk)	Total Cost (Tk)
1	25288	379320	25288	14000	20000	438608
2	120255	1803825	120255	14000	40000	1978080
3	9926	148890	9926	14000	10000	182816
4	180500	2707500	180500	14000	30000	2932000
5	30000	450000	30000	14000	15000	509000
6	16500	247500	16500	14000	17000	295000
7	124000	1860000	124000	14000	32000	2030000
8	65000	975000	65000	14000	14000	1068000
9	16700	250500	16700	14000	13000	294200
10	80200	1203000	80200	14000	24000	1321200
11	163000	2445000	163000	14000	28000	2650000
12	23000	345000	23000	14000	18000	400000
13	43000	645000	43000	14000	23000	725000
14	19800	297000	19800	14000	18000	348800
						15172704
					Total Cost(US$)	216,752.91

Source: Condensate Report, GTCL, 2003

After implementation of the SCADA system, the real time data of flow rate and pressure of the condensate can be monitored. The gas fields supply the condensate at a certain rate. If the flow rate varies significantly, it is considered that condensate is pilferaging from the line. So the concerned people check the line and find out the purging of the line. After SCADA system the frequency of pilferaging the condensate is less. So the amount of condensate loss is also less. There were 6 purging points in 2005. The loss of condensate was in tolerable limit. So it was not taken into account for the calculation. Hence, cost of repair clamp and repair cost were taken into account. So the amount required due to purging is given in the table 6.12.

Table 6.12: Total Cost due to Purging of Condensate Line in 2005

Sl No of Purging Points	Loss of Condensate (Liter)	Value of Condensate (Tk)	Wheeling Charge (Tk)	Cost of Repair Clamp (Tk)	Repair Cost (Tk)	Total Cost (Tk)
1	-	-	-	14,000	22000	36,000
2	-	-	-	14,000	30000	44,000
3	-	-	-	14,000	24000	38,000
4	-	-	-	14,000	18000	32,000
5	-	-	-	14,000	28000	42,000
6	-	-	-	14,000	30000	44,000
						236,000
				Total Cost (US$)		3,371.43

Source: Condensate Report, GTCL, 2005

So the saving from condensate after implementation of SCADA

= US$(216752.91 - 3,371.43)

= US$ 213,381.49

Total Cash Inflow = Savings from Site Offices + Savings from Liquidity Damages (Fertilizer) + Savings from Liquidity Damages (Power) + Savings from Condensate

= (1,131,496.00 + 34,285.71+ 3,072,000.00+ 213,381.49) $/year

= **4,451,163.20 $/year**

6.3 Gas Sector Perspective

6.3.1 Net Present Value (NPV)

Net present value (NPV) is the difference between an investment's market value and its cost. Net present value (NPV) of an investment project can be derived as the difference between the present value of benefits (PVB) and present value of costs (PVC) i.e. NPV= PVB-PVC. In other words, NPV is the difference between the present value of all cash inflows and present value of all cash outflows.

Total life of the SCADA system is assumed 20 years

Net Cash Flow = Cash Inflow – Cash outflow - Tax

For year 0 : Net Cash Flow = 0-$27,102,485.71-0

=- $27,102,485.71

For Year 1: Net Cash Flow = $4,451,163.20-$409,622.86-$2,448,139.76

= $ 1,593,400.58

Similarly

For Year 20: Net Cash Flow = $11,247,867.72-$1,035,096.56-$6,186,327.24

= $ 4,026,443.91

Now, depending on the discount rate (i), present worth factor will be different

For example, present worth factor at a discount rate of 15% for different future value are as follows:

For year 0 : present worth factor = $1/(1+0.15)^0 = 1$

Similarly,

For year 20 : present worth factor = $1/(1+0.15)^{20} = 0.061100279$

Net cash present value is calculated by using following formula

$$NPV = (b_0 - C_0)/(1+r_0) + (b_1 - C_1)/(1+r_1) + \ldots\ldots\ldots + (b_n - C_n)/(1+r_n) \qquad (6.1)$$

Where,

b_i = benefits derived from the project in year i.

c_i = Cost (investment, operating and other associated expenses) incurred by the project in year i.

r = discount rate

I = time period which runs from year zero to year n.

$\frac{1}{(1+i)^n}$ = present worth factor = Discount factor

NPV = (0-27,102,485.71)/(1+0.15)^0+(4,451,163.20-409,622.86-2,448,139.76)/(1+0.15)^1+........... + (11,247,867.72-1,035,096.56-6,186,327.24)/(1+0.15) ^20

= -27,102,485.71 +1,593,400.58.............+6,186,327.24

= - US$ 13,751,656.77

Net Present Value (NPV) is calculated at different discount rate. At discount rate 6%, 8% & 10%, NPV is found $413,826.85, -$4,224,454.29 & -$7,803,083.92 respectively which is shown in the table 6.13.

Table 6.13: NPV at Different Discount Rate

Year	Total out flow($)	Total Cash in flow($)	Tax($)	Net cash flow($)	Present Value at Various Discount Rate							
					6%		8%		10%		15%	
					Present worth factor	Present value($)	Present worth factor	Present value($)	Present worth factor	Present value($)	Present worth factor	Present value($)
0	27,102,485.71	0.00	0.00	-27,102,485.71	1.00	-27,102,485.71	1.00	-27,102,485.71	1.00	-27,102,485.71	1.00	-27,102,485.71
1	409,622.66	4,451,163.20	2,448,139.76	1,593,400.58	0.94	1,503,208.10	0.93	1,475,370.91	0.91	1,448,545.98	0.87	1,385,565.72
2	430,104.00	4,673,721.36	2,570,546.76	1,673,070.61	0.89	1,489,026.89	0.86	1,434,388.36	0.83	1,382,702.99	0.76	1,265,081.76
3	451,609.20	4,907,407.43	2,699,074.09	1,756,724.14	0.84	1,474,979.47	0.79	1,394,544.26	0.75	1,319,852.85	0.66	1,155,074.64
4	474,169.66	5,152,777.80	2,834,027.79	1,844,580.35	0.79	1,461,064.56	0.74	1,355,806.92	0.68	1,259,859.54	0.57	1,054,633.37
5	497,899.14	5,410,416.69	2,975,729.18	1,936,788.37	0.75	1,447,280.94	0.68	1,318,145.62	0.62	1,202,593.20	0.50	962,926.12
6	522,794.10	5,680,937.52	3,124,515.64	2,033,627.79	0.70	1,433,627.34	0.63	1,281,530.48	0.56	1,147,929.67	0.43	879,193.41
7	548,933.81	5,964,984.40	3,280,741.42	2,135,309.17	0.67	1,420,102.56	0.58	1,245,932.39	0.51	1,095,751.24	0.38	802,741.81
8	576,380.50	6,263,233.62	3,444,776.49	2,242,074.63	0.63	1,406,705.36	0.54	1,211,323.16	0.47	1,045,944.36	0.33	732,938.17
9	605,199.52	6,576,395.30	3,617,017.42	2,354,178.37	0.59	1,393,434.56	0.50	1,177,675.30	0.42	998,401.44	0.28	669,204.42
10	635,459.50	6,905,215.07	3,797,868.29	2,471,887.28	0.56	1,380,288.96	0.46	1,144,962.09	0.39	953,019.55	0.25	611,012.73
11	667,232.47	7,250,475.82	3,987,761.70	2,595,481.65	0.53	1,367,267.35	0.43	1,113,157.59	0.35	909,700.48	0.21	557,881.19
12	700,594.09	7,612,999.61	4,187,149.79	2,725,255.73	0.50	1,354,368.61	0.40	1,082,236.55	0.32	868,350.48	0.19	509,369.78
13	735,623.80	7,993,649.59	4,396,507.27	2,861,518.52	0.47	1,341,591.64	0.37	1,052,174.42	0.29	828,879.99	0.16	465,076.78
14	772,404.99	8,393,332.07	4,616,332.64	3,004,594.44	0.44	1,328,935.02	0.34	1,022,947.35	0.26	791,203.62	0.14	424,635.30
15	811,025.24	8,812,998.67	4,847,149.27	3,154,824.16	0.42	1,316,397.90	0.32	994,532.15	0.24	755,239.82	0.12	387,710.49
16	851,576.50	9,253,648.61	5,089,506.73	3,312,565.37	0.39	1,303,979.06	0.29	966,906.26	0.22	720,910.74	0.11	353,996.54
17	894,155.33	9,716,331.04	5,343,982.07	3,478,193.64	0.37	1,291,677.36	0.27	940,047.76	0.20	688,142.07	0.09	323,214.23
18	938,863.09	10,202,147.59	5,611,181.17	3,652,103.32	0.35	1,279,491.72	0.25	913,935.31	0.18	656,862.88	0.08	295,108.64
19	985,806.25	10,712,254.97	5,891,740.23	3,834,708.49	0.33	1,267,421.05	0.23	888,548.22	0.16	627,005.48	0.07	269,447.02
20	1,035,096.58	11,247,867.72	6,186,327.24	4,026,443.91	0.31	1,255,464.24	0.21	863,866.32	0.15	598,505.23	0.06	246,016.85
NPV						413,826.85		-4,224,464.29		-7,803,083.92		-13,751,856.77

6.3.2 Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is that discount rate at which Net Present Value is zero and benefit cost ratio is one i.e. it is the discount rate that equates the present values of project's benefits and costs.

IRR is calculated as follows:

$$\frac{r_a - r^*}{r_b - r_a} = \frac{NPVb}{NPVb - NPVa} \qquad (6.2)$$

$$r^* = IRR = ra + (rb\text{-}ra) \times \frac{NPV_a}{NPVa\text{-}NPV_b}$$

$$= 0.06 + (0.08\text{-}0.06) \times 413{,}826.85/(413{,}826.85+4{,}224{,}454.29)$$

$$= 0.062$$

IRR = 6.2 %

6.3.3 Profitability Index (PI) or Benefit Cost Ratio (BCR)

The benefit-cost ratio (BCR) or profitability index (PI) is the present value of an investment's future cash inflows divided by the present value of its cost. The Benefit-Cost Ratio (BCR) is derived by dividing present value of benefit (PVB) by present value of cost (PVC) i.e. BCR = PVB/PVC. The benefit cost ratio indicates benefit per taka of cost.

Profitability index (PI) or Benefit Cost Ratio (BCR) at 15% discount rate is 1.22 which is shown in the table 6.14

Table 6.14: Benefit Cost Ratio at 15% Discount Rate

Year	Total out flow($)	Total Cash in flow($)	Present worth factor	NPV of outflow($)	NPV of Inflow($)
0	27,102,485 71	0.00	1.00	27,102,485.71	0.00
1	409,622.66	4,451,163.20	0.87	356,193.79	3,870,576.70
2	430,104.00	4,673,721.36	0.76	325,220.42	3,534,004.61
3	451,609.20	4,907,407.43	0.66	296,940.38	3,226,700.04
4	474,189.66	5,152,777.80	0.57	271,119.46	2,946,117.43
5	497,899.14	5,410,416.69	0.50	247,543.87	2,689,933.31
6	522,794.10	5,680,937.52	0.43	226,016.32	2,456,026.06
7	548,933.81	5,964,984.40	0.38	206,364.55	2,242,458.58
8	576,380.50	6,263,233.62	0 33	188,419 81	2,047,462.18
9	605,199.52	6,576,395.30	0.28	172,035.46	1,869,421.99
10	635,459.50	6,905,215.07	0.25	157,075.87	1,706,863.56
11	667,232.47	7,250,475.82	0 21	143,417.10	1,558,440.64
12	700,594.09	7,612,999 61	0.19	130,946.05	1,422,924.08
13	735,623.80	7,993,649.59	0.16	119,559.43	1,299,191.53
14	772,404.99	8,393,332 07	0.14	109,162.98	1,186,218.36
15	811,025.24	8,812,998.67	0.12	99,670.63	1,083,068.94
16	851,576 50	9,253,648 61	0.11	91,003.53	988,889.03
17	894,155.33	9,716,331.04	0 09	83,090 18	902,898.68
18	938,863.09	10,202,147.59	0.08	75,864.94	824,385.75
19	985,806.25	10,712,254.97	0 07	69,267 99	752,700.03
20	1,035,096 56	11,247,867.72	0.06	63,244.69	687,247.86
	Total			30,534,645 06	37,295,529 52
	BCR				**1.22**

6.3.4 Pay back period (PBP)

The amount of time required to recover the initial investment is the pay back period. If the future cash flows are not discounted to calculate pay back period then it is called normal pay back period. But when future cash flows are discounted at an appropriate discount rate, then the required time to recover the initial investment is called discounted pay back period. The calculation of PBP is shown in the table 6.15.

