Republic of Uzbekistan

SJSC UZBEKENERGO

Republic of Uzbekistan
Preparatory Survey on Navoi Thermal Power Station Modernization Project

Final Report

March 2013

Japan International Cooperation Agency (JICA)

Tokyo Electric Power Services Co., LTD

Table of Contents

Chapter 6 Basic Design

Chapter 7 System Analysis and Grid Connection Plan

Chapter 8 Environmental Social Consideration

Chapter 13 Workshop in Japan

Abbreviations

ADB	Asian Development Bank
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
C/P	Counterpart
CCCGP	Combined Cycle Cogeneration Plant
CCPP	Combined Cycle Power Plant
CDM	Clean Development Mechanism
Df/R	Draft Final Report
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
ES	Engineering Stage
EPC	Engineering, Procurement and Construction Contract
FIRR	Financial Internal Rate of Return
F/R	Final Report
F/S	Feasibility Study
GT	Gas Turbine
GTW	Gas Turbine World
HHV	Higher Heating Value
HP	High Pressure
HRSG	Heat Recovery Steam Generator
I&C	Instrumentation and Control
Ic/R	Inception Report
IP	Intermediate Pressure
IFC	International Finance Corporation
IPP	Independent Power Producer
ISO	International Standard Organization
JICA	Japan International Cooperation Agency
JSC	Joint Stock Company
LHV	Lower Heating Value
LP	Low Pressure
MW	Mega Watt

NOx	Nitrogen Oxide
NG	Natural Gas
NGO	Non-Governmental Organization
NHC	National Holding Company
O&M	Operation and Maintenance
ODA	Official Development Assistance
OEM	Original Equipment Manufacturer
PSS/E	Power System Simulator for Engineering
SJSC	State Join Stock Company
SOx	Sulfur Oxide
ST	Steam Turbine
TOR	Terms of Reference
TPP	Thermal Power Plant
USD	United States Dollar
VAT	Value Added Tax
W/S	Work Shop
WB	World Bank

Units

Prefixes

μ	:	micro- = 10^{-6}
m	:	milli- = 10^{-3}
c	:	centi- = 10^{-2}
d	:	deci- = 10^{-1}
da	:	deca- = 10
h	:	hecto- = 10^{2}
k	:	kilo- = 10^{3}
M	:	mega- = 10^{6}
G	:	giga- = 10^{9}

Units of Length

m	:	meter
mm	:	millimeter
cm	:	centimeter
km	:	kilometer
in	:	inch
ft	:	feet
yd	:	yard

Units of Area

cm^2	:	square centimeter
m^2	:	square meter
km^2	:	square kilometer
ft^2	:	square feet (foot)
yd^2	:	square yard
ha	:	hectare

Units of Volume

m^3	:	cubic meter
l	:	liter
kl	:	kiloliter

Units of Mass

g	:	gram
kg	:	kilogram
t	:	ton (metric)

lb	:	pound

Units of Density

kg/m^3	:	kilogram per cubic meter
t/m^3	:	ton per cubic meter
mg/m^3N	:	milligram per normal cubic meter
g/m^3N	:	gram per normal cubic meter
ppm	:	parts per million
μg/scm	:	microgram per standard cubic meter

Units of Pressure

kg/cm^2	:	kilogram per square centimeter (gauge)
lb/in^2	:	pound per square inch
mmHg	:	millimeter of mercury
mmHg abs	:	millimeter of mercury absolute
mAq	:	meter of aqueous
lb/in^2, psi	:	pounds per square inches
atm	:	atmosphere
Pa	:	Pascal
bara	:	bar absolute

Units of Energy

kcal	:	kilocalorie
Mcal	:	megacalorie
MJ	:	mega joule
TJ	:	tera joule
kWh	:	kilowatt-hour
MWh	:	megawatt-hour
GWh	:	gigawatt-hour
Btu	:	British thermal unit

Units of Heating Value

kcal/kg	:	kilocalorie per kilogram
kJ/kg	:	kilojoule per kilogram
Btu/lb	:	British thermal unit per pound

Units of Heat Flux

$kcal/m^2h$	:	kilocalorie per square meter hour
Btu/ft^2H	:	British thermal unit per square feet hour

Units of Temperature

deg	:	degree

°	:	degree
C	:	Celsius or Centigrade
°C	:	degree Celsius or Centigrade
F	:	Fahrenheit
°F	:	degree Fahrenheit

Units of Electricity

W	:	watt
kW	:	kilowatt
A	:	ampere
kA	:	kiloampere
V	:	volt
kV	:	kilovolt
kVA	:	kilovolt ampere
MVA	:	megavolt ampere
Mvar	:	megavar (mega volt-ampere-reactive)
kHz	:	kilohertz

Units of Time

s	:	second
min	:	minute
h	:	hour
d	:	day
y	:	year

Units of Flow Rate

t/h	:	ton per hour
t/d	:	ton per day
t/y	:	ton per year
m^3/s	:	cubic meter per second
m^3/min	:	cubic meter per minute
m^3/h	:	cubic meter per hour
m^3/d	:	cubic meter per day
lb/h	:	pound per hour
m^3N/s	:	cubic meter per second at normal condition
m^3N/h	:	cubic meter per hour at normal condition

Units of Conductivity

μS/cm	:	microSiemens per centimeter

Units of Sound Power Level

dB	:	deci-bell

Units of Currency

Sum	:	Uzbekisutan Sum
US$	:	US Dollar
¥	:	Japanese Yen

List of Tables

List of Figures

Summary

1. Preface

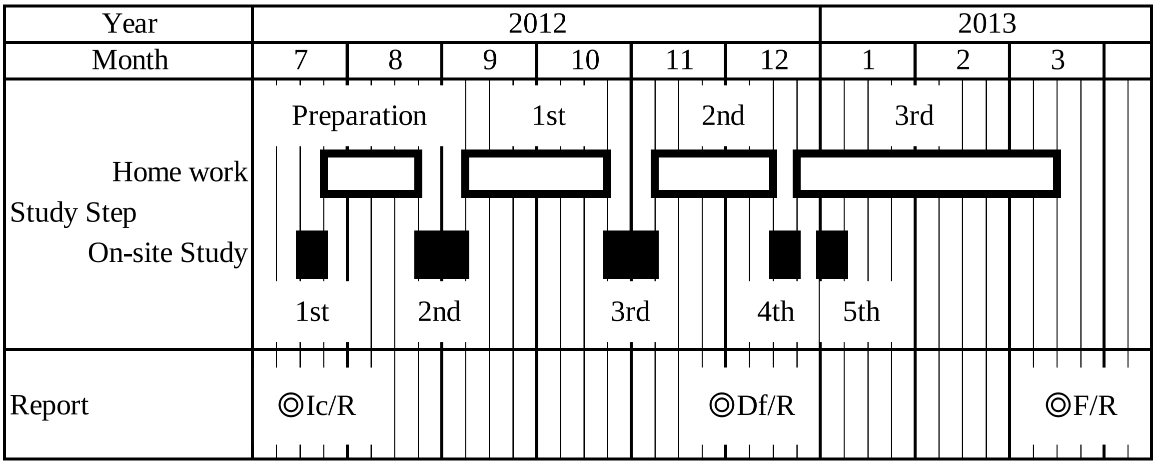
1.1 Purpose of Survey and Scope of Survey

1.1.1 Purpose of Survey

The purpose of survey consists in to carry out studies necessary for judging whether the introduction of “Navoi Thermal Power Plant Modernization Project (CCCGP No.2)”, for which the Government of Uzbekistan requests as an object of the yen loan is viable as an ODA project. The studies include the necessity of introduction, conceptual design, construction cost, implementation schedule, implementation (procurement and construction) methods, implementation structure, management and operation and maintenance systems and environmental and social considerations of the project.

1.1.2 Duration of the Study

Schedule of the Study is shown in Figure 1.1.2-1.



Source: Study Team

Figure 1.1.2-1 Schedule of the Study

2. Socio Economic Situation in Uzbekistan

2.1 Socio-economic Conditions

The mixture of mild population growth and urbanization characterizes the demography of Uzbekistan. The population of Uzbekistan reached 28 million in 2011. The total population grew at approximately 1% annually during the 2000’s. The country has the highest population density in Central Asia. The State Committee of the Republic of Uzbekistan on Statistics estimates that urban dwellers accounted for 51.4% of total population in 2011. In tandem with the growth of overall population, the labor force has been growing consistently.

2.2 Macroeconomic Conditions

A boom of international commodity markets such as cotton, gold and natural gas is one of the major factors behind strong economic growth in Uzbekistan. The GDP growth has exceeded 8%

since 2008. In addition to the boom in the commodity markets, the Uzbekistan government has supported investment in infrastructure for the recent years and this effort alleviates negative effects of a slowdown of the global economy. Based on the official figures, inflationary pressure has been tamed. An increase of consumer price was 6-8% per annum in the period from 2006 to 2010, more stable than in the early-2000s when inflation surpassed 20% annually. A rapid increase of the merchandize export in the 2000's was mainly due to the appreciation of commodity prices. As major export items in Uzbekistan are global commodities such as natural gas, cotton, and gold, the commodity boom in the last decade provided favorable terms of trade for export. Both the current account balance and the overall balance had been positive in the period from 2006 to 2010.

2.3 Government Finance and External debt

Strong economic growth, a boom in global commodity markets and tax reform contributed to the better performance of government revenue in recent years. Based on the official figures, the Uzbekistan government effectively controlled government expenditure within its revenue and maintained state budget surplus in the period from 2006 to 2010. The total debt outstanding and disbursed almost doubled from 2006 to 2010. Nevertheless, the external debt over GNI decreased in the same period. Uzbekistan has the second lowest external debt over GNI in Central Asia after Turkmenistan. Balance of payment data suggested that debt service accounted for 5.6% of the merchandize export and 23.9% of the trade surplus in 2010. This suggests that debt service is remained at a manageable level.

3. Overview of the power sector in Republic of Uzbekistan

3.1 Overview of power sector in the Republic of Uzbekistan

3.1.1 Overview of existing power generation facilities

In 2010, SJSC Uzbekenergo produced 50.158 GWh of electric power, of which 799.2 GWh was exported. In the same year, the SJSC Uzbekenergo imported 898.5 GWh of electric power.
The generation capacity of all the power generation facilities in the Republic of Uzbekistan exceeds 12,400 MW. The thermal power plants accounting for 85.1% and the hydraulic power plant accounting for 11.4% are run by the SJSC Uzbekenergo, and the remaining power generation facilities accounting for 3.5% are run by other organizations.

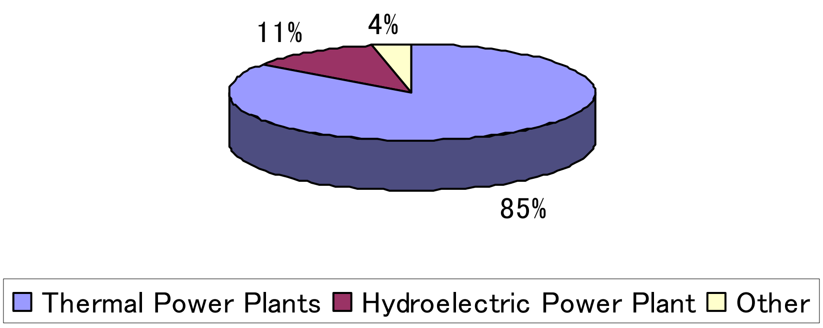


Figure 3.1.1-1 Share of Each Power Generation Capacity

The SJSC Uzbekenergo anticipates a substantial increase (around 1 to 2%) in electricity demand. To meet this growing demand, the company is planning to maintain the capacity of self support through introduction of new facilities, to improve the reliability and quality of power supply, to save power, and to enhance operation efficiency of fuel and power.