Initial Investment = $ 27,102,485.71

Table 6.15: Pay Back Period (PBP)

Year	Total out flow($)	Total Cash in flow($)	Tax($)	Net cash flow($)	Present Worth Factor 15%	Net cash flow, $(Discounted)	Accumulated Cash Flow, $(Undiscounted)	Accumulated Cash Flow, $ (discounted)
1	409,622.86	4,451,163.20	2,448,139.76	1,593,400.58	0.87	1,385,565.72	1,593,400.58	1,385,565.72
2	430,104.00	4,673,721.36	2,570,546.75	1,673,070.61	0.76	1,265,081.75	3,266,471.19	2,650,647.47
3	451,609.20	4,907,407.43	2,699,074.09	1,756,724.14	0.66	1,155,074.64	5,023,195.34	3,805,722.11
4	474,189.66	5,152,777.80	2,834,027.79	1,844,560.35	0.57	1,054,633.37	6,867,755.69	4,860,355.48
5	497,899.14	5,410,416.69	2,975,729.18	1,936,788.37	0.50	962,926.12	8,804,544.05	5,823,281.60
6	522,794.10	5,680,937.52	3,124,515.64	2,033,627.79	0.43	879,193.41	10,838,171.84	6,702,475.01
7	548,933.81	5,964,984.40	3,280,741.42	2,135,309.17	0.38	802,741.81	12,973,481.01	7,505,216.82
8	576,380.50	6,263,233.62	3,444,778.49	2,242,074.63	0.33	732,938.17	15,215,555.65	8,238,154.99
9	605,199.52	6,576,395.30	3,617,017.42	2,354,178.37	0.28	669,204.42	17,569,734.01	8,907,359.41
10	635,459.50	6,905,215.07	3,797,868.29	2,471,887.28	0.25	611,012.73	20,041,621.30	9,518,372.15
11	667,232.47	7,250,475.82	3,987,761.70	2,595,481.65	0.21	557,881.19	22,637,102.94	10,076,253.34
12	700,594.09	7,612,999.61	4,187,149.79	2,725,255.73	0.19	509,369.78	25,362,358.68	10,585,623.12
13	735,623.80	7,993,649.59	4,396,507.27	2,861,518.52	0.16	465,076.76	28,223,877.19	11,050,699.87
14	772,404.99	8,393,332.07	4,616,332.54	3,004,594.44	0.14	424,635.30		11,475,335.17
15	811,025.24	8,812,998.67	4,847,149.27	3,154,824.16	0.12	387,710.49		11,863,045.67
16	851,576.50	9,253,648.61	5,089,506.73	3,312,565.37	0.11	353,996.54		12,217,042.20
17	894,155.33	9,716,331.04	5,343,982.07	3,478,193.64	0.09	323,214.23		12,540,256.43
18	938,863.09	10,202,147.59	5,611,181.17	3,652,103.32	0.08	295,108.64		12,835,365.07
19	985,806.25	10,712,254.97	5,891,740.23	3,834,708.49	0.07	269,447.02		13,104,812.10
20	1,035,096.56	11,247,867.72	6,186,327.24	4,026,443.91	0.06	246,016.85		13,350,828.94

Undiscounted Pay Back Period (PBP) **12.61 year**

Discounted Pay Back Period (PBP) **> 20 year**

From the table it is found that normal pay back period is greater than 12 years but less than 13 years.

PBP = 12+(27,102,485.71-25,362,358.68)/(28,223,877.19-25,362,358.68) years

= 12 + 0.61

= 12.61 years

From discounted accumulated cash flow column it is found Pay back period is greater than life of the project period i.e. 20 years.

6.3.5 Average Accounting Return (AAR)

AAR is a financial indicator which is defined as the ratio of average net income and average book value. AAR is calculated in the following table 6.16

Average Net Income = Total Net Income/ 20

= US$ 33,034,338.65/20

= US$ 1,651,716.93

Average Book Value = Investment cost/2

= US$ 27,102,485.71/2

= US$ 13,551,242.86

Average Accounting Return (AAR) = Average Net Income/Average Book Value

= 1,651,716.93/13,551,242.86

= 0.12

= 12 %

Table 6.16: Average Accounting Return(AAR)

Year	Total out flow($)	Total Cash in flow($)	Net Cash Flow($)	Depreciation($)	Earning Before Tax($)	Tax($)	Net Income($)	Avg. Net Income($)	Avg. Book Value($)
0	27,102,485.71	0.00	-27,102,485.71	0.00	-27,102,485.71	0.00	-27,102,485.71		
1	409,622.86	4,451,163.20	4,041,540.34	1,355,124.29	2,686,416.06	2,222,847.19	463,568.87		
2	430,104.00	4,673,721.36	4,243,617.36	1,355,124.29	2,888,493.07	2,333,989.55	554,503.53		
3	451,609.20	4,907,407.43	4,455,798.23	1,355,124.29	3,100,673.94	2,450,669.03	649,984.92		
4	474,189.66	5,152,777.80	4,678,588.14	1,355,124.29	3,323,463.85	2,573,223.48	750,240.38		
5	497,899.14	5,410,416.69	4,912,517.55	1,355,124.29	3,557,393.26	2,701,884.85	855,508.81		
6	522,794.10	5,680,937.52	5,158,143.42	1,355,124.29	3,803,019.14	2,836,978.88	966,040.25		
7	548,933.81	5,964,984.40	5,416,050.59	1,356,124.29	4,060,926.31	2,978,827.83	1,082,098.48		
8	576,380.50	6,263,233.62	5,686,853.12	1,355,124.29	4,331,728.84	3,127,769.22	1,203,959.62		
9	605,199.52	6,576,395.30	5,971,195.78	1,355,124.29	4,616,071.50	3,284,157.68	1,331,913.82		
10	635,459.50	6,905,215.07	6,269,755.57	1,355,124.29	4,914,631.28	3,448,365.56	1,466,265.72	1,651,716.93	13,551,242.86
11	667,232.47	7,250,475.82	6,583,243.35	1,355,124.29	5,228,119.06	3,620,783.84	1,607,335.22		
12	700,594.09	7,612,999.61	6,912,405.52	1,355,124.29	5,557,281.23	3,801,823.03	1,755,458.20		
13	735,623.80	7,993,649.59	7,258,025.79	1,355,124.29	5,902,901.51	3,991,914.19	1,910,987.32		
14	772,404.99	8,393,332.07	7,620,927.08	1,355,124.29	6,265,802.80	4,191,509.89	2,074,292.90		
15	811,025.24	8,812,998.67	8,001,973.44	1,356,124.29	6,646,849.15	4,401,085.39	2,245,763.76		
16	851,576.50	9,253,648.61	8,402,072.11	1,355,124.29	7,046,947.82	4,621,139.66	2,425,808.16		
17	894,155.33	9,716,331.04	8,622,175.71	1,355,124.29	7,467,051.43	4,852,196.64	2,614,854.78		
18	938,863.09	10,202,147.59	9,263,284.50	1,356,124.29	7,908,160.21	5,094,806.47	2,813,353.74		
19	985,806.25	10,712,254.97	9,726,448.72	1,355,124.29	8,371,324.44	5,349,546.80	3,021,777.64		
20	1,035,096.56	11,247,867.72	10,212,771.16	1,355,124.29	8,857,646.87	5,617,024.14	3,240,622.74		
Total							33,034,338.65		

Average Accounting Return (AAR) **0.12**

6.4 National Perspective

6.4.1 Market value of Urea

During pre SCADA (2002 & 2003) and post SCADA (2005 & 2006), the rate of shutdown was 34 and 8 days respectively. So the market value of urea is saved for = 34-8 = 26 days for two years. The annual savings of market value of urea is 13 days. During savings of shutdown, the production of urea was suspended. Same savings of shutdown periods are also assumed for the rest of the fertilizer factories.

The market value of urea is shown in the table 6.17.

Table 6.17: Market value of Urea

Name of Factory	Capacity (Metric Ton)		Price/Metric Ton (Tk)	Savings of Shutdown period (Day)	Price of Urea (Tk)	Gas Required (MMSCFD)	Gas price/mcf (Tk)	Total gas Price (Tk)	Total price of Urea deducting gas price (Tk)
	Urea	Liquid NH3							
GUFFL	1422	800	4800	13	88732800	45	64	3.7E+07	51292800
ZFCL	1600	900	4800	13	99840000	48	64	4E+07	59904000
JFCL	1700	1000	4800	13	106080000	50	64	4.2E+07	64480000
CUFL	1700	1000	4800	13	106080000	50	64	4.2E+07	64480000
PUFF	305	200	4800	13	19032000	14	64	1.2E+07	7384000
					Total price of urea				247540800

Source: Load Despatch Centre, TGTDCL

Total market price of urea = US$ 3,536,297.143

6.4.2 Market Value of Power

Before SCADA system (2002 & 2003), Raujan was out of generation for 42 days and after SCADA system (2005 & 2006), Raujan was out of generation for 10 days due to lack of load management. So the market value of power generation is saved for = 42-10 = 32 days for 2 years or 16 days per year due to implementation of SCADA system. These 16 days are assumed for other power stations.

Capacity of the Raujan Power station = 360MW

Price/kwh = 1.5 Tk

Market Value =360x1000x1.5x24x16 Tk/yea

= 2,07,360,000 Tk/year

Around 95 mmscfd gas is required to generate 360 MW power

So total gas required for 16 days = 95x16 mmscf

= 1520 mmscf

Price of gas = 1520x1000x74.6 Tk (PDB Rate =2.61 Tk/cum)

= 1,13,392,000 Tk

Market Value of Power (deducting gas price) = (2,07,360,000 -1,13,392,000) Tk

= 93,968,000 Tk (US$ 1,342,400)

Total Generation Capacity of other power station of PDB = 2200 MW

Market Value = 2200x1000x1.5x24x16 Tk

= 1,267,200,000 Tk

Around 580 mmscfd gas is required to generate 2200 MW power

So total gas required for 16 days = 580x16 mmscfd

= 9280 mmscf

Price of total gas = 9280x1000x 74.6 Tk (PDB Rate =2.61 Tk/cum)

= 6,92,288,000 Tk

Market value of power (deducting gas price) = (1,267,200,000 – 6,92,288,000) Tk

= 5,74,912,000 Tk (US$ 8,213,028.57)

So total market value of power = US$ (8,213,028.57+1,342,400)

= US$ 9,555,428.57

Total Cash Inflow = Savings from Site Offices + Savings in national economy from Fertilizer

+ Savings in national economy from Power + Savings from Condensate

Total Cash Inflow = 1,131,496.00 +3,536,297.143+ 9,555,428.57+ 213,381.49

= **US$ 14,436,603.20**

6.4.3 Net Present Value (NPV)

Net Present Value (NPV) is calculated at different discount rate. At discount rate 15%, 20%, 25% & 27%, the net present value is $23,898,169.80, $10,668,083.27, $2,400,760.32& -$51,134.96 which is shown in the table 6.18.

Table 6.18: NPV at Different Discount Rate

Year	Total out flow($)	Total Cash in flow($)	Tax($)	Net cash flow($)	Present Value at Various Discount Rate							
					15%		20%		25%		27%	
					Present worth factor	Present value($)	Present worth factor	Present value($)	Present worth factor	Present value($)	Present worth factor	Present value($)
0	27,102,465.71	0.00	0.00	-27,102,465.71	1.00	-27,102,465.71	1.00	-27,102,465.71	1.00	-27,102,465.71	1.00	-27,102,465.71
1	409,622.86	14,436,603.20	7,940,131.78	6,086,848.56	0.87	5,292,911.81	0.83	5,072,373.82	0.80	4,869,478.87	0.79	4,792,794.16
2	430,104.00	15,158,433.36	8,337,138.35	6,391,191.01	0.76	4,832,658.61	0.69	4,438,327.09	0.64	4,090,362.25	0.62	3,962,546.36
3	451,609.20	15,916,355.03	8,753,995.27	6,710,750.56	0.66	4,412,427.43	0.58	3,883,536.21	0.51	3,435,904.29	0.49	3,276,121.00
4	474,189.66	16,712,172.76	9,191,695.03	7,046,288.08	0.57	4,028,739.09	0.48	3,398,094.18	0.41	2,886,159.60	0.38	2,708,603.96
5	497,899.14	17,547,781.42	9,651,279.78	7,398,602.50	0.50	3,678,413.03	0.40	2,973,332.41	0.33	2,424,374.07	0.30	2,239,396.99
6	522,704.10	18,425,170.49	10,133,843.77	7,768,622.62	0.43	3,358,551.03	0.33	2,601,865.66	0.26	2,036,474.22	0.24	1,851,469.95
7	548,933.81	19,346,429.01	10,640,535.96	8,156,959.25	0.38	3,066,503.12	0.28	2,276,457.82	0.21	1,710,636.34	0.19	1,530,742.67
8	576,380.50	20,313,750.46	11,172,562.76	8,564,807.21	0.33	2,798,850.67	0.23	1,991,900.42	0.17	1,436,936.21	0.15	1,265,574.82
9	605,199.52	21,329,437.99	11,731,190.89	8,993,047.57	0.28	2,556,385.40	0.19	1,742,912.67	0.13	1,207,026.41	0.12	1,046,341.38
10	635,459.50	22,395,909.89	12,317,750.44	9,442,699.95	0.25	2,334,091.01	0.16	1,525,048.78	0.11	1,013,902.19	0.09	865,085.40
11	667,232.47	23,515,705.38	12,933,637.96	9,914,834.95	0.21	2,131,126.56	0.13	1,334,417.86	0.09	851,677.84	0.07	715,220.05
12	700,594.09	24,691,490.65	13,580,319.86	10,410,576.70	0.19	1,945,811.22	0.11	1,167,615.46	0.07	715,409.38	0.06	591,330.30
13	735,623.80	25,926,065.18	14,259,335.85	10,931,105.53	0.16	1,776,610.25	0.09	1,021,683.52	0.05	600,943.88	0.04	488,895.13
14	772,404.99	27,222,368.44	14,972,302.64	11,477,660.81	0.14	1,622,122.40	0.08	893,955.56	0.04	504,792.86	0.04	404,204.64
15	811,025.24	28,583,486.86	15,720,917.78	12,051,543.85	0.12	1,481,068.28	0.06	782,211.14	0.04	424,026.00	0.03	334,184.94
16	851,576.50	30,012,661.21	16,506,963.66	12,654,121.04	0.11	1,352,279.73	0.05	684,434.74	0.03	356,161.84	0.02	276,294.63
17	894,155.33	31,513,294.27	17,332,311.85	13,286,827.09	0.09	1,234,690.19	0.05	598,880.40	0.02	299,192.75	0.02	228,432.57
18	938,863.09	33,088,958.98	18,199,027.44	13,951,068.45	0.08	1,127,325.63	0.04	524,020.35	0.02	251,321.91	0.01	188,861.57
19	985,806.25	34,743,406.93	19,108,873.81	14,648,726.87	0.07	1,029,297.49	0.03	458,517.81	0.01	211,110.40	0.01	156,145.40
20	1,035,096.56	36,480,577.28	20,064,317.50	15,381,163.22	0.06	939,793.36	0.03	401,203.06	0.01	177,332.74	0.01	129,096.59
NPV						23,896,189.80		10,868,083.27		2,400,760.32		-51,134.96

6.4.4 Internal Rate of Return (IRR)

IRR is calculated as follows

$$\frac{r_a - r^*}{r_b - r_a} = \frac{NPVb}{NPVb - NPVa}$$

$$r^* = IRR = ra + (rb\text{-}ra) \times \frac{NPV_a}{NPVa\text{-}NPV_b}$$

= 0.25+ (0.27-0.25) x 2,400,760.32/(2,400,760.32+51,134.96)

IRR = 0.27 =27%

6.4.5 Profitability Index (PI) or Benefit Cost Ratio (BCR)

Profitability index (PI) or Benefit Cost Ratio (BCR) at 15% discount rate is 4.03 which is shown in the table 6.19.

Table 6.19: Benefit Cost Ratio at 15% Discount Rate

Year	Total out flow($)	Total Cash in flow($)	Present worth factor	NPV of outflow($)	NPV of Inflow($)
0	27,102,485.71	0.00	1.00	27,102,485.71	0.00
1	409,622.86	14,436,603.20	0.87	356,193.79	12,553,568.00
2	430,104.00	15,158,433.36	0.76	325,220.42	11,461,953.39
3	438,706.08	15,916,355.03	0.66	288,456.37	10,465,261.79
4	447,480.20	16,712,172.78	0.57	255,848.26	9,555,239.03
5	456,429.81	17,547,781.42	0.50	226,926.28	8,724,348.68
6	465,558.40	18,425,170.49	0.43	201,273.74	7,965,709.66
7	474,869.57	19,346,429.01	0.38	178,521.06	7,273,039.28
8	484,366.96	20,313,750.46	0.33	158,340.42	6,640,601.06
9	494,054.30	21,329,437.99	0.28	140,441.07	6,063,157.49
10	503,935.39	22,395,909.89	0.25	124,565.12	5,535,926.40
11	514,014.09	23,515,705.38	0.21	110,483.85	5,054,541.50
12	524,294.38	24,691,490.65	0.19	97,994.37	4,615,016.15
13	534,780.26	25,926,065.18	0.16	86,918.74	4,213,710.40
14	545,475.87	27,222,368.44	0.14	77,091.37	3,847,300.80
15	556,385.39	28,583,486.86	0.12	68,376.70	3,512,752.90
16	567,513.09	30,012,661.21	0.11	60,647.16	3,207,296.13
17	578,863.36	31,513,294.27	0.09	53,791.39	2,928,400.81
18	590,440.62	33,088,958.98	0.08	47,710.62	2,673,757.26
19	602,249.44	34,743,406.93	0.07	42,317.25	2,441,256.63
20	614,294.42	36,480,577.28	0.06	37,533.56	2,228,973.45
	Total			30,041,135.24	120,961,810.80
	BCR				4.03

6.4.6 Pay back period (PBP)

The calculation of Pay Back Period (PBP) is shown in the table 6.20.

Table 6.20: Pay Back Period (PBP)

Year	Total out flow($)	Total Cash in flow($)	Tax($)	Net cash flow($)	Present Worth Factor 15%	Net cash flow, $(Discounted)	Accumulated Cash Flow, $(Undiscounted)	Accumulated Cash Flow, $ (discounted)
1	409,622.86	14,436,603.20	7,940,131.76	6,086,848.58	0.87	5,292,911.81	6,086,848.58	5,292,911.81
2	417,815.31	15,158,433.36	8,337,138.35	6,403,479.70	0.76	4,841,950.62	12,490,328.28	10,134,862.43
3	426,171.62	15,916,355.03	8,753,995.27	6,736,188.14	0.66	4,429,153.05	19,226,516.42	14,564,015.48
4	434,695.05	16,712,172.78	9,191,695.03	7,085,782.70	0.57	4,051,319.26	26,312,299.12	18,615,334.74
5	443,388.95	17,547,781.42	9,651,279.78	7,453,112.68	0.50	3,705,514.23	33,765,411.80	22,320,848.97
6	452,256.73	18,425,170.49	10,133,843.77	7,839,069.99	0.43	3,389,046.28		25,709,895.25
7	461,301.87	19,346,429.01	10,640,535.96	8,244,591.19	0.38	3,099,447.21		28,809,342.46
8	470,527.91	20,313,750.46	11,172,562.76	8,670,659.80	0.33	2,834,454.07		
9	479,938.46	21,329,437.99	11,731,190.89	9,118,308.63	0.28	2,591,992.41		
10	489,537.23	22,395,909.89	12,317,750.44	9,588,622.22	0.25	2,370,160.76		
11	499,327.98	23,515,705.38	12,933,637.96	10,082,739.44	0.21	2,167,216.51		
12	509,314.54	24,691,490.65	13,580,319.86	10,601,856.26	0.19	1,981,562.74		
13	519,500.83	25,926,065.18	14,259,335.85	11,147,228.50	0.16	1,811,736.27		
14	529,890.84	27,222,368.44	14,972,302.64	11,720,174.95	0.14	1,656,396.60		
15	540,488.66	28,583,486.86	15,720,917.78	12,322,080.43	0.12	1,514,315.73		
16	551,298.43	30,012,661.21	16,506,963.66	12,954,399.11	0.11	1,384,368.88		
17	562,324.40	31,513,294.27	17,332,311.85	13,618,658.02	0.09	1,265,525.87		
18	573,570.89	33,088,958.98	18,198,927.44	14,316,460.65	0.08	1,156,843.31		
19	585,042.31	34,743,406.93	19,108,873.81	15,049,490.81	0.07	1,057,457.30		
20	596,743.15	36,480,577.28	20,064,317.50	15,819,516.62	0.06	966,576.88		

Undiscounted Pay Back Period (PBP) **4.11** Year

Discounted Pay Back Period (PBP) **6.45** Year

6.4.7 Average Accounting Return (AAR)

AAR is a financial indicator which is defined as the ratio of average net income and average book value.

AAR is calculated in the following table 6.21.

Table 6.21: Average Accounting Return(AAR)

Year	Total out flow($)	Total Cash In flow($)	Net Cash Flow($)	Depreciation ($)	Earning Before Tax($)	Tax($)	Net Income($)	Avg. Net Income($)	Avg.Book Value($)
0	27,102,485.71	0.00	-27,102,485.71	0.00	-27,102,485.71	0.00	-27,102,485.71		
1	409,622.86	14,436,603.20	14,026,980.34	1,355,124.29	12,671,856.06	7,714,839.19	4,957,016.87		
2	430,104.00	15,158,433.36	14,728,329.36	1,355,124.29	13,373,205.07	8,100,581.15	5,272,623.93		
3	451,609.20	15,916,355.03	15,464,745.83	1,355,124.29	14,109,621.54	8,505,610.21	5,604,011.34		
4	474,189.66	16,712,172.78	16,237,983.12	1,355,124.29	14,882,858.83	8,930,890.72	5,951,968.12		
5	497,899.14	17,547,781.42	17,049,882.28	1,355,124.29	15,694,757.99	9,377,435.25	6,317,322.74		
6	522,794.10	18,425,170.49	17,902,376.39	1,355,124.29	16,547,252.10	9,846,307.01	6,700,945.09		
7	548,933.81	19,346,429.01	18,797,495.21	1,355,124.29	17,442,370.92	10,338,622.36	7,103,748.56		
8	576,380.50	20,313,750.46	19,737,369.97	1,355,124.29	18,382,245.68	10,855,553.48	7,526,692.20		
9	605,199.52	21,329,437.99	20,724,238.47	1,355,124.29	19,369,114.18	11,398,331.16	7,970,783.02		
10	635,459.50	22,395,909.89	21,760,450.39	1,355,124.29	20,405,326.11	11,968,247.71	8,437,078.39	9,080,724.20	13,551,242.66
11	667,232.47	23,515,705.38	22,848,472.91	1,355,124.29	21,493,348.62	12,566,660.10	8,926,688.52		
12	700,594.09	24,691,490.65	23,990,896.56	1,355,124.29	22,635,772.27	13,194,993.11	9,440,779.16		
13	735,623.80	25,926,065.18	25,190,441.38	1,355,124.29	23,835,317.10	13,854,742.76	9,980,574.34		
14	772,404.99	27,222,368.44	26,449,963.45	1,355,124.29	25,094,839.17	14,547,479.90	10,547,359.27		
15	811,025.24	28,583,486.86	27,772,461.63	1,355,124.29	26,417,337.34	15,274,853.89	11,142,483.45		
16	851,576.50	30,012,661.21	29,161,084.71	1,355,124.29	27,805,960.42	16,038,596.59	11,767,363.83		
17	894,155.33	31,513,294.27	30,619,138.94	1,355,124.29	29,264,014.66	16,840,526.42	12,423,488.24		
18	938,863.09	33,088,958.98	32,150,095.89	1,355,124.29	30,794,971.60	17,682,552.74	13,112,418.86		
19	985,806.25	34,743,406.93	33,757,600.68	1,355,124.29	32,402,476.40	18,566,680.38	13,835,796.02		
20	1,035,096.56	36,480,577.28	35,445,480.72	1,355,124.29	34,090,356.43	19,495,014.39	14,595,342.04		
Total							181,614,483.98		
Average Accounting Return (AAR)								0.67	

6.4.8 Summary of Financial Analysis

The findings of the above two perspectives are summarized in the table 6.22.