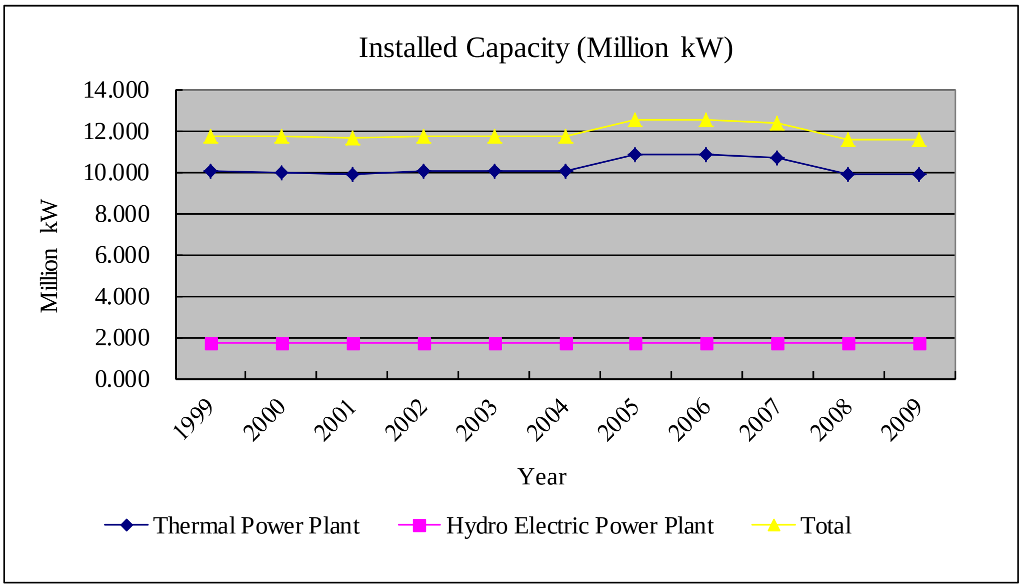
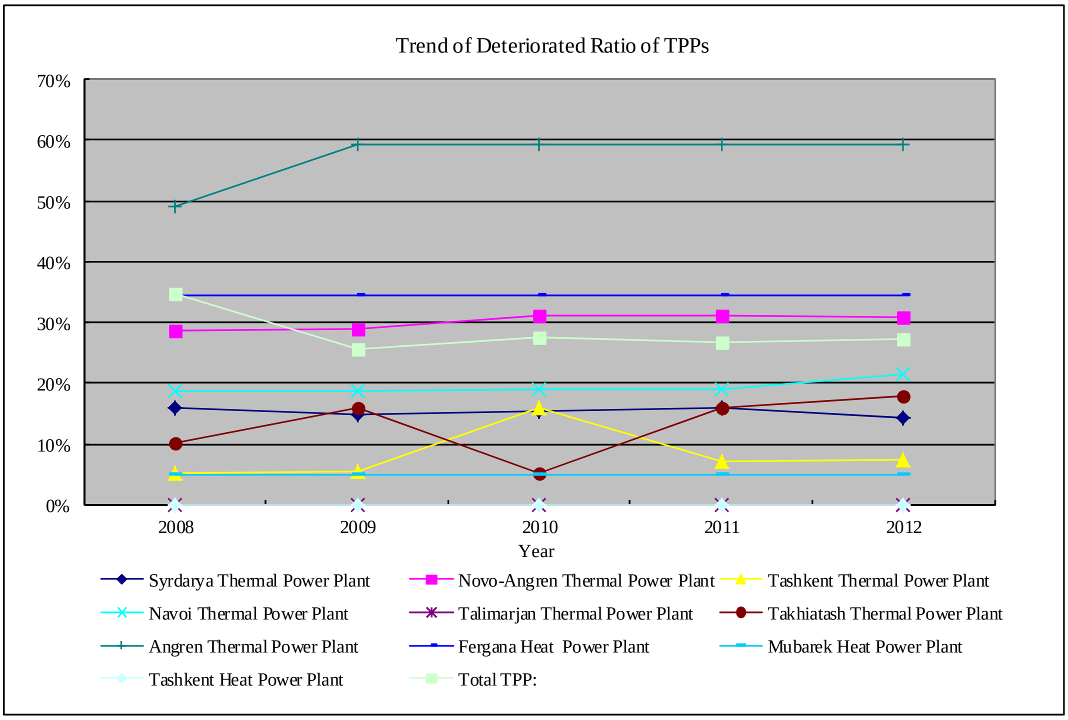


Figure 3.1.1-2 Transition of installed capacity of thermal and hydroelectric power plants

As shown in Figure 3.1.1-3, average deteriorated ratio (= (Installed capacity – Available capacity)/Installed capacity x 100) shows around 30%, that is, one third of installed capacity was lost. Largest deteriorated thermal power plant is Angren thermal power plant which shows around 60% of deteriorated ratio, that is, more than half of installed capacity was lost. Recovery of this lost capacity is urgent issue in power sector in Uzbekistan.



Source: SJSC Uzbekenergo

Figure 3.1.1-3 Transition of Deteriorated Ratio of the Existing TPPs

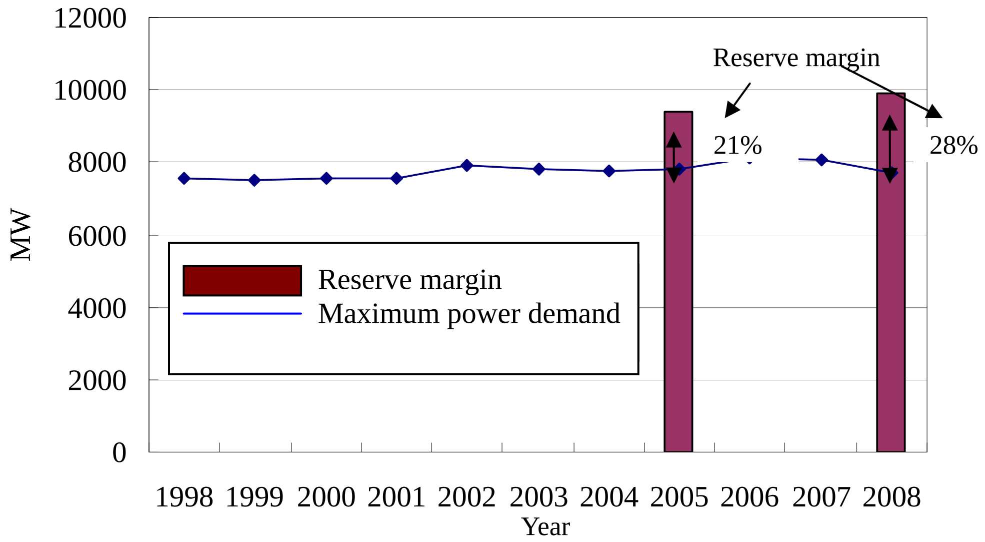
3.1.2 Overview of power transmission facilities

(1) Power grid system

The power grid system in the Republic of Uzbekistan was constructed at the time of the former Soviet Union, where five countries including Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan were assumed as constituting one integral area. Thus, after independence of each country, the power grid system constitutes an international linkage system. The 500 kV transmission line is also linked to Russia via Kyrgyzstan and Kazakhstan. Thus, the power grid system is characterized by a large scale system and operation of stable frequency. The 500 kV and 220 kV lines are used in the trunk network, and the 110 kV lines serve for local supply systems. The vast majority of the trunk network consists of one-circuit transmission lines. The outage at the time of transmission line trouble is minimized by parallel operation of the 500 kV and 220 kV circuits.

3.1.3 Power demand

Figure 3.1.3-1 shows the transition of the generation and consumption of power in the last 5 years. The overall demand for electric power in the Republic of Uzbekistan had exhibited annual reduction for ten years after independence in 1991 due to economic confusion and stagnation of industrial activities. However, economy has been on an upward trend after that, and the overall demand for electric power is also on an upward trend, even though this trend is very slow.



Source: SJSC Uzbekenergo

Figure 3.1.3-3 Transition of the imported and exported electric power in the last ten years

3.1.4 Power generation development plan

According to Power Generation Development Plan up to 2015 made by SJSC Uzbekenergo; expansion of the Talimarjan thermal power plant, expansion of the Navoi thermal power plant, expansion of the Novo-Angren thermal power plant and modernization of the Tashkent heat supply power plant are approved as the important projects for electric power development in that time period. For the funds of these projects, the SJSC Uzbekenergo depends mainly on the loans from JICA and other international cooperation agencies.

Table 3.1.4-1 Power generation development plan up to 2015

No.	Name of plants	Type of plants	Installed capacity, MW	Type of fuel	Year of launching
1	Construction of CCGT at Navoi TPP	Combined cycle gas turbine	478	Natural gas	2012
2	Construction of gas turbine plant at Tashkent Heat Power Plant	Gas turbine plant	3x27	Natural gas	2013-2015
3	Construction of two CCGT at Talimarjan TPP	Combined cycle gas turbine	2x450	Natural gas	2014
4	Construction of power generating unit at Angren TPP	Thermal power plant	150	Coal	2014
5	Construction of CCGT at Tashkent TPP	Combined cycle gas turbine	370	Natural gas	2014
6	Expansion of Mubarek Heat Power Plant with installation	Gas turbine plant	140	Natural gas	2014

No.	Name of plants	Type of plants	Installed capacity, MW	Type of fuel	Year of launching
	of GTP				
7	Expansion of Navoi TPP with installation of second CCGT unit	Combined cycle gas turbine	450	Natural gas	2015

(Note) TPP: Thermal Power Plant, CHP: Combined Heat and Power
Source: SJSC Uzbekenergo

3.1.5 Power demand forecast

SJSC Uzbekenergo planned power generation by their Thermal Power Plant from 2012 to 2020 is shown in Table 3.1.6-1. During the term its growth rate will be around 1.0% per year.
As described in item 3.1.2, the available capacity of the existing thermal power plants is reduced to 70% of their installed capacity in 2012. Therefore, new installation or modernization of power plant is necessary to cover such gap between maximum power demand and available capacity. On the other hand, 2,569MW generation capacity is planned to be developed, as shown in Table 3.1.5-1. This figure includes the capacity by replacement of the existing power plants. Therefore, to keep the stability of power supply to correspond to increasing power demand, it is necessary to implement said power generation development plan steadily.

Table 3.1.5-1 Power Demand Forecast up to 2020

Unit: Billion kWh

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electric Power Demand	50.5	50.7	51.2	51.7	52.2	52.7	53.3	53.8	54.4
Growth Ratio (vs. previous year)	-	0.40%	0.99%	0.98%	0.97%	0.96%	1.14%	0.94%	1.12%

Source: SJSC Uzbekenergo

3.2 Electricity and Heat Tariff

Tariff reform brought a significant reduction of cross-subsidy to the power sector by the mid-2000s. Since then, tariff structure has been economically rational. On retail prices of electricity, Uzbekenergo submits a tariff petition to the Ministry of Finance which reviews and approves electricity tariff. The retail prices of electricity have been revised twice or three time each year during the period of 2010-2012. The data obtained from SJSC Uzbekenergo show that average price of electricity tariffs has margin over production cost which includes fuel cost, maintenance cost, depreciation and interest payment. With the current level of electricity tariff, it is plausible that SJSC Uzbekenergo obtains revenue sufficient for both investment and operation costs for power generation.

On the wholesale and retail prices of heat, tariff is revised every year. Based on the data obtained from SJSC Uzbekenergo, heat revenue surpassed production cost including fuel cost, maintenance cost, depreciation and interest payment. It is concluded that heat tariff is at or above cost recovery level. Navoi TPP, a subsidiary of SJSC Uzbekenergo, submits a tariff petition to the Ministry of Finance with production cost data once a year. Navoi TPP made profit from heat production in the period of 2007-2010. This may imply that heat production covered production costs required directly for its operation.

4. Survey of Navoi Power Plant Facilities

4.1 Site situation

4.1.1 Site selection

The planned candidate construction site for the CCCGP No.2 (450MW) power plant is adjacent to the Navoi thermal power plant approximately 7 km northwest of Navoi city (city hall).
The candidate construction sites selected for a new power plant are two sites (candidate sites A and B) adjacent to the existing Navoi thermal power plant.
Candidate site A is situated in the area adjacent to the west side of the CCCGP No.1 currently under construction in the west of the existing Navoi thermal power plant.
Candidate site B is situated in the area adjacent to the north side of the existing Navoi.
It must be examined which of the candidate construction sites, A or B, are more suited as a candidate site for the CCCGP No.2 (450MW) power plant.
As the result of examining of the candidate construction site, site A is superior to candidate site B as a candidate construction site for a new power plant.
Thus, candidate side A is recommended as a construction site for a new power plant.

4.1.2 Site condition

In the planned construction site for CCCGP No.2 (candidate site A), approximately 9 hectares of the site required for power plant construction has been prepared almost completely.
However, the transmission lines of the four series and their foundations have not been removed.
Thus, the transmission lines of the four series and their foundations must be removed or relocated.

4.2 Existing facilities

4.2.1 Overview of the existing equipment in Navoi Thermal Power Station

(1) Configuration of Power and Heat Supply System

The overview of the existing power and heat supply system of Navoi Thermal Power Station is as shown in Figure 4.2.1-1.

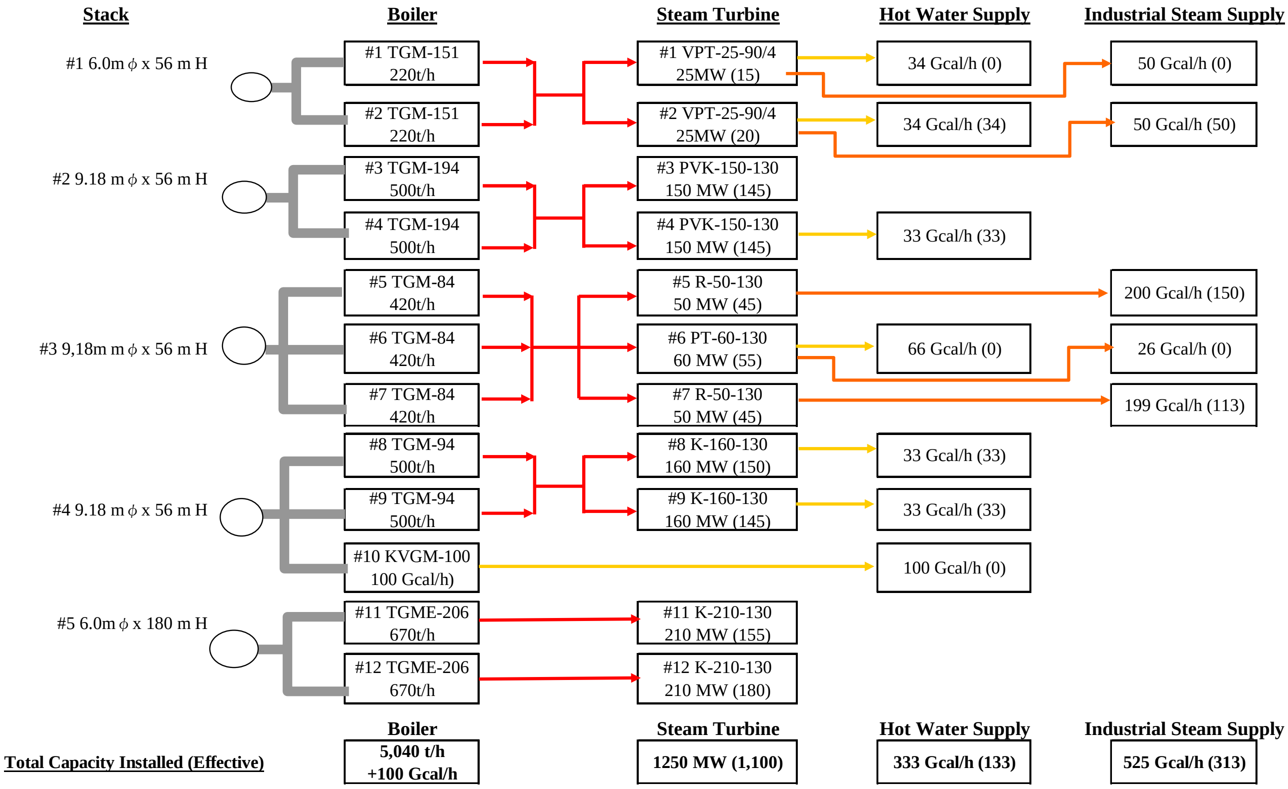


Figure 4.1.2-1 Heat and power supply system of Navoi Thermal Power Station

4.2.2 Situation of the existing equipment

Power generation units of Navoi Thermal Power Station consist of 12 boilers, 11 turbines, and 11 generators, and, the amount of rated generating steam is 5,040t/h and the rated power generation output is 1,250 MW. Operation of Unit No.1 was commenced in 1963 and 49 years have passed. Total operation hours of the units until now are about 220,000 to 360,000 hours, and degradation by operation is also progressing considerably in addition to aged deterioration.

Table 4.2.2-1 Operating Record of Navoi Thermal Power Plants

Unit №	Type of Plant	Installed (Effective) Capacity			Start-up Year	Operating Hours	Service Factor (%)$^{(1)}$
		Power (MW)	Heat Supply (Gcal/hr)				
			Hot water	Industrial steam			
1	Heat and Power	25 (15)	34 (0)	50 (0)	1963	316,680	73.7
2	Heat and Power	25 (20)	34 (34)	50 (50)	1963	362,468	84.4
3	Power	150 (145)	-	-	1964	349,172	83.0
4	Heat and Power	150 (145)	33 (33)	-	1965	308,577	74.9
5	Heat and Power	50 (45)	-	200 (150)	1966	339,774	84.3
6	Heat and Power	60 (55)	66 (0)	26 (0)	1967	311,919	79.1

Unit №	Type of Plant	Installed (Effective) Capacity			Start-up Year	Operating Hours	Service Factor (%)[1]
		Power (MW)	Heat Supply (Gcal/hr)				
			Hot water	Industrial steam			
7	Heat and Power	50 (45)	-	199 (113)	1971	314,936	87.6
8	Heat and Power	160 (150)	33 (33)	-	1968	326,414	84.6
9	Heat and Power	160 (145)	33 (33)	-	1969	317,604	84.3
10	Heat	-	100 (0)	-	1972	238,353	68.0
11	Power	210 (155)	-	-	1980	231,961	82.7
12	Power	210 (180)	-	-	1981	222,739	82.0
Total	-	1,250 (1,100)	333 (133)	525 (313)	-	-	-

Note (1): Averaged Service Factor (%) = The total operating hours/the total calendar hours from start-up to present time ×100.

5. Fuel Supply Plan

5.1 Natural gas reserves in Uzbekistan

The proven natural gas reserves in Uzbekistan register an abundant figure of 1.603 trillion cubic meters (hereinafter referred to as "Tcm"), as of December 2011. The gas fields are concentrated in the Amu Darya Basin in the southwest of the country and in the Central Ustyurt plateau in the west of Aral Sea.
The following illustrates the transition of the proven natural gas reserves in Uzbekistan:

Table 5.1-1 Amount of proven natural gas reserves in Uzbekistan

Unit: Tcm

	At end 2001	At end 2010	At end 2011
Proved reserves	1.700	1.600	1.603

Source: BP Statistical Review of World Energy 2012

Table 5.1-2 shows the natural gas development projects in Uzbekistan. The development of these gas fields are expected to increase the proven natural gas reserves in Uzbekistan.

Table 5.1-2 Natural gas development projects in Uzbekistan

Field	Target production volume	Target reserves
Southwest Gissar and central Ustyurt region (7 fields)	3 Bcm/year	0.1Tcm
Western Ustyurt region (4 fields)	-	1Tcm
Khauzak and Kandym fields in Bukhara-Khiva and Gissar regions	4 Bcm/year	0.25Tcm
Aral Sea Surgli field	0.08 Bcm/year	-
Surkhandarya region Baisun field	2.2 Bcm/year	-
West Urga / Western Ustyurt region (3 fields)	0.7 Bcm/year	-

Source: Global Insight IEA and trade press

5.2 Possibility of gas supply to CCCGP No.2

An agreement was signed with the JSC Uztransgaz for the supply of the natural gas of the Navoi Thermal Power Plant. The agreement between the Navoi Thermal Power Plant and JSC Uztransgaz for the supply of natural gas is updated every year. The annual contracted volume for 2012 is 2,876.080million m^3N/year.

At present, the Navoi Thermal Power Plant uses two types of natural gas; a natural gas containing sulfur content and a natural gas hardly containing sulfur. CCCGP No.2 is planning to use the natural gas that hardly contains the sulfur contents used in CCCGP No.1. The volume that can be supplied amounts to 419,300m^3N/h (450,000m^3/h at 20 degrees Celsius).

The natural gas is supplied from the Zevarda gas field and the Kultak gas field located in the Amu Darya Basin in the south of Uzbekistan to the Navoi Thermal Power Plant. The natural gas produced in the Zevarda gas field and Kultak gas field is refined in the Mubarek Gas Processing Plant, and then is supplied to the Navoi Thermal Power Plant through the Navoi Gas Distribution Station.

The natural gas used in CCCGP No.1 and CCCGP No.2 can be supplied in the volume of 419,300m^3N/h By contrast, a total of natural gas consumption in CCCGP No.1 and CCCGP No.2 is 189,057m^3N/h. This shows that the natural gas can be supplied to the Navoi Thermal Power Plant.

5.3 Order of priority for gas supply in the event of gas insufficiency at the Navoi Thermal Power Plant

There has been no public disclosure of the proven natural gas reserves and production volume in the Zevarda gas field and Kultak gas field that supply natural gas to the Navoi Thermal Power Plant. Since supply of electricity and hot water is essential to public life, the Government of Uzbekistan is required to ensure that natural gas is supplied to the Navoi Thermal Power Plant on a priority basis. Should there be any shortage of natural gas supply to the Navoi Thermal Power Plant; CCCGP No.2 will be operated on a priority basis as it is characterized by high power generation efficiency and capable of generating a greater volume of heat.

6. Basic Design

6.1 Conceptual Design

6.1.1 Design Conditions

Design conditions shall be specified to complete the feasibility study for this project. However, all the detailed design conditions are still undecided because of less time schedule for discussion and study during the period of preparation of the feasibility study. Some design conditions may be tentatively specified or assumed at this feasibility study stage and will be revised or finalized at the further detailed design stage of this project. As for the design conditions necessary for completion of the feasibility study on Navoi Thermal Power Plant Modernization Project, the table 6.1.1-1 in the body text shall be referred to.

6.1.2 Outline of Cogeneration System

This plant is a combined cycle cogeneration plant (CCCGP) which concurrently produces both heat and power energies. The plant is comprised of main components of a gas turbine, a gas turbine generator, a HRSG with a supplementary duct firing facility, a steam turbine, a steam turbine generator, a fuel gas compressor station, a water pre-treatment facility for export steam, a water pre-treatment facility for export hot water and a hot water production system.

The plant shaft configuration is of multi-shaft type where the gas and steam turbine shafts are separated.

The gas turbine is of a large capacity F class type which is available in the world market with a wealth of commercial operating experience.

The HRSG is of triple-pressure and reheat cycle type. The F class gas turbine is commonly coupled with the triple-pressure and reheat cycle HRSG to elevate the plant thermal efficiency.

The HRSG is equipped with a supplementary duct firing facility to meet the heat and power output requirements of this project.

The steam turbine is of triple-admission, dual-extraction of medium and low pressure steams and condensing type. The medium pressure steam is extracted from the IP steam turbine section and exported to adjacent companies as industrial steam as it is. The low pressure steam from the LP steam turbine section is supplied to the production system of the district hot water.

The hot water production system consists of a water storage tank, water pre-treatment facilities, deaeration facility, steam to water heat exchangers and a hot water storage tank.

The Figure 6.1.2-1 is the simplified schematic diagram of the combined cycle cogeneration plant of this project

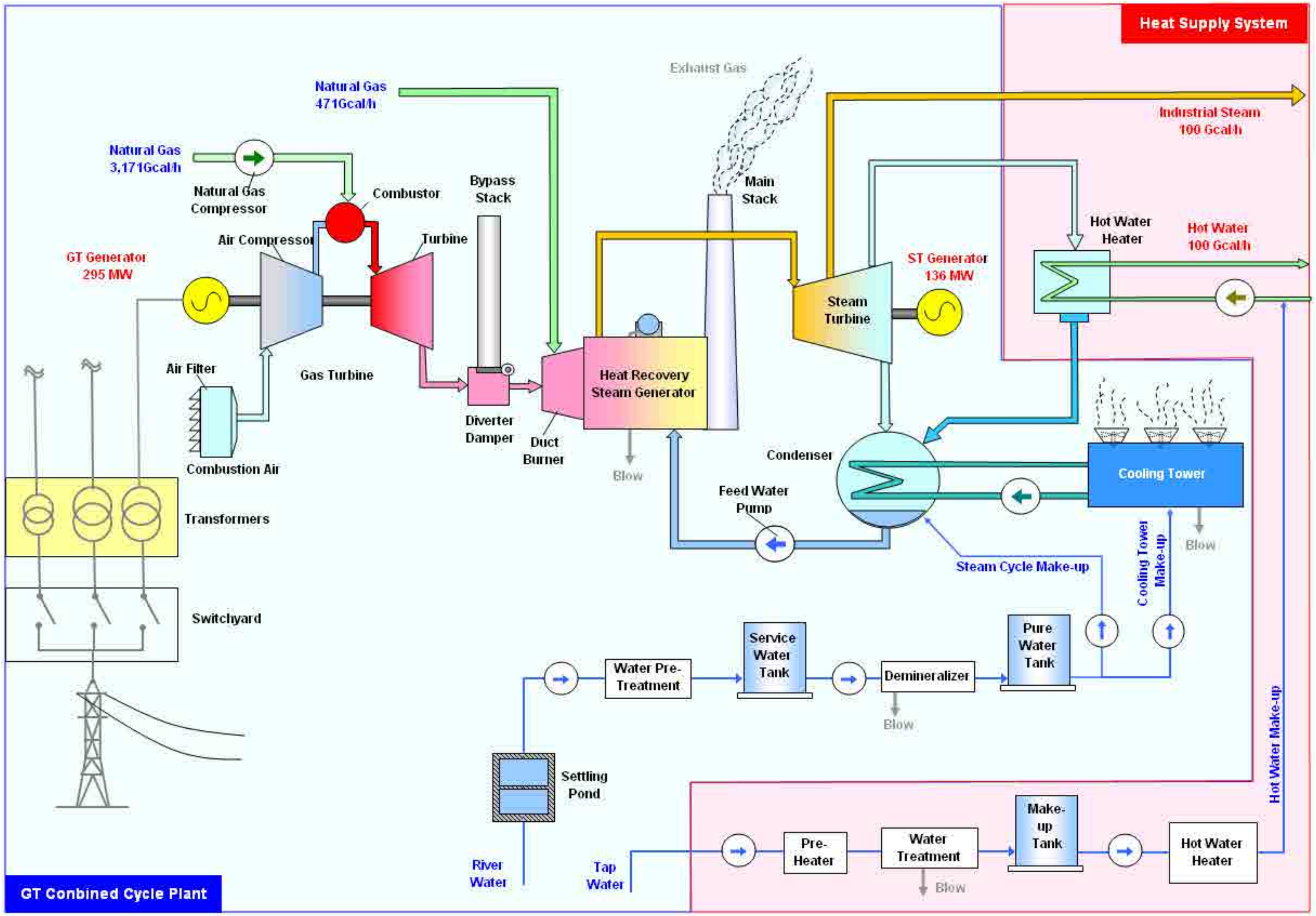


Figure 6.1.2-1 Simplified Schematic Diagram of Total Cogeneration System

6.1.3 Study on Shaft Configuration

The shaft configuration was studied and four (4) types of shaft configurations were compared from various points of view. The details of comparison process and results are described in the final report.