Table 6.22: Summary of Financial Analysis (at 15% Discount Rate)

Financial Parameters	Gas Sector Perspective	National Perspective
Net Present Value (NPV)	-$13,751,656.77	$23,898,169.80
Internal Rate of Return (IRR)	6.2 %	27 %
Pay Back Period (PBP)	12.61 year (undiscounted)/more than 20 year (discounted)	4.11 year (undiscounted)/6.45 year (discounted)
Benefit Cost Ratio (BCR)	1.22	4.03
Average Accounting Return (AAR)	12%	67%

From gas sector point of view, it is found that, Net Present Value (NPV) is negative and Internal Rate of Return (IRR) is 6.2%, which is less than required rate of return, Pay Back Period is 12.61 year (undiscounted), more than 20 year (discounted), Benefit Cost Ratio is 1.22, Average Accounting Return is 12%. So these financial parameters indicate that the project is not feasible.

From national point of view, Net Present Value (NPV) is positive and Internal Rate of Return (IRR) is grater than required rate of return, Pay Back Period is 4.11 year (undiscounted), 6.45 year (discounted), Benefit Cost Ratio is greater than one, Average Accounting Return is 67%. So these financial parameters indicate that the project is feasible.

CHAPTER 7: CONCLUSIONS & RECOMMENDATIONS

The following conclusions and recommendations are drawn from the findings presented in the previous chapters.

7.1 Conclusions

- From the analysis of gas sector perspective, it is found the project is not financially viable.
- From the analysis of national perspective, it is found that the project is financially viable.
- Due to implementation of the SCADA system, the savings of shutdown period for power station and fertilizer factories are 12 days and 8 days per year respectively.
- From the analysis it is inferred that the number of pilferages of condensate has been reduced from 14 to 6 annually due to implementation of the SCADA system
- There are a number of benefits of the SCADA system which can not be quantified. The value of the benefits can not be measured in terms of monetary gain. Therefore these are not reflected in the financial analysis.
- Financial parameters alone are not enough to evaluate the SCADA system fully.
- Full benefits from the SCADA system can not be derived due to lack of trained man power, not operating the valves remotely and non-functioning of the pipeline application software for leak detection, load balancing, load scheduling, line pack.

7.2 Recommendations

- A SCADA system can be installed in the distribution pipeline to monitor and control the parameters of Town Bordering Station (TBS), Regulating Metering station (RMS), District Regulating Station (DRS) and Distribution Main (DM) line.

- Meters at intake and off take points of pipeline should be installed for efficient monitoring and controlling of the SCADA system.

- New gas fields, transmission lines and bulk customers should be taken under SCADA system

- Training should be ensured for the concerned personnel of the SCADA system.

- The rest of the high pressure transmission lines owned by distribution companies should be handed over to GTCL for proper load management.

- A technical committee may be formed to take the necessary actions for removing the shortcomings of the SCADA system in order to get maximum benefits.

BIBLIOGRAPHY

BGSL (2005-2006): Annual Report.

BGSL and KAFCO (2005): Gas Supply Agreement.

Brown, P. R.(2003): "Telecommunication System Overview Manual" SCADA and Telecommunication System, Sercks Controls Ltd.

Cooper, D.R., and Schindler, P.S., (2006): *Business Research Methods,* Mcgraw-Hill International Edition, New York.

Domjan, J. and Parkes B. (2002):"Functional Design Specification" SCADA and Telecommunication System, Sercks Controls Ltd.

GTCL (2007): Daily Report on Gas Production and Supply Statistics-19th March.

GTCL (2003-2005): Condensate Report.

GTCL (2005-2006): Annual Report.

GTCL (2007): Monthly Report on "On Gas Production and Despatch Schedule" March.

GTCL (2006): Monthly Progress Report, December.

GTCL (2006): Salary Statement.

GTCL (2007): Report on "High Pressure Transmission Lines", Operation Division.

GUFFL (2006): Annual Report.

Kennedy, J.L. (1993): *Oil and Gas Pipeline Fundamentals,* PennWell Publishing Company, Oklahoma.

Larson, K.D. (1997): *Essentials of Financial Accounting*, Michael W. Junior, New Delhi.

Lewin, R.(2002): "SCADA System Overview Manual", SCADA and Telecommunication System, Sercks Controls Ltd.

National Committee Report (2002): "Gas Demand Projections and Determination of Recoverable Reserve & Gas Resource Potential in Bangladesh", June.

Petrobangla (2007): Report on "Updated Gas Reserve Scenario of Bangladesh", Marketing and Production Division.

Ross S.A., Westerfield R.W. and Jordan B.D. (2003): *Fundamentals of Corporate Finance*, Tata McGraw-Hill, New Delhi.

Revised Project Proforma (2002): SCADA –Telecommunication System Project.

Saleque, K. A. (2001): " A Vision in Bangladesh Gas Sector for the new Millennium", Paper Presented in Seminar of Petrobangla Engineers Association, Dhaka, March 31.

Saleque, K. A. (2002): "Gas Demand-Supply Scenario of Bangladesh-An Objective Analysis", Paper Presented in Seminar of Petrobangla Engineers Association, Dhaka, September 28.

Serck Controls (2004): "Bangladesh Gas Infrastructure Development Project-SCADA Component" Sercks Controls Ltd.

TGTDCL and CDC Horipur (1998): Gas Supply Agreement.

TGTDCL and ZFCL (1975) :Gas Supply Agreement.

APPENDIX-A

Table A1: Updated Gas Reserves Scenario of Bangladesh

Sl No	Field Name	Year of Discovery	Reserves(GIIP) in BCF				Recoverable						Recovery Factor
			Proven (P1)	Probable (P2)	Possible (P3)	Total (P1+P2+P3)	P1	Produced upto Dec'06	NetP1	P2	P3	Remaining Total (P1+P2+P3)	
A. Producing													
1	Bakhrabad	1969	1129.00	370.00	-	1499.00	790.00	662.32	127.68	259.00	-	386.68	69.97
2	Beanibazar	1981	243.00	-	-	243.00	170.00	44.36	125.64	-	-	125.64	69.96
3	Habiganj	1963	5100.00	39.00	-	5139.00	3825.00	1396.93	2428.07	27.00	-	2455.00	75.00
4	Jalalabad	1989	730.00	466.00	213.00	1409.00	511.00	362.82	148.18	326.00	149.00	623.18	70.00
5	Kailastilla	1962	1524.00	1196.00	1297.00	4017.00	1067.00	381.15	685.85	837.00	908.00	2430.85	70.01
6	Meghna	1990	102.00	68.00	-	170.00	72.00	35.60	36.4	48	-	84.4	70.59
7	Narshingdi	1990	236.00	72.00	80.00	388.00	165.00	68.64	96.36	50.00	56.00	202.36	69.92
8	Rashidpur	1960	1398.00	604.00	1000.00	3002.00	979.00	398.38	580.62	423.00	700.00	1703.00	70.03
9	Salda Nadi	1996	75.00	90.00	-	165.00	53.00	48.78	4.22	63.00	-	67.22	70.67
10	Sangu	1996	1031.00	-	-	1031.00	848.00	398.62	449.38	-	-	449.38	82.25
11	Sylhet	1955	524.00	160.00	-	684.00	367.00	184.17	182.83	112.00	-	294.83	70.04
12	Titas	1962	5714.00	1611.00	2433.00	9758.00	4000.00	2635.06	1364.94	1128.00	1703.00	4195.00	70.00
13	Feni	1981	67.6	146.00	103.00	316.6	52.00	39.5	12.5	77.00	72.00	161.50	76.92
14	Fenchuganj	1998	85.00	319.00	-	404.00	60.00	37.03	22.97	223.00	-	245.97	70.59
15	Moulbibazar	1999	462.00	-	-	462.00	347.00	56.88	290.12	-	-	290.12	75.11
	Sub-total: A		18420.6	5141.00	5126.00	28687.6	13306.00	6750.24	6555.76	3573.00	3588.00	13715.13	
B. Non-Producing													
16	Begumganj	1997	14.00	33.00	108.00	155.00	10.00	0	10.00	23.00	76.00	109.00	71.43
17	Bibyana	1998	1584 00	1561.00	3423.00	6568.00	1209.00	0	1209.00	1192.00	3124.00	5525.00	76.33
18	Kutubdia	1977	-	65	-	65	-	0	-	46.00	-	46.00	70.77
19	Semutang	1969	174.00	-	-	174.00	121.80	0	121.8	-	-	121.8	70.00
20	Shahbazpur	1995	366.00	300.00	957.00	1623.00	256.00	0	256.00	210.00	670.00	1136.00	69.95
	Sub-total: B		2138.00	1959.00	4488.00	8585.00	1596.80	0	1596.8	1471.00	3870.00	6937.8	
C. Production Suspended													
22	Chatak(west)	1959	379.00	298.00	362.00	1039.00	265.00	25.8	239 2	209.00	253.00	701.20	69.92
14	Kamta	1981	27.3	45.00	-	72.3	21.00	17.05	3.95	25.00	-	28.95	76.92
	Sub-total:C	-	406.3	343.00	362.00	1111.3	286.00	42.85	243.15	234.00	253.00	730.15	
	Grand Total in BCF		20964.90	7443.00	9976.00	38383.9	15188.8	6793.09	8395.71	5278.00	7711.00	21384.71	
	Grand Total in TCF		20.96	7.44	9.98	38.38	15.19	6.79	8.40	5.28	7.71	21.38	

Table A2: Sample Daily Gas Report by SCADA System

Gas Intake/Off-take Scenario of N-S and H-A Pipeline on Hourly Basis

Reporting Period : 08:00 AM 29/04/2007 - 07:00 AM 30/04/2007 (Units are in MMSCFD)

A. Gas In-Take of N-S and H-A Pipeline on hourly Basis

Intake / Time	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	Avg. Flow
Habiganj GF(NS1)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Beanibazar GF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
KTL-II GF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Jalalabad GF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
*Fenchuganj GF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
*Bibyana GF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Habiganj GF(NS2)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Khatihata Input	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
*Moulvibazar GF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rashidpur GF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Intake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

B. Gas Despatch From N-S and H-A Pipeline on hourly Basis

Off-take / Time	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	Avg. Flow
KTL-II to AITOSL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
*Nanakhan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fenchuganj 90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A-B Pipeline	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BB1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BB2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
VS-1 Tie	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ash. Main Line	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Offtake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table A2: Sample Daily Gas Report by SCADA System (Contd.)