Since the first priority is given to the operational flexibility (simple cycle operation) and operating reliability (hour basis), the multi-shaft CCPP with the bypass system can be recommended.

6.2 Scope of the Project

The scope of this Project includes the design, manufacture, transportation and delivery to the Site, construction at the Site, testing and commissioning, and maintenance for a period of one (1) year after Taking Over of the plant herein described.

The combined cycle cogeneration plant to be installed shall be of nominal 450MW highly efficient combined cycle block in a one on one multi-shaft configuration comprising one (1) low-NOx gas turbine, one (1) triple pressure reheat, indoor type heat recovery steam generator (HRSG) equipped with duct firing burners, one (1) reheat, two-extraction, condensing type steam turbine, two (2) electric generators, and miscellaneous auxiliary equipment.

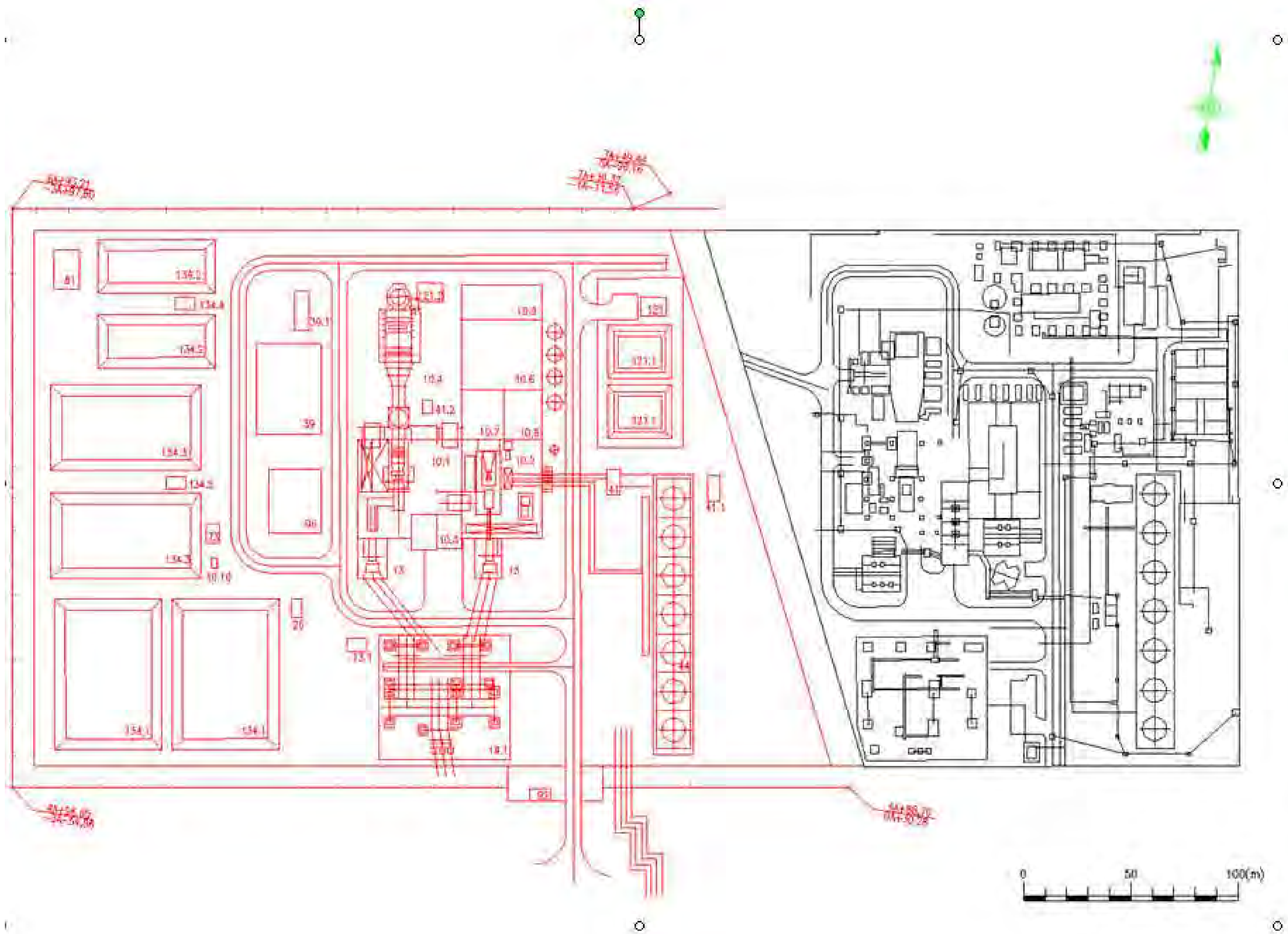
The facility and equipment, as described herein, shall include the following:

(1) Power generation equipment
(2) Transmission Lines and Substation
(3) Heat supply system
(4) Mechanical Equipment of Auxiliaries and Balance of Plant (BOP)
(5) Electrical Equipment of Auxiliaries and Balance of Plant (BOP)
(6) Civil and Building Works
(7) Environmental
(8) Tools, Spare parts, consumable, etc.

6.3 Plot Plan

Candidate site is situated in the area adjacent to the west side of the CCCGP No.1 in the west of the existing Navoi thermal power plant.

The conceptual arrangement of CCCGP No.2 is as shown in below.



Number	Equipment/Facility Name
	[10. Main Building]
10.1	Gas turbine
10.2	Steam turbine
10.3	Electrical equipment
10.4	Heat recovery steam generator (HRSG)
10.6	Water treatment and wastewater treatment
10.7	Deaerator, Boiler feed water pump, condensate make-up pump, and chemical dosing pump
10.8	Heater and deaerator for hot water supply system
10.9	Utility building
10.10	Emergency turbine lubrication tank (underground)
11.	Stack
13.	Step-up transformers (GT & ST)
19.1	220 kV switchyard
26.	Emergency diesel generator
39.	Natural gas boost-up compressor
39.1	Natural gas distribution station
41.	Circulating water pump station
41.1	Cooling tower blow down tank
41.2	Drainage pump
44.	Cooling tower (7 units)
73	Air compressor with receiver
81.	Electro hydraulic control (EHC) station
92.	Security gate
96.	Oil storage (oil in packages)
121.	Fire pump station
121.1	Reserve water tanks for fire fighting (2 tanks)
121.2	Boost-up station for fire fighting
	[134. Sludge dump area for waste water treatment system]
134.1	Evaporating pond for hot water heater chemical wash
134.2	Sludge dump for oil contaminated water (2 sections)
134.3	Sludge dump for waste water treatment (2 sections)
134.4	Treated water return pump station for oil contaminated water
134.5	Pump station for chemical water treatment

Figure 6.3-1 Plot plan

6.4 Basic Systems for Plant Design

6.4.1 Gas Turbine System

The gas turbines shall be of single shaft configuration, open cycle, heavy duty F class temperature level type with dry low NO_x design suitable for the specified natural gas.

6.4.2 Steam Turbine System

The steam turbine shall be of a reheat, three-admission, two-extraction, two-casing, condensing type directly connected to the generator. The steam shall be downward exhausted to a surface condenser which is cooled by fresh circulating water which is in turn cooled with a mechanical draft wet type cooling tower. The steam turbine shall be of a three (3) pressure-level turbine with HP, IP and LP sections. The medium pressure level of steam may be extracted from the IP section for export to adjacent industrial companies. The low pressure level of steam may be extracted from the LP section for production of hot water for district heating.

6.4.3 Heat Recovery Steam Generators and Auxiliaries

One Heat Recovery Steam Generator (HRSG) associated with one gas turbine generator of combined cycle block will be installed. The HRSG shall be of the fired, three-pressure, natural or forced circulation, reheat type of proven design in accordance with the requirements of internationally recognized codes and standards, where applicable.

The HRSG shall be designed to operate on the exhaust gas of the gas turbine fired with natural gas. Furthermore, the HRSG shall be designed to operate with a duct burning system fired with natural gas.

6.4.4 Heat Supply System

Supply of processing steam for neighboring industries (industrial steam supply) and supply of hot water for district heating (hot water supply) shall be carried out, using two adjustable steam extractions from the steam turbine of CCCGP No. 2.

In accordance with Preliminary Feasibility Study of the project, the capacities of the industrial steam supply and the hot water supply are 230 Gcal/h and 120 Gcal/h respectively. However, the Study Team would like to recommend that the capacities should be 100 Gcal/h and 100 Gcal/h in order to maintain the reliability of the heat supply systems in cooperation with the existing heat supply systems.

6.4.5 Water Treatment Plant

A complete water treatment system comprising water settling ponds, water pre-treatment plant, and demineralized (DM) water plant shall be provided to supply the make-up water required for the steam turbine and HRSG cycle of CCCGP No. 2. Since the industrial steam is extracted from the steam turbine and consumed in the neighboring chemical companies, its make-up water needs to be provided through the demineralized water plant.

On the other hand, the make-up water of hot water, of which water quality is different from of the demineralized water, shall be provided through the other water treatment facilities in the hot water supply system as described in Section 6.4.4 “Heat supply system”.

The consumptions of demineralized water and pre-treated water are estimated as 19,050m^3/day and 20,990m^3/h respectively. The raw water of 20,990m^3/day is supplied from the Zarafshan River. The consumption of city water is 6,045m^3/day, among which 6,000m^3/day is used for the hot water make-up water and 45m^3/day is used for the potable water.

6.4.6 Fuel Gas Supply System

Natural gas is used as the fuel for CCCGP No.2 as well as CCCGP No.1. The natural gas is supplied to the Navoi Thermal Power Plant from the Navoi Gas Distribution Station through two pipeline systems having a diameter of 720 mm.
This required pressure level is approximately 3 through 5MPa although this value differs according to each gas turbine manufacturer. Since the operation of the gas turbine depends on the fuel gas compressor, it is recommended to install a total of two fuel gas compressors including one spare, similar to the case of CCCGP No.1.

6.4.7 Electrical Equipment

The electrical system will be designed on the basis of the multi shaft configuration of the having two (2) generators, Gas Turbine Generator and Steam Turbine Generator and two (2) generator step-up transformers, Gas Turbine Transformer and Steam Turbine Transformer. The voltage of the power output from the gas turbine and steam turbine generators will be stepped up to 220kV via GT step-up transformer and ST step-up transformer. The output from these two GT transformers and ST transformer is merged and transmitted to the 220kV substation. The bus switching arrangement utilizes double bus and one circuit breaker with transfer bus scheme.

6.4.8 I&C Equipment

All control and monitoring functions necessary for startup, normal operation and shutdown of the CCCGP shall be provided in Central Control Room (CCR) The CCR will be normally manned. Operator Workstation with Human Machine Interface (HMI) and a microprocessor based Distributed Control System (DCS) including redundant controllers using a plant-wide redundant communication highway shall be provided to allow the operators to control CCCGP and to receive monitoring and alarm information.