[illegible]

Table A3: Sample Report on Flow of Condensate by SCADA System

Data for Point [illegible] condensate stream [illegible]

14-MAY-2007 [illegible] to 14-MAY-2007 [illegible]

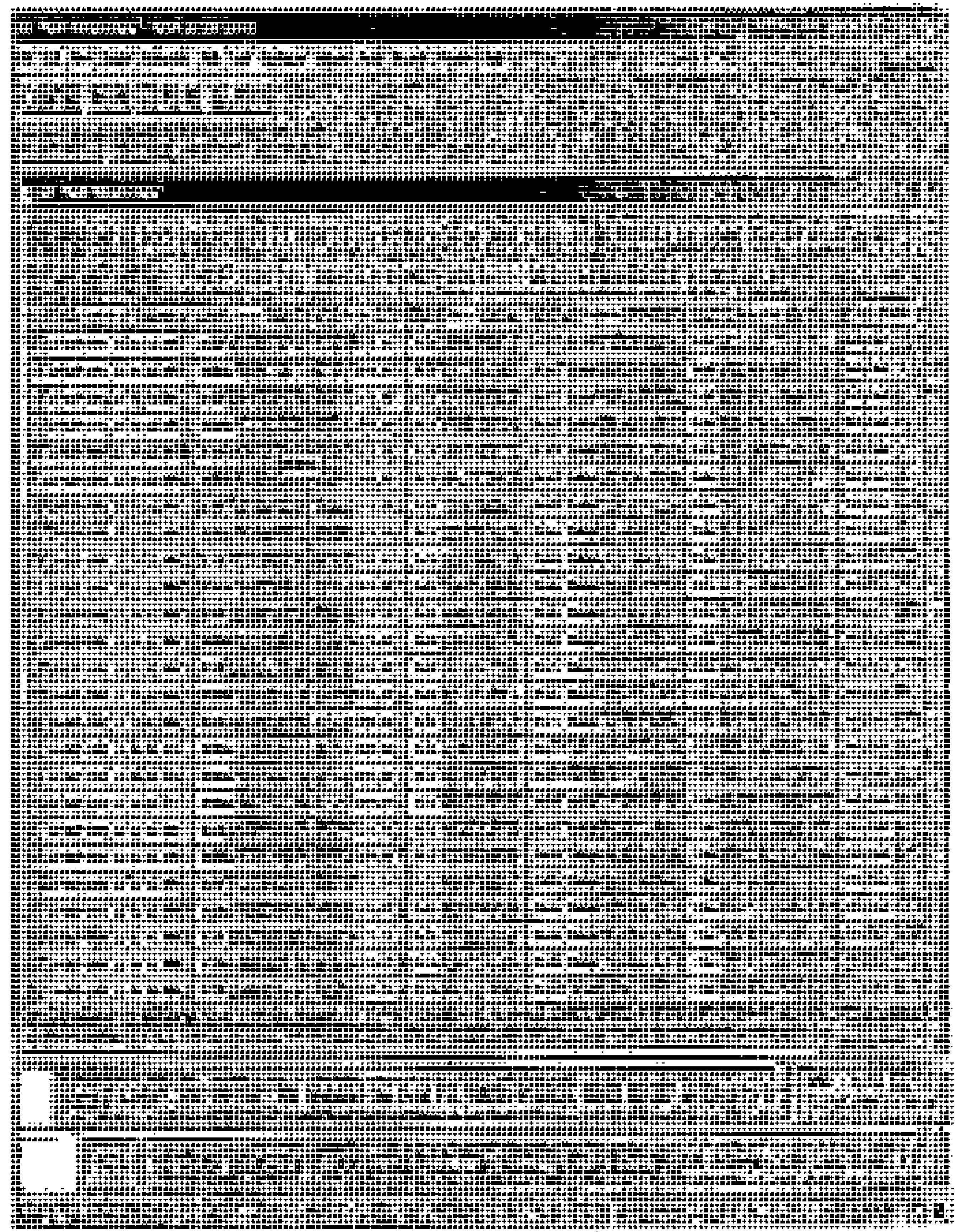
Date-Time	State	Value	Units	Reason	Override
14-MAY-2007 [illegible]	NORMAL	153.02	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	151.11	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	152.11	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	146.41	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	141.39	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	135.92	bph	Report	None
14-MAY-2007 [illegible]	NORMAL	135.92	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	131.35	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	124.35	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	111.53	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	111.43	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	105.14	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	91.11	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	93.31	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	81.73	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	83.07	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	77.13	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	71.37	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	66.91	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	61.21	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	55.74	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	50.37	bph	Rate Change	None
14-MAY-2007 [illegible]	LOW	43.07	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	43.59	bph	Report	None
14-MAY-2007 [illegible]	LOW	43.59	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	37.82	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	31.26	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	25.31	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	17.69	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW LOW	4.41	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW LOW	5.31	bph	Report	None
14-MAY-2007 [illegible]	LOW	16.43	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	15.41	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	21.31	bph	Report	None
14-MAY-2007 [illegible]	LOW	24.51	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	29.61	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	34.61	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	33.94	bph	Report	None
14-MAY-2007 [illegible]	LOW	37.76	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	44.66	bph	Significant Change	None
14-MAY-2007 [illegible]	LOW	47.89	bph	Rate Change	None
14-MAY-2007 [illegible]	NORMAL	52.97	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	50.14	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	51.40	bph	Report	None
14-MAY-2007 [illegible]	NORMAL	51.15	bph	Significant Change	None
14-MAY-2007 [illegible]	NORMAL	48.71	bph	Significant Change	None

Table A4: Sample Report on Flow Rate of Jalalabad Gas Field by SCADA System

Data for Point: [illegible] Jalalabad [illegible] (MMSCFD)
14-MAY-2007 17:[illegible] to 14-MAY-2007 06:[illegible]

Date-Time	State	Value	Units	Reason	Override
14-MAY-2007 17:30:00.000	Normal	163.70	MMSCFD	Report	None
14-MAY-2007 17:15:00.000	Normal	161.61	MMSCFD	Report	None
14-MAY-2007 17:00:00.000	Normal	163.09	MMSCFD	Report	None
14-MAY-2007 16:45:00.000	Normal	163.24	MMSCFD	Report	None
14-MAY-2007 16:30:00.000	Normal	163.29	MMSCFD	Report	None
14-MAY-2007 16:15:00.000	Normal	162.40	MMSCFD	Report	None
14-MAY-2007 16:00:00.000	Normal	159.56	MMSCFD	Report	None
14-MAY-2007 15:45:00.000	Normal	159.46	MMSCFD	Report	None
14-MAY-2007 15:30:00.000	Normal	160.23	MMSCFD	Report	None
14-MAY-2007 15:15:00.000	Normal	160.17	MMSCFD	Report	None
14-MAY-2007 15:00:00.000	Normal	160.31	MMSCFD	Report	None
14-MAY-2007 14:45:00.000	Normal	159.79	MMSCFD	Report	None
14-MAY-2007 14:30:00.000	Normal	159.61	MMSCFD	Report	None
14-MAY-2007 14:15:00.000	Normal	159.62	MMSCFD	Report	None
14-MAY-2007 14:00:00.000	Normal	159.62	MMSCFD	Report	None
14-MAY-2007 13:45:00.000	Normal	159.51	MMSCFD	Report	None
14-MAY-2007 13:30:00.000	Normal	157.13	MMSCFD	Report	None
14-MAY-2007 13:15:00.000	Normal	155.10	MMSCFD	Report	None
14-MAY-2007 13:00:00.000	Normal	157.12	MMSCFD	Report	None
14-MAY-2007 12:45:00.000	Normal	155.53	MMSCFD	Report	None
14-MAY-2007 12:30:00.000	Normal	157.31	MMSCFD	Report	None
14-MAY-2007 12:15:00.000	Normal	157.35	MMSCFD	Report	None
14-MAY-2007 12:00:00.000	Normal	156.61	MMSCFD	Report	None
14-MAY-2007 11:45:00.000	Normal	156.62	MMSCFD	Report	None
14-MAY-2007 11:30:00.000	Normal	156.92	MMSCFD	Report	None
14-MAY-2007 11:15:00.000	Normal	156.76	MMSCFD	Report	None
14-MAY-2007 11:00:00.000	Normal	156.21	MMSCFD	Report	None
14-MAY-2007 10:45:00.000	Normal	157.11	MMSCFD	Report	None
14-MAY-2007 10:30:00.000	Normal	157.78	MMSCFD	Report	None
14-MAY-2007 10:15:00.000	Normal	156.67	MMSCFD	Report	None
14-MAY-2007 10:00:00.000	Normal	157.65	MMSCFD	Report	None
14-MAY-2007 09:45:00.000	Normal	156.81	MMSCFD	Report	None
14-MAY-2007 09:30:00.000	Normal	155.92	MMSCFD	Report	None
14-MAY-2007 09:15:00.000	Normal	156.80	MMSCFD	Report	None
14-MAY-2007 09:00:00.000	Normal	155.91	MMSCFD	Report	None
14-MAY-2007 08:45:00.000	Normal	157.21	MMSCFD	Report	None
14-MAY-2007 08:30:00.000	Normal	157.31	MMSCFD	Report	None
14-MAY-2007 08:15:00.000	Normal	157.66	MMSCFD	Report	None
14-MAY-2007 08:00:00.000	Normal	156.33	MMSCFD	Report	None
14-MAY-2007 07:45:00.000	Normal	156.65	MMSCFD	Report	None
14-MAY-2007 07:30:00.000	Normal	157.25	MMSCFD	Report	None
14-MAY-2007 07:15:00.000	Normal	156.12	MMSCFD	Report	None
14-MAY-2007 07:00:00.000	Normal	156.61	MMSCFD	Report	None
14-MAY-2007 06:45:00.000	Normal	156.51	MMSCFD	Report	None
14-MAY-2007 06:30:00.000	Normal	157.61	MMSCFD	Report	None
14-MAY-2007 06:15:00.000	Normal	156.64	MMSCFD	Report	None