6.4.9 Civil engineering and architectural facilities

The following lists up the planned CCCGP No.2 structures and buildings:

Table 6.4.9-1 List of planned CCCGP No.2 structures and buildings

No.	Names of buildings and structures
10a	Main building consisting of:
10a-1	- gas-turbine unit room
	- steam turbine room
10a-2	- insertion for GCP (general control panel) and electrical devices
10a-3	- stack of electrical devices (under CACI (complex air-cleaning installation))

10a-4	- area for steam boiler-utilizer - chimney - tank farm of CWT (chemical water treatment)
10a-5	- Gas unit
10a-6	- building of Chemical water treatment (CWT) and Integrated industrial effluent treatment (IIET) - area for tank farm Set of washing equipment - tank farm:
10a-7	- deaerator room with feed water pump and chemicals dosing system
10a-8a	- boiler room with heating system deaerator
10a-9a	- engineering and residential building
13a	Open installation of transformers with rerolling ways
	- oil collector (underground based) for collecting accident-related oil from the transformers
	- capacity of accidental discharge of turbine oil
	- network of accidental oil runoffs
19a	ODU-220 kV
19b	Bus-bar assembly
19d	HV-220 kV AC - 3×300, with length of 0.7 km from bus-bar assembly CCGT-450 with installation for gas switch in cell #10A of existing ODU-220 kV.
25a	Cable tunnels and channels
26a	Electrical container with backup diesel
28a	Technological trestles
	- heating networks
	- heating network feeding pipelines
	- hot water (forward and backward) pipelines with armature
	- steam pipelines with armature
	- condensate return pipelines with armature
	- pipeline to GSPU (gas separator pump unit)
39a	Gas separator pump unit (GSPU) with armature
39b	Gas processing facility (GPF)
39c	System of purge and dump gas pipelines of CCGT and GSPU

73a	Compressor room for compressed air with receivers
81a	Electrolysis room with receivers, including nitrogen generating room on sludge disposal site of oily water at flow rate 8-10 m/h, pressure of 20-22 m
Technical water supply at the site	
41a	Circulation pump station - above-ground part - underground part
41b	Circulation water lines - 2Ø1420×10 - 2Ø1620×10
43b	Water lines of supplementary at the production site 2Ø377×8 L=300 lm
44a	Ventilator cooling stacks 18 × 18m
44b	Pumping installation for cooling stack scavenging
46a	Pumping installation for drainage of main building - above-ground part - underground part
46b	Circular drainage of main building
46c	Pressure water passage of drainage of main building - Ø219 × 6
99a	Piezometric network at the CCGT production site
	- in site roads
	- access road
	- transfer of HV-220 kV
	- excavation works
	- soil embankment
	- transformer rerolling ways
	- Security fencing of the territory with the check-point
	- towers
	- trenches
	- security lighting
	- security alarm

6.5 Construction program

6.5.1 Material/equipment procurement program

Equipments required for the construction of the Uzbekistan site are almost imported from overseas countries. Materials such as cement, aggregate, sand, rebar etc. can be procured in Uzbekistan.

6.5.2 Material/equipment transport program

Since Uzbekistan is an inland country without a coast line, difficulties are found in the transport of large-sized heavy products.
In the 450MW-class CCCGP No.2, the maximum weight of a product will exceed 300 tons even when the heavy product is divided in several parts for transportation.
Several months will be required for transportation when consideration is given to the canal transportation route by the Volga canal from the Black Sea (the Black Sea through the Caspian Sea) and the inland transportation route (through the Republic of Turkmenistan).
Again, when a construction program is to be worked out, a sufficient transportation period must be taken into account with consideration given to the frozen period of the Volga and the distance of transportation.

7. System Analysis and Grid Connection Plan

7.1 System analysis

7.1.1 Objective

A 450 MW combined cycle co-generation plant No.2 (hereafter called as CCCGP No.2), which is scheduled to begin its operation in 2015, is to be added to the Navoi Thermal Power Plant. The objective of the power system analysis is to evaluate the impact of installing this facility under normal condition and emergency condition against the nation’s power grid, specifically to the 220-kV network surrounding the power plant. The task of this system analysis is mainly composed of three sub-tasks, namely power flow analysis, fault current analysis, and stability analysis.

7.1.2 Premise

(1) Examined Case
The analysis covers the 220-kV network surrounding Navoi Thermal Power Plant, bordered by three 500 kV substations, namely, Syrdaria Substation, Guzar Substation, and Karakul Substation. Figure 7.1.2-1 shows the area to be analyzed in this study (220-kV power system network around Navoi Power Plant as of year 2010). The analysis simulates the winter peak of year 2015, as the commission of the generation facility is scheduled in the year. The system analysis is carried out using PSS/E software, while SJSC Uzbekenergo uses another software, “Mustang,” which had been developed in former Soviet Union.

Source: SJSC Uzbekenergo

Figure 7.1.2-1 Analyzed network area (Left: Analyzed area, Right: part of the analyzed area)

(2) Input Data/ Data Source

The JICA Study Team cited its key input data such as generated power and load from the preliminary study conducted by SJSC Uzbekenergo, SAESP. For the line constants and parameters related to generators, the team referred to the figures provided by SJSC Uzbekenergo's National Dispatch Center (NDC). Data which are not available in the above two sources are supplemented from the other sources such as SJSC Uzbekenergo's answer sheet to the team's questionnaire and the past JICA Study.

7.1.3 Power Flow Analysis

(1) Calculation Results

a. Loading

The power flow has analyzed with and without the new CCCGP No.2 to the Navoi Thermal Power Plant. For all the transmission lines, the calculated flow was within the allowable current capacity. For N-1 criteria, the sections which are "From K-Mozof Substation (SS) to Navoi Thermal Power Plant (TPP)" and "From Himiya SS to Navoi TPP" were evaluated. These cases showed that the analyzed network also satisfies the N-1 standard.

b. Voltage

For the purposes of maintaining the proper voltage, the shunt capacitors with required capacity might be necessary to be installed into the several substations, because several buses at substations show the voltage below their operation range (-10 % of base voltage).

7.1.4 Fault Current Analysis

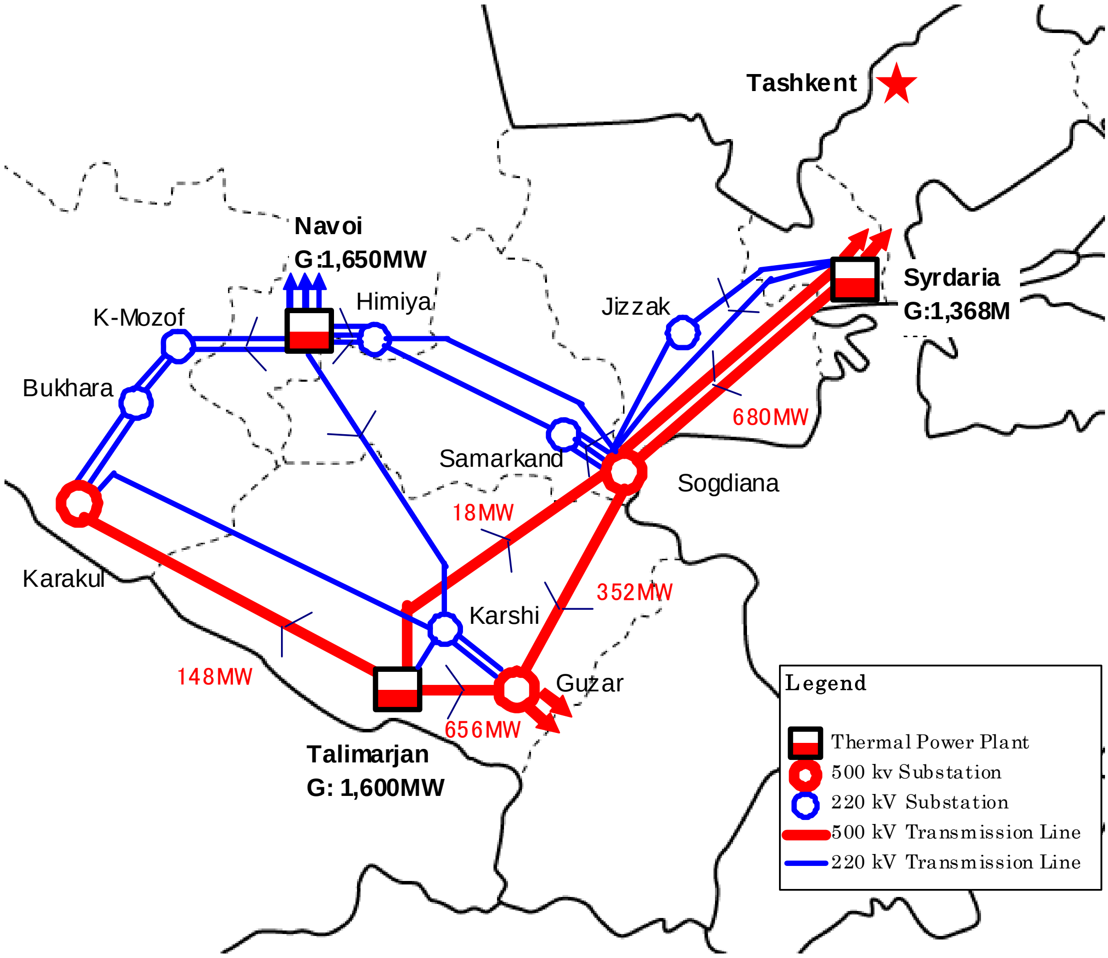
This analysis evaluates the impact of adding the new CCCGP No.2.

The 3-phase short-circuit current values for the 500 kV and 220 kV buses for major substations were examined (with and without 450-MW CCCGP No.2) as the most severe condition. The influence of introduction of 450 MW combined cycle power plant on the network system was +0.5 kA for a 500kV bus and +0.4 kA for a 220kV bus of Navoi Thermal power Plant in average. In summary, the current was within the rated current capacity, and therefore, the impact of adding CCCGP No.2 is confirmed to be small.

7.1.5 Dynamic Stability Analysis

System stability in the disturbance cases are examined under following conditions.
The fault sequence is described as follows:

0ms: Single circuit three-phase short-circuit fault at the selected section.
160ms: Fault clearance and the 1circuit open.
10s: End of calculation



Source: Developed by JICA Study Team

Figure 7.1.1-1 Power Flow Diagram for the Stability Analysis (During Winter Peak in 2015).

Table 7.1.1-1 shows the stability analysis results for three representative cases. The fault locations in the table were selected considering their heavy power flow.

Table 7.1.1-1 Stability Analysis Results

Case	Fault Section (1cct)	Result
Case 1	220 kV Navoi TPP – K-Mozof SS Transmission line	Stable
Case 2	220 kV Navoi TPP – Himiya SS Transmission line	Stable
Case 3	500kV Talimarjan TPP – Guzar SS	Stable

For the planned system in the year 2015, the oscillation waveforms of phase angle differences were found converged in the case of a single circuit fault of the primary heavy-loaded sections near Navoi TPP. Therefore, it was confirmed that the planned system was stably operated under such severe conditions.

7.1.6 Conclusion and Observations

The analysis revealed that there will be no significant problem of power flow, voltage, short-circuit current, and dynamic stability caused by connecting the new 450 MW CCCGP No.2 of the Navoi Thermal Power Plant to the currently-planned power system of year 2015. Therefore it is confirmed that the installation of CCCGP No.2 would not require to modify or strengthen the currently-planned power system.

7.2 Grid Connection Plan

For the transmission line and substation design of this project, the materials and information provided by the counterpart and JICA Report" Republic of Uzbekistan Supplemental Study to enhance the collaboration with NEDO on Tashkent Heat Supply Power Plant Modernization Project" were referred to.

7.2.1 Layout of Transmission Line

Concept of transmission line route selection

- The locations of towers are set to be good distance from west settlement and close to new thermal power stations as much as possible.
- The distance transmission lines is set to be secured as 40m in light of the length of tower arms, Right of Way (ROW: 25m)
- Although, some boundary towers between new towers and existing towers are considered as the reconstruction, it is possible to need to reconstruct more some towers and reinforce the members of towers, since there are unclear points which are the situation and the design conditions of existing towers.

7.2.2 Basic design conditions of Transmission lines

For the basic design of this project, both the Regulations on Electrical Devices (PUE) and Uzbek-Standard (GOST) were referred.

7.2.3 Designs on a bay and bus bar into an existing substation

(1) Standard of Bay design

The study team has made assumptions in the basic design of such facilities based on international standards and our experiences of overseas design works.

(2) Design of Bus & bay in the existing substation

220kV cable system has been applied in this study due to safety and maintenance reasons. The route of bus bar is planning to be located under eight (8) transmission lines. The study team recommends that the underground cable system should be utilized in the bus bar from bay of the CCCGP No.2 due to secure an availability to prevent interruptions by maintenance and turbulence from other transmission lines.

8. Environmental Social Consideration

8.1 Environmental status

8.1.1 Air quality

At residential, industrial and roadside area in Navoi City in 2010, the nitrogen dioxide (NO_2) concentration is 0.015~0.11 mg/m^3, higher than the maximum permissible concentration (MPC) at the maximum level with annual average of 0.04 mg/m^3.
This value satisfies the hourly and the annual average standard of IFC/WB EHS Guidelines.
The sulfur dioxide (SO_2) concentration is 0.001～0.009 mg/m^3, which is well below MPC at the maximum level. This value satisfies the standard value specified in IFC/WB EHS General Guidelines.

8.1.2 Water quality

It should be noted that water quality of Zerefshan River in Navoi, upstream of the power plant, exceeds the Uzbekistan standard in SS, oil content, sulfate, heavy metals, and other items.
The inlets of the power plant is located upstream of the outlets, thus intake water not getting any impacts by the discharge; however, water quality of SS, oil content and sulfate exceeds the MPC.
Salinity and water temperature are increasing every year, for which the existing power plant is said to be one of the pollution source.

8.1.3 Noise and vibration

Noise level in the residential area located 1km fro the site is 54dB, which satisfies the Uzbekistan environmental standard (55dB) and IFC/WB EHS General Guidelines.
The survey of vibration around the power plant site has not been conducted.

8.1.4 Natural environment

Navoi power plant site is situated in the western side of Zerafshan lowland which is a plain within the submontane district, surrounded by a flat district extending 10km.The layer of the project area consists of quaternary deposit of alluvial clayey loam and sandy loam, 5m to 10m thick.

The wind around the project site is mainly east wind, so the exhaust gas from Navoi power plant is blown westward. The average wind speed in the project area is 1.9~3.5m/s throughout the year exceeding of 8m/s is rare.

Zerafshan River is 750km long, flowing from east to west. River water is taken between Zaatdin Village and Navoi City to be used at 4 irrigation canals. Remaining river water flows beside Navoi power plant site.

The project site is adjacent to the residential area and the power plant already under influence of human activity.
Precious species of plant and animals designated by IUCN (International Union for Conservation of Nature and Natural Resources) and by the Uzbekistan Red Data Book are not observed.

30 species from 7 families of aquatic organisms are observed in Zerafshan River, Most of the aquatic organisms are local species, 4 species are categorized as Least Concern (LC) with IUCN List.

8.1.5 Social environment

The existing Navoi power plant site is located 6km northwest of Navoi City, the south side is the residential area of Uyrot Village, the east side is the residential area of Michurin Village, the west side is the mixture of residential area and farmland of Yangiobod Village.
The near residential area from the existing power plant site is located 650m west and 400m south west of the site.

8.2 Environmental Impact Assessment and other legal system

8.2.1 The gap with JICA Environmental Guidelines (April 2010)

The comparison was made between the content of the EIA for CCCGP No.2 with the requirement of JICA Guideline on Environmental and Social Consideration.
In the result of this review, most of the information related to following plans were not described in the EIA Report for CCCGP No.2 and were not explained to resident peoples and affected peoples.

- Environmental management Plan in the construction and operation phase
- Monitoring Plan in the construction and operation phase
- Land Acquisition and Resettlement Action Plan (LARAP)

8.3 Scoping and TOR of the survey

8.3.1 Result of the review of the EIA

The EIA describes that emission of NO2 before the project implementation was 3,543 t/ y, and will both decrease to 3,454t/y after the project is in operation.

The estimated NO2 concentration from Unit 3 and 8 which are to be decommissioned in this project is 67.15μg/m^3(0.79MPC), whereas the estimated concentration from CCCGP No.2 is 14.455μg/m^3(0.17MPC). Consequently, this project will largely contribute to the decrease of NO2 concentration.

In this project, adoption of forced-draft cooling tower system was planned in the EIA, but forced draft air cooling system will also be considered. The amount of thermal water discharge into Zerafshan River will decrease after decommission of Unit 3 and 8.

According to the regulation in Uzbekistan, water temperature rise at 500m downstream of the water outlet shall be 3 ºC or less. The estimated maximum water temperature rise by blow-down from a forced-draft system at 100m downstream of the outlet is 0.5 ºC.

Washing wastewater is generated from the water treatment system for CCCGP No.2 at the rate of 92.5m3/h and is discharged into Zerafshan River after treatment.

The estimated noise level in the residential area near other project site, taking into consideration of the attenuation effect of the buildings and the green zone, will be below the environmental standard value. The estimated vibration level from the power plant is less than 50dB.

According to the EIA, 30 households (11 households in Uyrot village and 19 households in Yangiobod Village) will be resettled as a result of land acquisition for transmission line etc.

8.4 The result of survey

8.4.1 Reassessment of the prediction

(1) Air pollution

Emission amount of NO_2 from CCCGP No.2 increases from 18.3g/s to 32.5g/s; therefore, prediction on the impact caused by NO_2 emission was conducted using emission gas data.
The maximum ground concentration becomes similar to the one of the initial plan, if stack height is set to 90m; thus complying with the regulatory standard of Uzbekistan.

However, in consequence of consultation with Uzbekistan, there was a requirement to keep height of the stacks as low as possible. As a result of the consideration by Uzbekenergo through a method used in Uzbekistan, the stack height was set to 90m, on the ground that the maximum ground concentration standard from CCCGP No.2 in Uzbekistan is satisfied by the stack height of 90m.

Assessing impact of the pollutants at the whole power plant, it is necessary to consider the operation condition and gas emission amount of the existing power plant along with the operation of CCCGP No.2.

In case of shutting-down of Unit 3 and 8, NO_2 emission is increased to 4,687ton/year compared to 4,636 ton/year before CCCGP No.2 in operation. However in case of shutting-down of Unit 3, 6, 8 and 10, NO_2 emission is decreased to 4,146 ton/ year.

The maximum ground concentration of NO_2 generated by the operation of CCCGP No.2 and Unit3, 6, 8, 10 are shut down, 2～9μg/m3 will be decreased in all wind speed. In this case, assuming that NO_2 concentration around the power plant will become about the same as the standard of Uzbekistan, 85μg/m^3, or even lower.

(2) Water pollution

In this project, forced-draft cooling tower system was finally adopted. This system does not generate large amount of thermal effluent as is the case of one-through system, and only the 240m3/h of blow-down from cooling tower will be generated.

The reduction of thermal effluent due to the shutdown of Unit 3 and 8 is 28,000m^3/h. The total amount of effluent after this project will be about 60% with the reduction of about 27,760m^3/h.

Since used water in CCCGP No.2 is tap water, waste water is enough to comply with the regulatory standard of Uzbekistan as well as EHS Guideline of IFC/WB.
However, water quality at the outlet of the waste treatment facility shall be monitored to confirm the compliance to the effluent standard of Uzbekistan and IFC/WB.

(3) Noise

During construction phase, the noise level resulting from the operation of the construction machinery is slightly over 55dB at 300m from the boundary of the site, and below 55 dB at 400m from the boundary, which meets daytime environmental standard of the Uzbekistan and

IFC/WB guidelines, but exceeds the nighttime standard of 45dB. The mitigation measure will be made to minimize the noise impact.

During operation phase, noise levels from CCCGP No1 and CCCGP No.2 is below 55dB at 300m from the boundary of the site, which meets daytime environmental standard of the Uzbekistan and IFC/WB guidelines, but not satisfied the nighttime standard. The mitigation measure will be made to minimize the noise impact.

(4) Vibration

During construction phase, the vibration level of the construction machinery at the residential area 300m from the plant site is below 40dB which is very low.
During operation phase, the vibration level at the residential area 300m from the project site is 30dB, a sufficiently low level.

8.4.2 Environmental assessment

The environmental impact assessment according to the result of the survey was conducted.
Environmental management plan and monitoring plan were prepared in according to the environmental impact assessment.

8.5 Comparison of alternatives including zero-option

8.5.1 Consideration of the zero option

In the case where CCCGP No.2 is not constructed and the existing old-type power plants (Unit 3 and Unit 8) continue operation, the air quality around the plant area and will remain in a bad condition, the reliability of the facility will decrease, and the risk of accident will increase.

8.5.2 Consideration of the alternative project site

In the EIA, the north end of the existing power plant site is considered as an alternative site for constructing CCCGP No.2.
However, further consideration of this plan was called off as technical, topology and many resettlement of household.

8.5.3 Consideration of cooling system for the condenser

While the condensers in the existing power plants, except Unit 11 and 12, adopt one-through system, either forced draft cooling tower system or forced draft air cooling system will be adopted in the CCCGPNo.2 power plant.

The use of air-cooling system has no actual achievement in the past in Uzbekistan, and in conclusion the forced-draft cooling-tower cited in the EIA was adopted.

8.6 Environmental management plan (mitigation measures)

8.6.1 Environmental management plan during construction phase

At the construction phase, the PIU of the SJSC Uzbekenergo and Navoi Power Plant shall carefully consider the construction activity with supervision consultant and encourage the EPC contractor to well understand the necessary mitigation measures and to implement them.

8.6.2 Environmental management plan during operation phase

Navoi power plant is responsible for organizing an environmental management unit to develop and implement the environmental management plan as a mitigation measures.

Basic policy of the environmental management plan is to coordinate with the local community, and sufficient explanation of the positive mitigation measures for the local people is very important.

8.7 Environmental monitoring plan

The environmental monitoring plan during construction and operation phase is made to monitor air, water, noise etc to keep the values specified in Uzbekistan environmental laws.

8.8 LARAP

Four (4) times of public consultation for giving explanation about the project and the EIA has been held as follows.

- EIA explanation meeting
- Supplementary Interview with Affected People
- Additional Stakeholder meeting on Environmental and Social Consideration
- Stakeholder meetings related to resettlement

In the above meetings, Project Owner held several meetings in order to obtain consent from the residents. Finally, all resettlement households agreed with the relocation to new places.

8.9 Brief resettlement Action plan

8.9.1 Analysis of the legal framework concerning land acquisition and resettlement

There are no laws or legislation in Uzbekistan that specifically address matters related to involuntary resettlement. However, land acquisition is governed by the several laws and regulations. These regulations provide a sound basis for acquiring land for public purposes and for compensating land users according to the registered use of the land.

Where there are gaps between the Uzbekistan legal framework for resettlement and JICA's Policy on Involuntary Resettlement, practicable mutually agreeable approaches will be designed consistent with Government practices and JICA's Policy.

The JICA's principle of avoidance or minimization of resettlement is reflected in Uzbekistan Legislation. Uzbekistan has ensured that all land and structures will be registered prior to resettlement, at no cost to the displaced persons, and then transferred or compensated under the relevant entitlement.
The appropriate actions will be implemented in order to address the gap between Uzbek laws and regulations and JICA's policy.

8.9.2 Necessity of land acquisition and resettlement

A resolution was issued by Karmana District Hokim № 605-K of 11th July, 2012 on forming a

special commission to estimate the size of compensation to citizens whose households includes in the resettlement zone.
The Project will affect to 33 households located at two makhallas “Uyrot” and “Yangiobod”. Thus, there are 139 displaced persons at this zone. All of the displaced persons will be needed of the compensations and assistances. Of 33 households, there are 10 households located at makhalla “Yangiobod” that were refused by local authorities to register as the legal owners of assets on the using land plots.

8.9.3 Implementation of socioeconomic survey concerning land acquisition

1) Population census survey
Navoi Province is located in the central part of Uzbekistan. The area of the province constitutes 110.8 thousand square kilometers or 24.8% of total area of the country. Population is 886 thousand.

2) Property/estate survey
Total loss of affected area (housing and household outbuildings) for 12 households in Uyrot makhalla is 4,745.9m^2 and for 11 households in Yangiobod makhalla is 1,012.2m^2. For 10 Illegal households, 1,228.0m^2 basis will be acquired.

3) Household finance/life survey
The average monthly income per households is USD$277; that is USD$2.28 per household member a day. This amount is somewhat higher than USD$2.15 – the poverty level established by the World Bank and other international organizations in Uzbekistan as a required minimum per person a day for purchasing basic food items.

8.9.4 Requirement of compensation for lost assets and livelihood restoration

1) Compensation of lost assets
All registered assets were valued by independent evaluation agency through calculating the real replacement cost based on cost of materials, type of construction, labor, transport and other construction costs. Total buildings replacement cost for 23 legal displaced persons is USD$ 641,501.
Monetary support for 10 illegal displaced persons by the SJSC Uzbekenergo is USD$ 20,488.

2) Livelihood restoration
Legal owners will be assisted by the SJSC Uzbekenergo to organize legal documents in support of their ownership.
Regarding the 10 uninhabited illegal houses, the expense for the houses will be paid by the Navoi TPP as a support activity.

8.9.5 Grievance system

JICA’s Guideline requires that a grievance redress mechanism is established and maintained.
Grievance Focal Point is an organization handling all the complaints from the local inhabitants, and is established within Makhalla which is an organization of the inhabitants, and within districts which is an administrative organization.

8.9.6 Implementation system

The main institutions that will be involved in Land Acquisition and Resettlement activities are the SJSC Uzbekenergo as executing agency, PIU, Design Institute Project Consultants, Provincial and District and municipal town authorities, State Unitary Enterprise Land and Immovable Cadastre Service at district level..

8.9.7 Implementation schedule

The resettlement plan has to include the full details of all land and resettlement arrangements, including verification of asset viability by the displaced persons. It is expected that this can take place prior to loan approval by JICA.
The project loan is expected to be approved in February or March 2013. Construction is set to start at the end of October 2014.

8.9.8 Cost and funding

The budget for land preparation costs is USD$10,361, for housing and structures is USD$641,501, for trees is USD$4,072 and for structures for illegal people is USD$20,488. The total budget is USD$744,064 including contingency (10%).
The SJSC Uzbekenergo will allocate 100% of the cost of compensation at replacement cost.