Table A5: Screen Shot of Pressure of Jalalabad Gas Field by SCADA System



APPENDIX-B

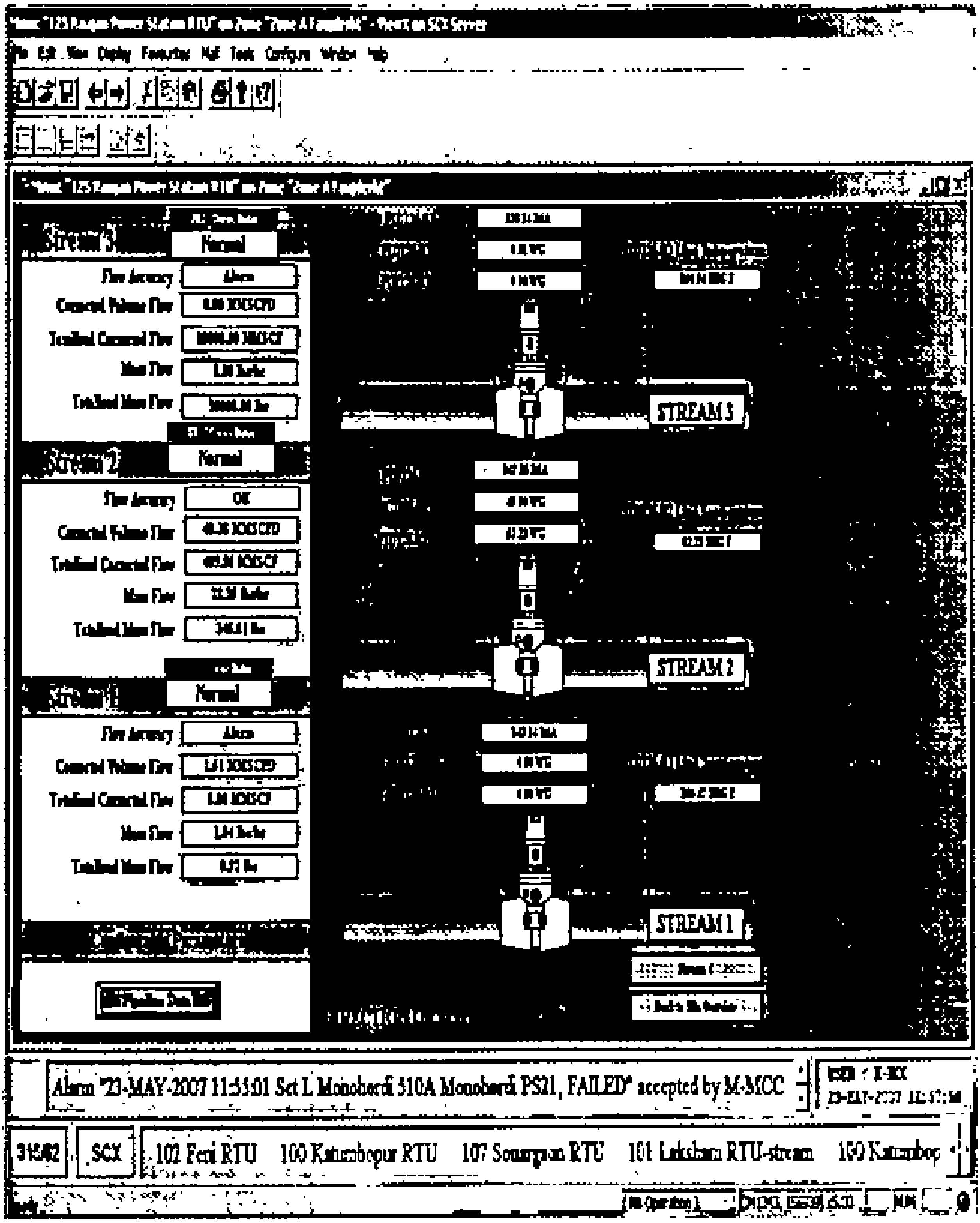


Figure B1: Screen Shot of Flow Data of Raujan Power Station by SCADA System

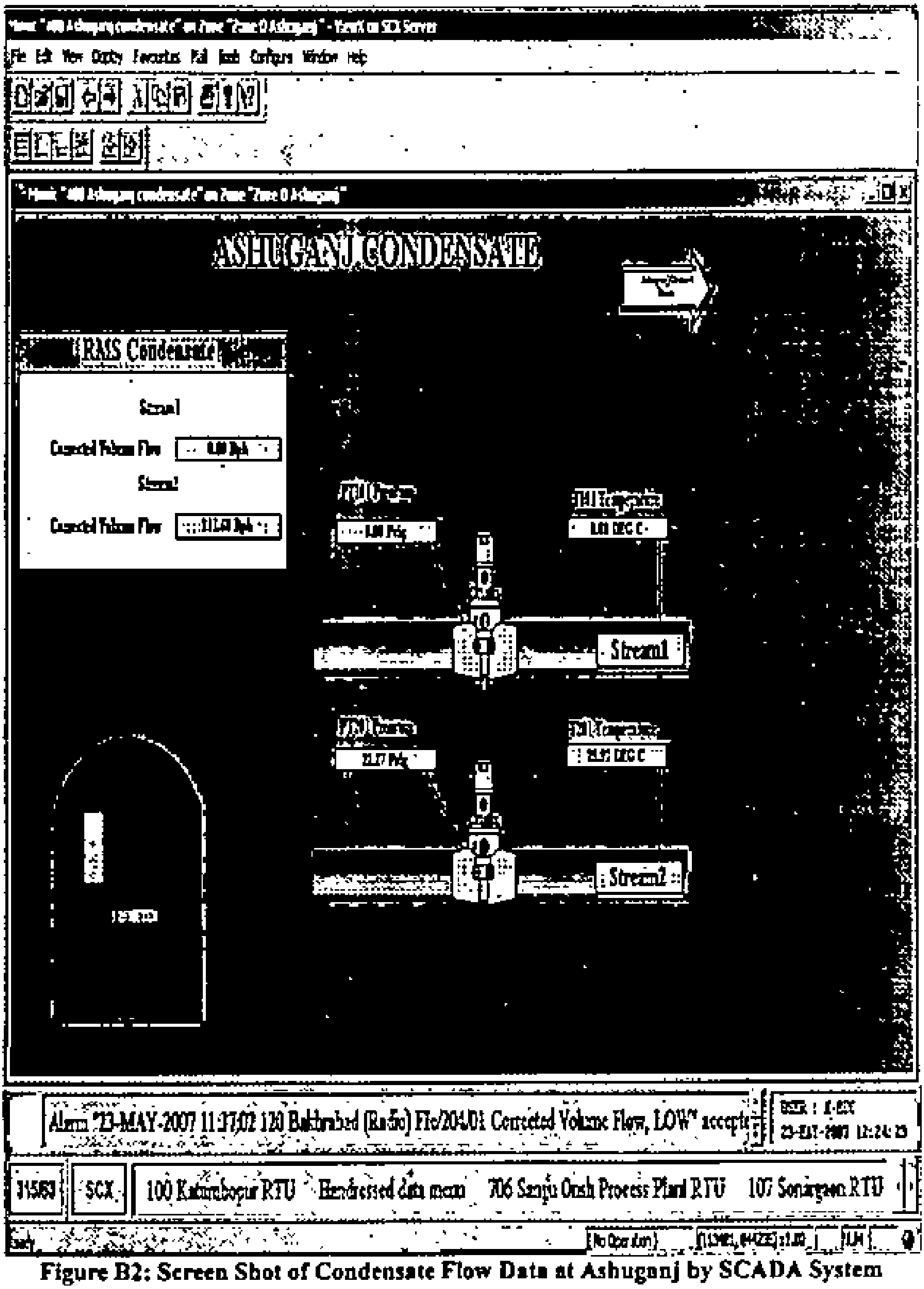


Figure B2: Screen Shot of Condensate Flow Data at Ashuganj by SCADA System

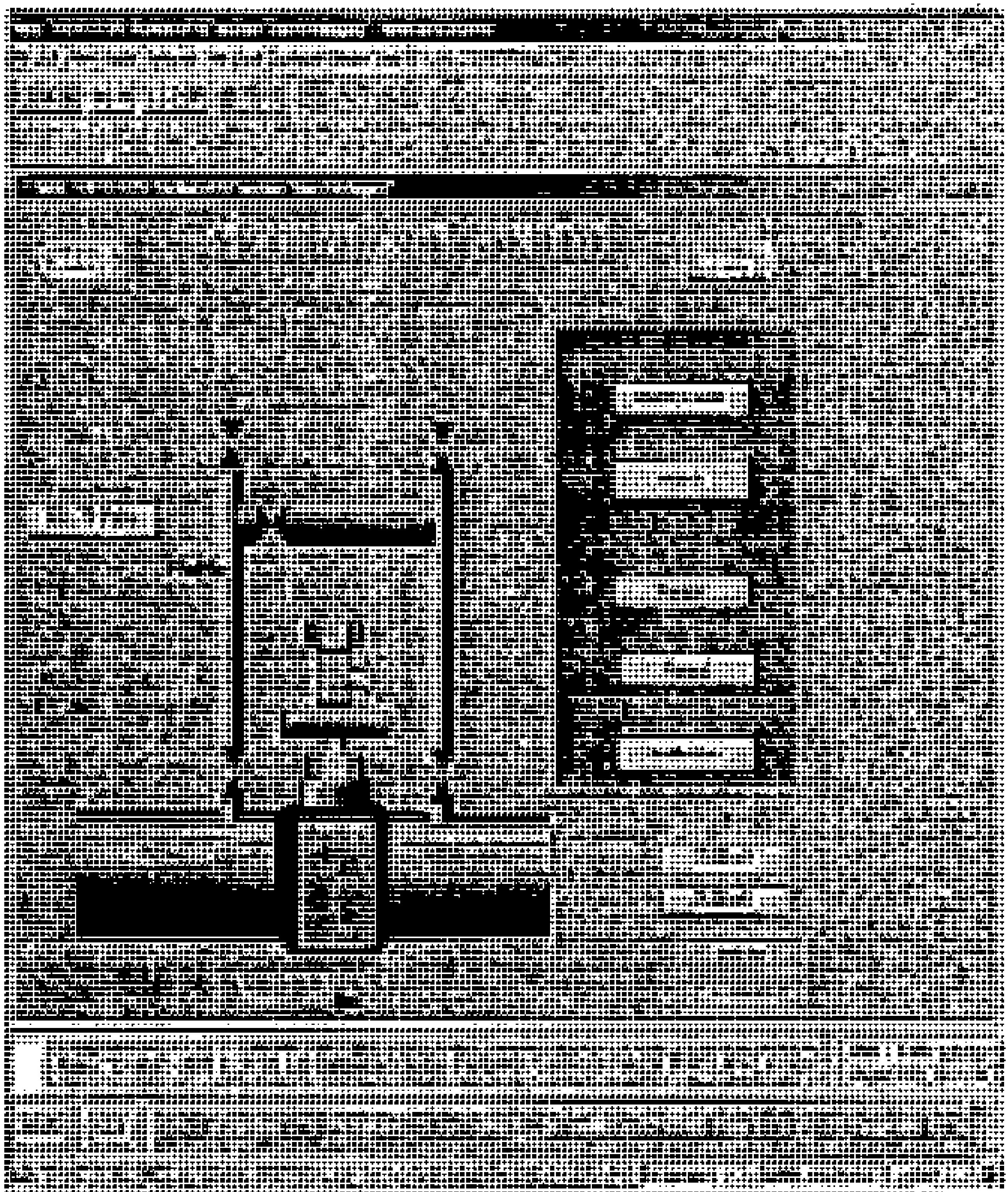