8.9.9 Monitoring system/monitoring form

The Land Acquisition and Resettlement activities will be monitored internally and externally. Internal monitoring will be carried out by the PIU and in conjunction with District Hokimiyat. External monitoring agency will be selected by PIU and approved by JICA.
The monitoring and reporting will continue for two years since the all affected households finish relocating to the new place.

11. Proposal for implementation scheme and operation, maintenance and management system

11.1 Financial Stability

SJSC Uzbekenergo is financially sound. At the end of 2011, both Current Ratio and Quick Ratio are more than 1.0 time with sizable margins upon 0.7 times, which is conventionally considered a cut-off point. Liquidity is unlikely to be a problem in the foreseeable future. In 2011, Uzbekenergo’s debt accounted for only 30% of its equity. Net Interest Payment/EBIT shows that Uzbekenergo’s profitability covered interest payment. These suggest that both size of debt and interest payment were at manageable level. The result of the financial evaluation suggests that this project does not affect the financial health of SJSC Uzbekenergo.

11.2 Proposal for the operation maintenance management system and scheme for this Project

The Study Team would like to propose the following for the operation maintenance management for this Project.

(1) Operation maintenance management system for this Project
The Study Team proposes that the operation and maintenance management division should consist of the operation and maintenance groups, similarly to the case of the existing units. This will ensure a clearer definition of the job responsibilities and smoother job execution.

(2) Improvement of operation skill
For the “CCPP Navoi - 478MW Shop”, the facilities operation technique has been acquired at the time of commissioning. The Study Team propose introduction of simulator facilities for the purpose of further improvement of the operation skill in future.

(3) Performance management
One of the biggest causes for deterioration of the gas turbine performance is found in the contamination of the compressor passageway.
The Study Team would like to propose that the optimum compressor blade washing frequency should be determined by subsequently accumulating the operation data and compressor blade washing efficiency data.

(4) Maintenance of gas turbine
The maintenance level of the gas turbine has a serious impact on the availability factor of the overall power generation facilities.
The Study Team would like to propose that the hot parts should be inspected and replaced under supervision of the technical advisor of the OEM.

12. CDM Related Surveys

12.1 CDM Methodology

In CDM, the emission reduction volume under the project is defined as follows:
・Emission reduction volume = Baseline emission volume - Project emission volume

A project emission volume refers to the volume of emission from an actual project, whereas the emission volume in the baseline scenario means an emission volume in a "scenario unrealized if the project does not fall under a CDM project."

The EIA of this project calculates the emission reduction volume according to the stipulations in the above-mentioned report. The specific calculation method and calculation results are as follows.

・Estimation of Effect of GHG Reduction Based on the CDM Methodology

a. Baseline emission volume
- Annual power supply: 450,000 kW × 8,000 hr = 3.60 GWh
- Emission coefficient: 593 g CO_2 / kWh
- Annual baseline emission volume: 2,134,800 t CO_2

b. Project emission volume
- Annual fuel consumption: 763.5 × 10^6 Nm^3 (natural gas)
- Emission coefficient: 1.9 t CO_2 / 1,000 Nm^3
- Annual project emission volume: 1,450,650 t CO_2

c. Emission reduction volume when the project is implemented
- Annual emission reduction volume = 2,134,800 t CO_2 - 1,450,650 t CO_2 = 684,150 t CO_2

12.2 CDM Related Procedure

The DNA (Designated National Authority) of Uzbekistan, the Technology Transfer Agency under the Ministry of Economy of the nation, is responsible for CDM.
Uzbekistan worked on the introduction of global warming gas emission control measures. As a result, the nation has introduced as many as 100 laws and regulations, including the "Law of Republic of Uzbekistan on the Rational Energy Use" enacted in 1997, to protect the environment directly and indirectly and control use of natural resources and energy.

12.3 CDM Application

Uzbekistan has established the DNA in the country and been working on CDM projects ever since to meet the Kyoto Protocol.
To this end, the Government of Uzbekistan picked up 33 projects in 2009 to work on whether CDM is applicable to these projects.

CDM application in the power generation sector has been studied mostly by SJSC Uzubekenergo. This body has been working currently to file application documents of this project and preceding CCCGP No.2 Project in 2013 to the Ministry of Economy.

13. Workshop in Japan

This workshop was intended to obtain findings and experiences that could be effectively employed in the phase of implementing a yen loan project in the future. The counterparts of Uzbekistan were invited to Japan to make a field trip to the factories of major equipment manufacturers and combined cycle power plants and to listen to the lectures on the combined cycle power generation, in such a way that the related people would get required information.

Chapter 1 Preface

1.1 Background of Survey

In the Republic of Uzbekistan (hereinafter referred to as Uzbekistan), as a result of satisfactory economical development since 2002, demand for electricity is increasing at the average yearly rate of approximately 2%. According to the power demand estimation by Uzbekistan in 2004, it is expected that demand for electricity will increase at the equivalent rate and the maximum demand will reach approximately 11,200 MW at least in 2014.

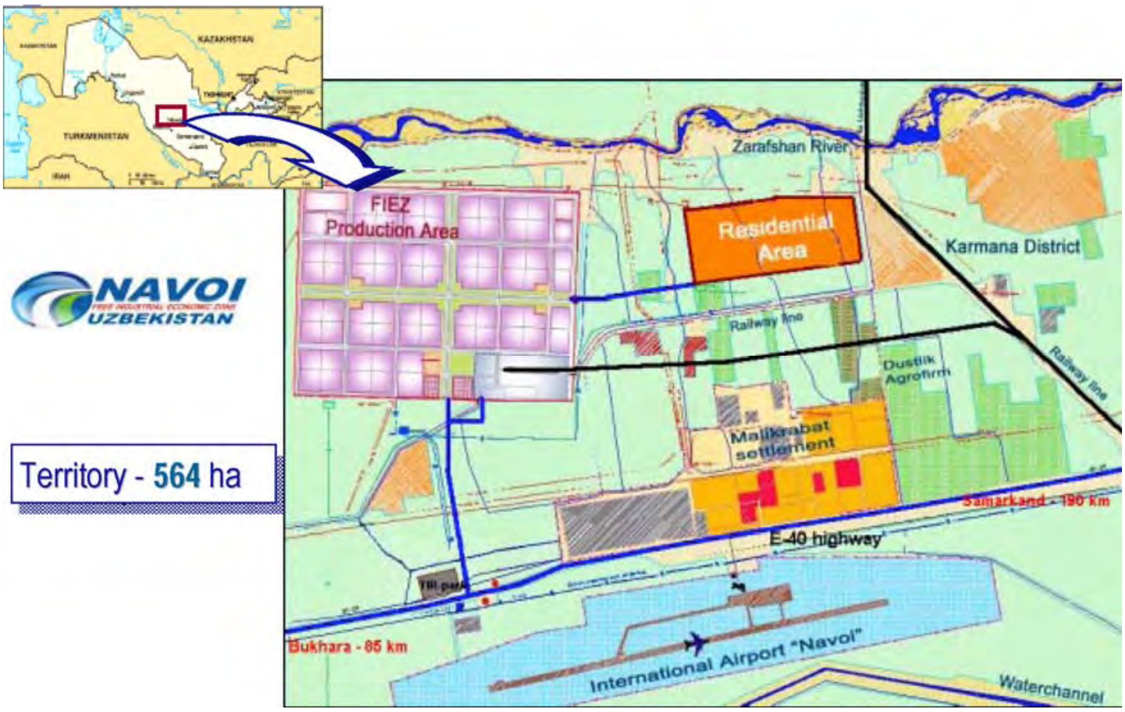
On the other hand, though the rated capacity of the total power generation in Uzbekistan is approximately 12,400 MW in 2009, the actual power generation capacity stays less than approximately 10,000 MW, since many power plants have been used for 40 to 50 years since they were constructed. Aging facilities have low power generation efficiency and cause such problems as more emission of greenhouse gas, NOx, etc. per generated electric energy.

On these backgrounds, the SJSC Uzbekenergo of Uzbekistan, since it is urged not only to introduce high-efficiency power generation facilities out of regard for the environment by utilizing fuel efficiently but to increase the power generation capacity in preparation for future electricity shortage, is working to modernize the aging thermal power plants.

This project intends to modernize the existing Navoi Thermal Power Plant (1,250 MW) near the Navoi City, Uzbekistan, as a part of these activities. Near the Navoi City, there is the largest-scale national metal mining complex in Uzbekistan, which is an important basis of economical development of Uzbekistan. A special industrial and economic free zone with an area of 564 ha was established near the Navoi Airport, which was constructed newly with President's Decree in 2008, in order to call in overseas countries' investments actively. The Navoi Power Plant is expected to be modernized to meet the demands for electric power and heat energy necessary for those investments. Figure 1.1-1 shows the outline of the Navoi special industrial and economic free zone introduced by the Shaxkat Tsuryagan of Vice Minister of the Ministry of Foreign Economy, Investments and Trade in the Japan–Uzbekistan Economical Cooperation Conference held in April 2010.

Table 1.1-1 shows the facility capacity and the current effective capacity of the twelve units of the Navoi Power Plant. Eight of the twelve units are of heat and power supply type, three are of power supply type, and one is of heat supply unit. Among them, the oldest unit has been used for as long as 50 years and others have been used for 30 years or more. They are superannuated. For example, it is found from this table that the effective capacity of the heat supply units lowered by a remarkable 50%, while the effective capacity of the power generating facilities lowered by approximately 10%. On such a background, the Combined Cycle Cogeneration Plant (hereinafter to be collectively called as CCCGP) No.2 featuring high energy conversion is to be introduced in time for disusing the existing power plants Nos. 3 and 8 by 2015. Having borrowed money from the Reconstruction and Development Fund of Uzbekistan, the SJSC Uzbekenergo is now constructing CCCGP No.1 adjacent to the Navoi Power Plant. At present, the construction makes good progress as scheduled and is scheduled to be completed in October this year.

In March 2012, the Uzbekistan Government requested yen loan for this project to the Japanese Government. Thus, this survey is conducted to make preparations for appraisal of the yen loan for introduction of CCCGP No.2.



Source: Material of Japan–Uzbekistan Economical Cooperation Conference in 2010

Figure 1.1-1 Navoi Special Industrial and Economic Free Zone

Table 1.1-1 Capacity of Navoi Thermal Power Plant

Unit No.	Facility type	Capacity of power generating facilities (MW)	Capacity of heat supplying facilities (Gcal/hr.)		Operation started in	Effective capacity of power generating facilities (MW)	Effective capacity of heat supplying facilities (Gcal/hr.)	
			For supplying heat to region	For industry			For supplying heat to region	For industry
1	Cogeneration plant	25	34	50	1963	15	0	0
2	Cogeneration plant	25	34	50	1963	20	34	50
3	Power generation	150	-	-	1964	145	-	-
4	Cogeneration plant	150	33	-	1965	145	33	-
5	Cogeneration plant	50	-	200	1966	45	-	150
6	Cogeneration plant	60	66	26	1967	55	0	0
7	Cogeneration plant	50	-	199	1971	45	-	113
8	Cogeneration plant	160	33	-	1968	150	33	-
9	Cogeneration plant	160	33	-	1969	145	33	-
10	Heat supplying	-	100	-	1972	-	0	-
11	Power generation	210	-	-	1980	155	-	-
12	Power generation	210	-	-	1981	180	-	-
Total		1,250	333	525		1,100	133	313

Source: Pre-F/S Report

1.2 Purpose of Survey and Scope of Survey

1.2.1 Purpose of Survey

The purpose of survey consists in to carry out studies necessary for judging whether the introduction of “Navoi Thermal Power Plant Modernization Project (CCCGP No.2)”, for which the Government of Uzbekistan requests as an object of the yen loan is viable as an ODA project. The studies include the necessity of introduction, conceptual design, construction cost, implementation schedule, implementation (procurement and construction) methods, implementation structure, management and operation and maintenance systems and environmental and social considerations of the project.