Figure B3: Screen Shot of CP Data at Kathlatta Valve Station by SCADA System

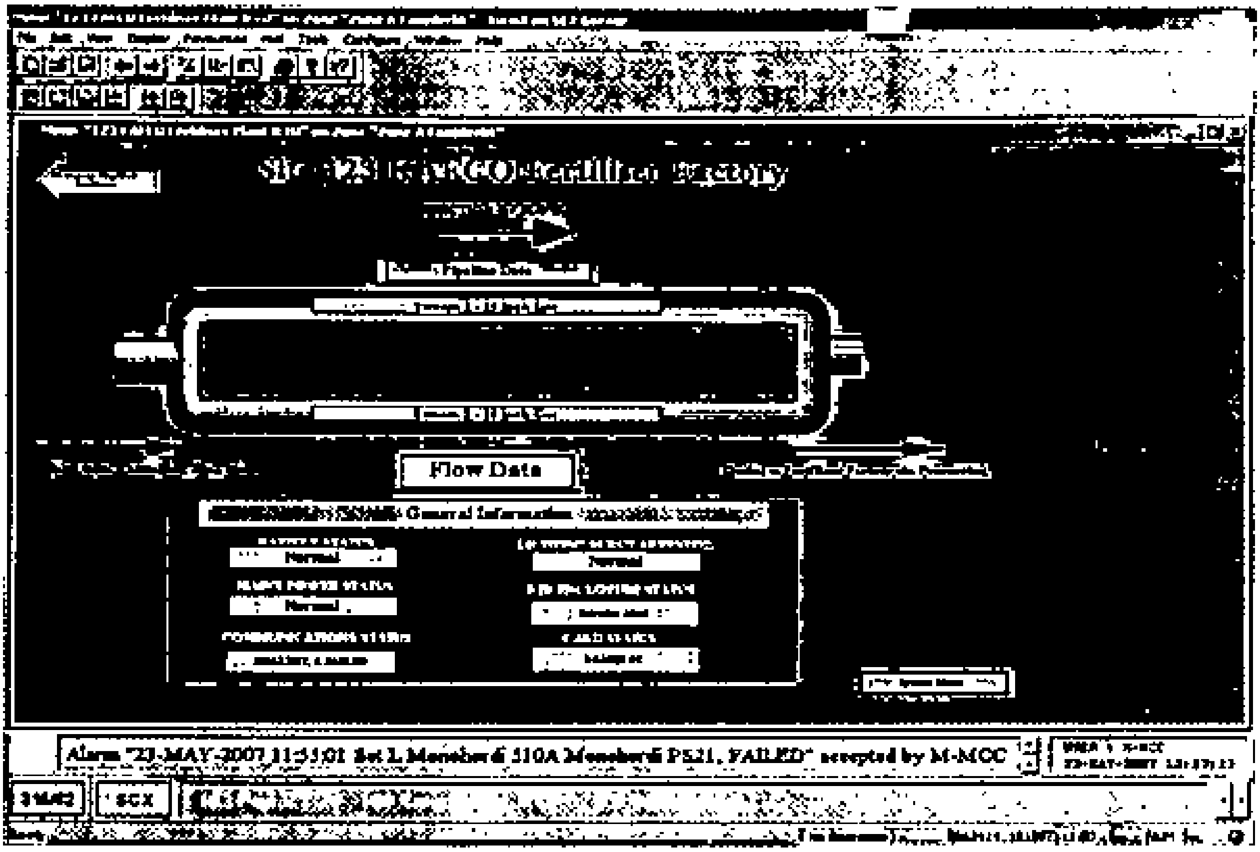


Figure B4: Screen Shot of RTU Status at KAFCO Fertilizer Factory by SCADA System

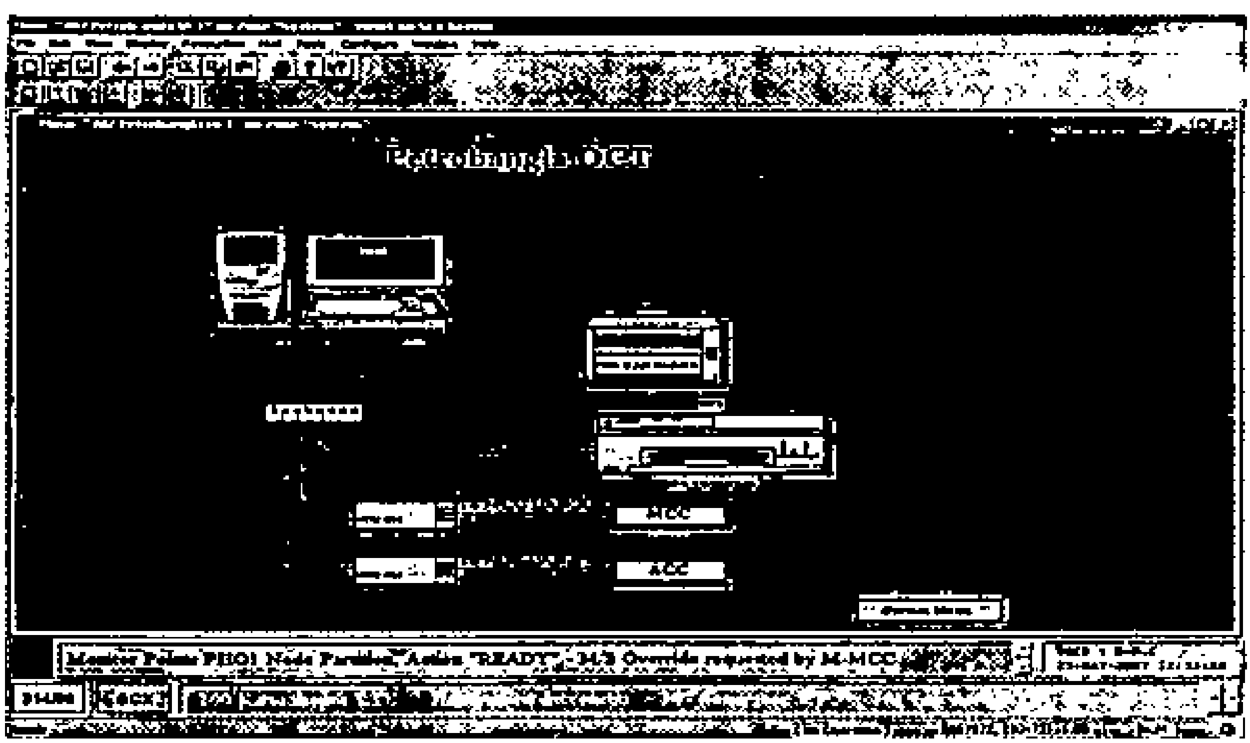


Figure B5: Screen Shot of Petrobangla OCT Status by SCADA System

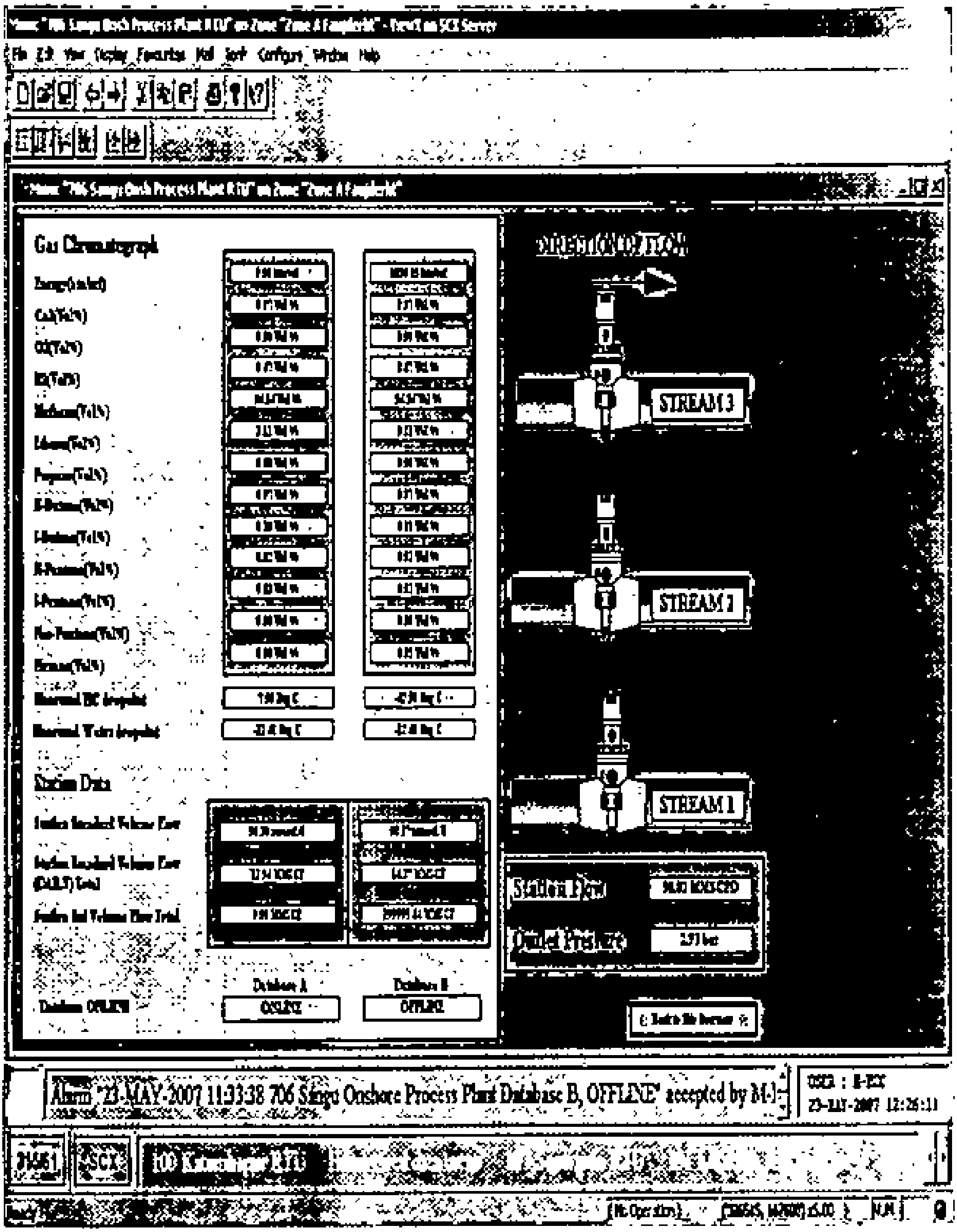
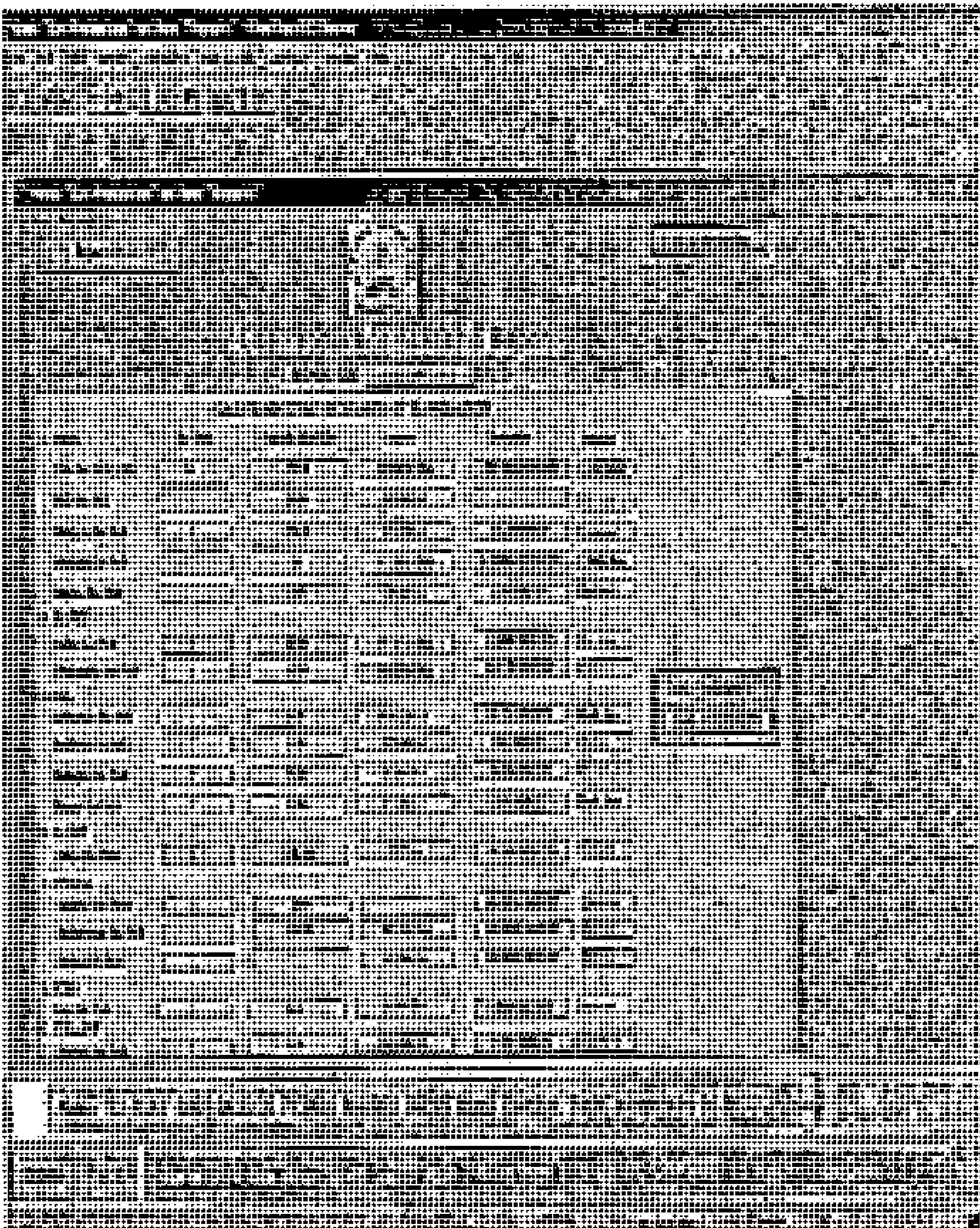


Figure B6: Screen Shot of Gas Chromatograph of Sangu Gas Field by SCADA System



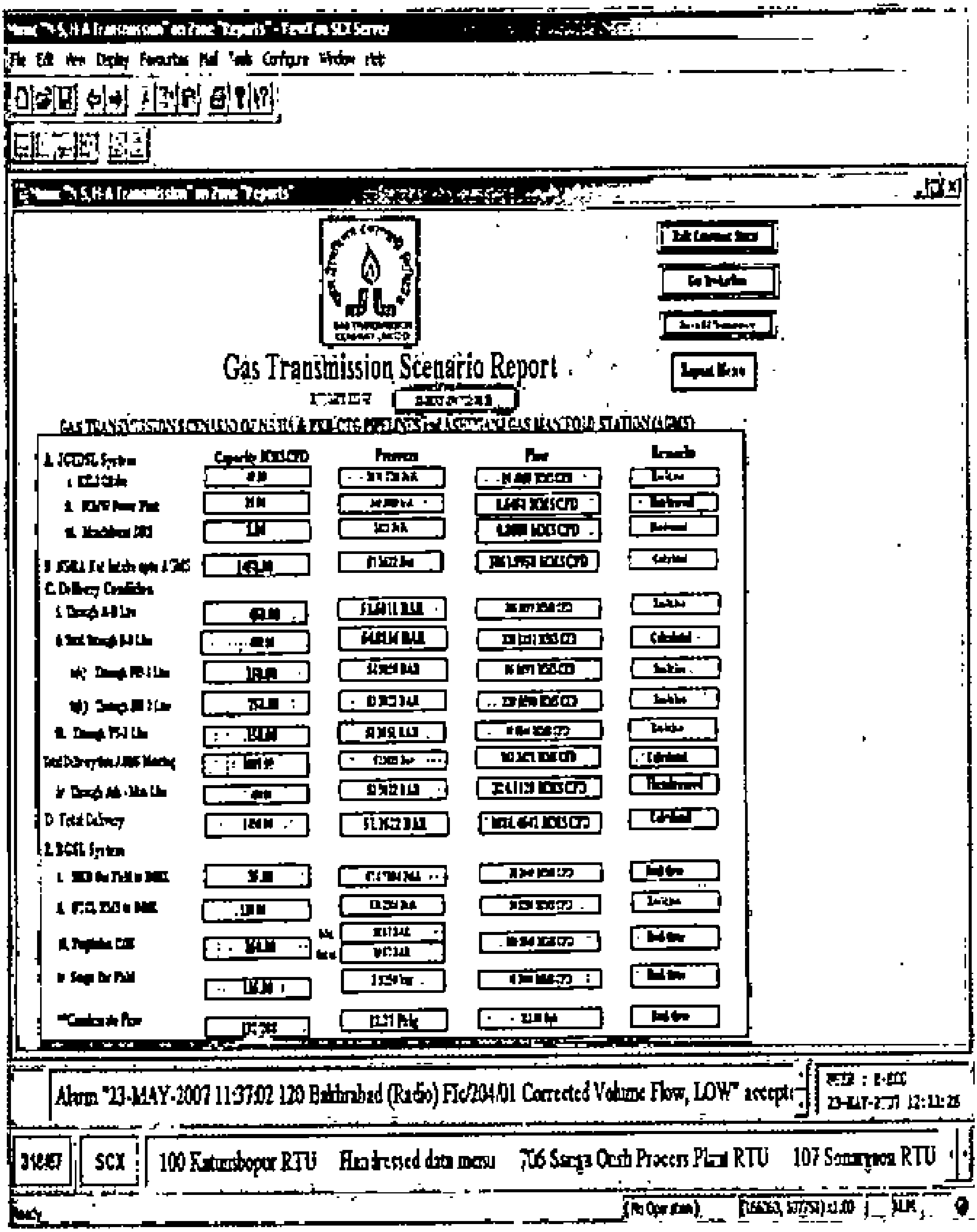


Figure B8: Screen Shot of Gas Transmission Scenario Report by SCADA System

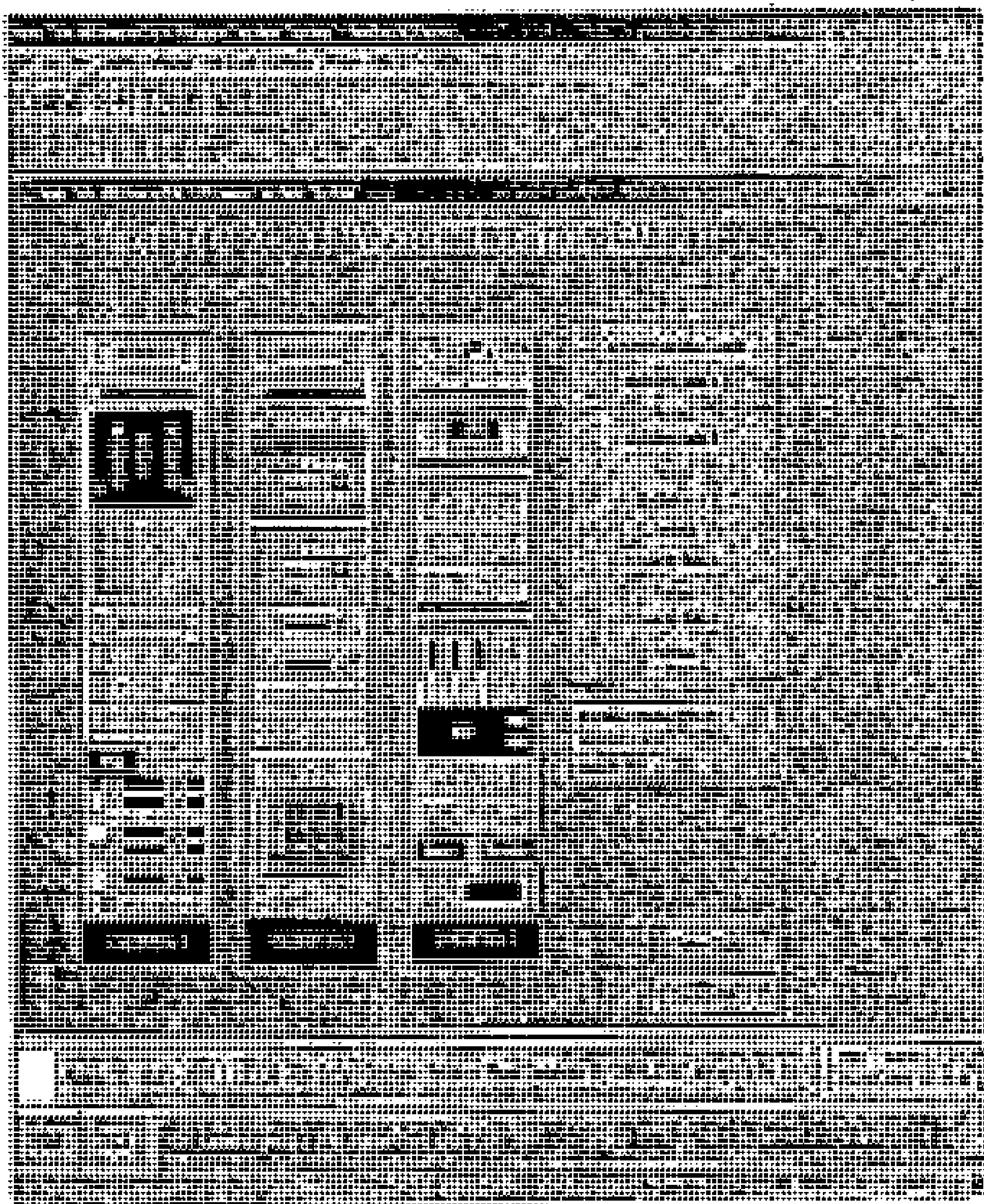


Figure B9: Screen Shot of Demra-BKB M/W Communications Status by SCADA System

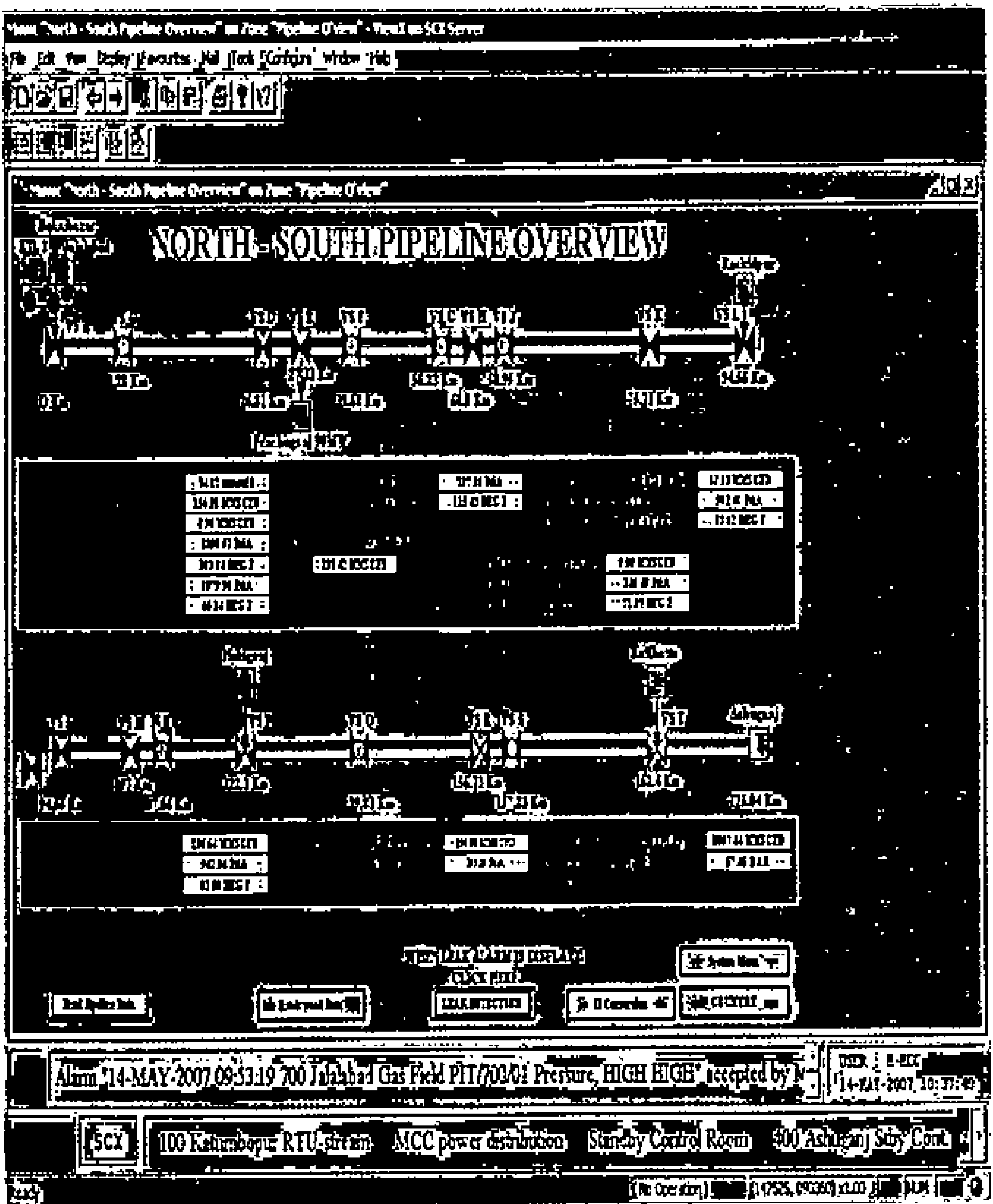


Figure B10: Screen Shot of North-South Pipeline Overview by SCADA System