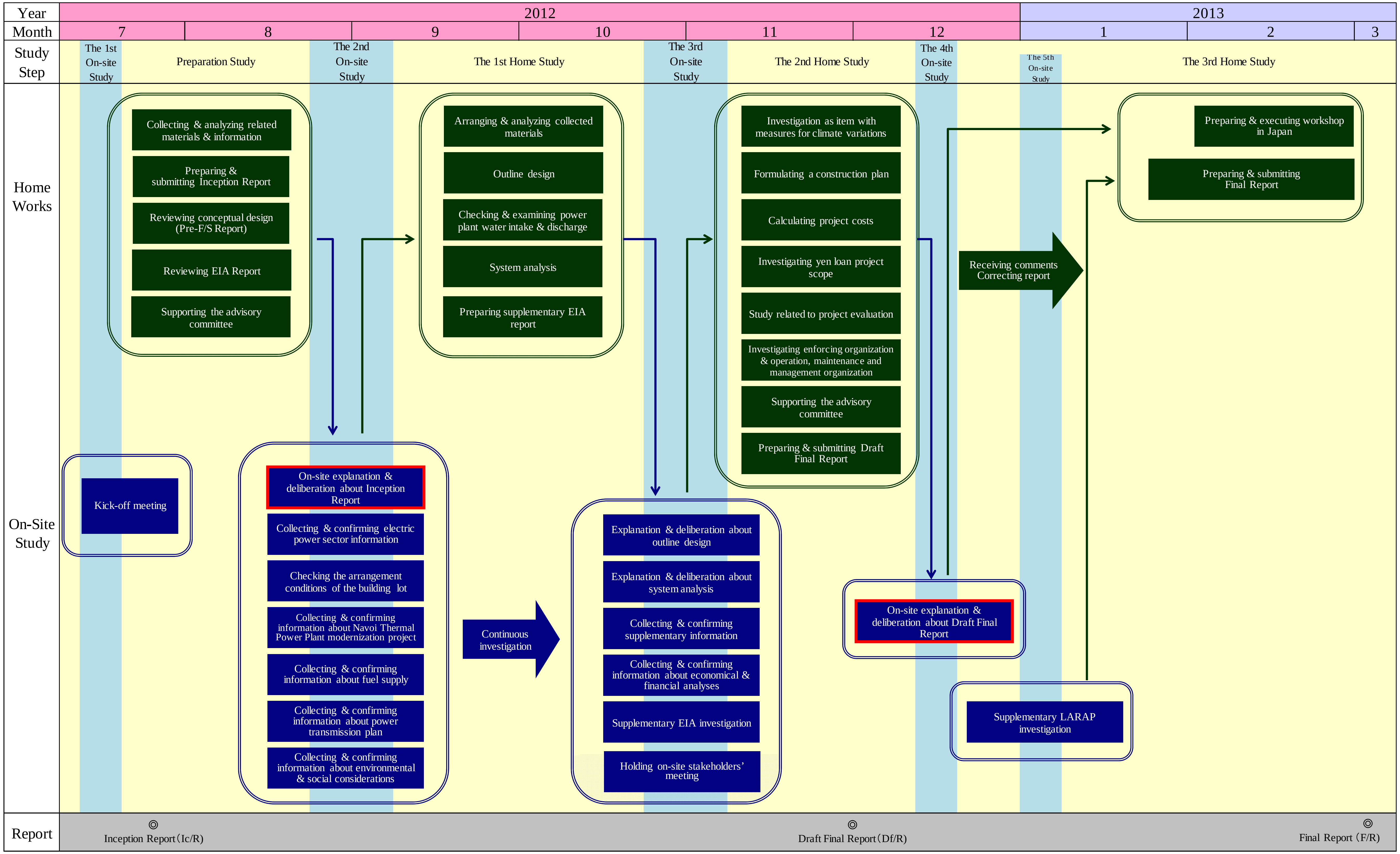
1.2.2 Scope of Survey

The scope of this survey is as follows:

(1) Confirmation of the plan studied by upper level structure of Uzbekistan
(2) Collection and confirmation of information about the electric power sector
(3) Collection and confirmation of information related to modernization of the Navoi Thermal Power Plant
(4) Check and review of the conceptual plan (Pre-F/S Report)
(5) Check and review of the EIA Report
(6) Check of the current situation and future prospect of fuel supply
(7) Check and examination about taking in and draining of power plant water
(8) Check of the present conditions of the project candidate sites
(9) Support of holding of the meeting with stake holders on the site
(10) Support of the advisory committee in JICA related to environmental issues
(11) Survey on electrical network systems
(12) Supplementary survey of EIA report
(13) Conceptual design including the heat supply system
(14) Inland transportation and construction plan
(15) Estimation of project cost
(16) Proposal about the project scope for the yen loan
(17) Proposal about the implementation organization, management and operation and maintenance systems
(18) Survey related to project evaluation
(19) Survey on countermeasures against climate change
(20) Support of implementation of technical training in Japan

1.2.3 Duration of the Study

Schedule of the Study is shown in the next page.



Source: Study Team

Figure 1.2.3-1 Schedule of the Study

1.3 Organization of the Team

Table 1.3-1 shows the names and duties of the study team (hereinafter referred to as the Team) members.

Table 1.3-1 Organization of the Team

Name	Duty
Hideyuki OKANO	Team Leader / Power Plant System Planning Expert
Kenji MIKATA	CCCGP System Expert
Toru KAMO	Fuel Supply Planning Expert
Hideki ASAYAMA	Mechanical Expert
Masamichi SHOJI	Electrical and I&C Expert
Mistake SHIMADA	Civil Engineering & Construction Planning Expert
Yasuhiro YOKOSAWA	Transmission Expert
Atsumasa SAKAI	Power System Analysis Expert
Norihiko FUKAZAWA	Environmental Consideration Expert
Yoko HAMADA	Social Consideration Expert
Nobuyuki KOBAYASHI	Economical & Financial Analyst

Source: Study Team

Chapter 2 Socio-economic Situation in Uzbekistan

2.1 Overview

Uzbekistan is a landlocked country with approximately 28 million residents in 2011. The country has the largest population among the five counties in Central Asia (Kazakhstan, Kyrgyz, Tajikistan, Turkmenistan, and Uzbekistan). In terms of Gross Domestic Product, Uzbekistan has the second largest economy in Central Asia only after that of Kazakhstan. Although its economy is growing at a rapid pace in recent years, Uzbekistan is still classified as a Lower-middle-income economy by the World Bank. External trade is commodity-driven. Major Merchandize export items are oil/gas and energy products, cotton, and foodstuff while major merchandize import items are machinery, chemical products, and foodstuff. Major trade partners are Russian Federation, Kazakhstan, and China for export and Russian Federation, Korea, and China for import.

Table 2.1-1 Basic Indicators

Country Name	Republic of Uzbekistan
Surface Area	447,400 square km
Population	27. 8 million (2011)
GDP (Nominal, Sums million)	77,750,600 (2011)
GDP (Nominal, USD million)	43,494 (2011)
GDP per Capita (USD)	1,572 (2011)
GDP Growth (Real, %)	8.3% (2011)
Merchandize export (USD million)	10,529 (2010)
Merchandize import (USD million)	8,044 (2010)
Exchange rate (Year average)	1787.60 sums/USD (2011)
Exchange rate (Year-end)	1795.00 sums/USD (2011)

Source: Ministry of Foreign Affairs of Japan (http://www.mofa.go.jp/), JETRO (http://www.jetro.go.jp/indexj.html), ADB “Key Indicators for Asia and the Pacific 2012”

2.2 Socio-economic Conditions

2.2.1 Population

The mixture of mild population growth and urbanization characterizes the demography of Uzbekistan. The total population has experienced a steady growth as the annual growth rate had been slowed down from the mid-1990s to the early-2000s and has stayed at approximately 1% for the last decade. The country has the highest population density among the five counties in Central Asia (Kazakhstan, Kyrgyz, Tajikistan, Turkmenistan, and Uzbekistan). The State Committee of the Republic of Uzbekistan on Statistics estimates that urban dwellers accounted for more than a half of total population (51.4%) in 2011.

Table 2.2.1-1 Population Trends (1995-2010)

	1995	2000	2005	2010
Total population (million)	22.9	24.8	25.9	27.4
Population growth (annual change, %)	2.0	1.3	0.9	1.2
Density (persons per square km)	53	58	62	63

Source: ADB "Key Indicators for Asia and the Pacific 2012"

2.2.2 Labor Force

The labor force has been growing consistently as steady growth of population resulted in an increase in working-age population. In 2010, employment of the agricultural sector accounted for 26.8 % of the employed labor force and that of the industry sector for 13.2%. The number of unemployed workers remained stable for the last several years.

Table 2.2.2-1 Labor Force in Uzbekistan

	2006	2007	2008	2009	2010
Total labor force (thousands)	11,493	11,299	11,603	11,930	12,287
Employed	10,467	10,735	11,035	11,328	11,628
Unemployed (registered)	26	23	17	20	16
Annual growth of labor force (%)	3	2	3	3	3

Source: ADB "Key Indicators for Asia and the Pacific 2012"

2.3 Macroeconomic Conditions

2.3.1 Gross Domestic Product

Higher prices of global commodities such as cotton and gold are one of the major factors affecting the overall economy in recent years. Partially due to the favorable external conditions, Uzbekistan has enjoyed a rapid expansion of its economy since the mid-2000s. The agricultural sector in which cotton is a major crop, remained approximately 20% of GDP, though its share in the economy has been gradually declined. The Industry sector grew at a relatively high rate but a slowdown of the global economy has affected this sector since 2008 when the Lehman Brothers bankruptcy caused economic downturn worldwide. However, the Uzbekistan government has supported investment in infrastructure in recent years and this effort alleviates negative effects of the external shock. On the demand side, private consumption remained robust and contributed to an expansion of the service sector.

Table 2.3.1-1 GDP by Industry Origin

	2006	2007	2008	2009	2010
GDP (% change, constant price)	7.4	7.7	9.0	8.1	8.5
Agriculture (% change, constant price)	6.2	6.5	4.7	5.8	6.6
Industry (% change, constant price)	7.5	6.6	6.8	4.1	4.2
Service (% change, constant price)	8.6	13.4	15.3	9.3	11.6
GDP by sector origin					
Agriculture (% of GDP at current price)	27.9	25.9	21.9	20.6	19.8
Industry (% of GDP at current price)	29.9	29.9	32.3	33.6	33.4
Service (% of GDP at current price)	42.2	44.2	45.9	45.8	46.8

Source: ADB "Key Indicators for Asia and the Pacific 2012"

2.3.2 Production Index

Agricultural and fishery production had been growing at consistent pace in the period from 2007 to 2010. Industrial production had grown at a faster pace than agricultural and fishery production, though the economic downturn worldwide slowed its growth in 2009 and 2010. Machinery production, in particular automobile, prevented a sharp decrease in industrial production.

Table 2.3.2-1 Annual Growth of Production Indexes

	2007	2008	2009	2010
Agricultural and Fishery Production Index (Annual growth, %)	6.1	4.5	5.7	6.8
Industrial Production Index (Annual growth, %)	12.1	12.7	9.0	8.3

Source: JETRO (http://www.jetro.go.jp/indexj.html)

2.3.3 Inflation and Money Supply

According to official figures, inflation was more stable in the period from 2006 to 2010 than in the early-2000s when inflation surpassed 20% per annum. The inflation of the food price index is even milder than that of the consumer price index. Change of the producer price index has been much more volatile than that of the consumer price index. Money supply, both nominal and percentage of GDP, was expansive from 2006 to 2008.

Table 2.3.3-1 Inflation and Money Supply

	2006	2007	2008	2009	2010
Consumer price index (annual change, %)	8.7	6.1	7.2	7.8	7.6
Food price index (annual change, %)	7.4	2.0	3.3	4.4	4.8
Producer price index (annual change, %)	30.2	14.1	9.1	24.7	15.6
Money Supply (M2, billion Sums)	3,146	4,598	6,088	N/A	N/A
M2 (% of GDP at current market price)	15.2	16.3	18.0	N/A	N/A

Source: ADB “Key Indicators for Asia and the Pacific 2012”

2.3.4 Balance of Payment

A rapid increase of the merchandize export for the last decade is mainly due to robust commodity prices, in particular natural gas. As major export items in Uzbekistan are commodities such as natural gas, cotton, and gold, the commodity boom in the 2000s provided favorable terms of trade for export. An increase of the merchandize import is slower than that of the merchandize export but stronger private sector consumption stimulated import of machinery such as automobile parts. Remittance from immigrant workers outside of Uzbekistan is a sizable portion in the balance of payment. Because of the above factors, both the current account balance and the overall balance had been positive in the period from 2006 to 2010. Nevertheless, Uzbekistan Sums was steadily depreciating over US Dollars in the same period. In consideration of a relatively high inflation and export competitiveness, the Central Bank of the Republic of Uzbekistan allowed nominal depreciation of the currency under an adjustable peg system.

Table 2.3.4-1 Balance of Payment

(Unit: million USD)

	2006	2007	2008	2009	2010
Trade balance	1,744	2,296	2,204	1,613	2,484
Merchandise exports	5,615	8,026	9,817	10,890	10,529
Merchandise imports	3,841	5,730	7,612	9,277	8,044
Current balance	2,933	4,267	4,472	4,136	5,663
Other goods, services, and income	-12	20	229	179	1,021
Unrequired transfer	1,171	1,951	2,038	2,344	1,150
Overall balance	1,564	2,155	2,731	2,200	5,663
Direct Investment	195	739	918	987	N/A
Current account balance (% of GDP)	17.2	19.1	17.4	12.6	6.6
Overall balance (% of GDP)	9.2	9.6	10.6	6.7	14.3
Exchange rate (Sums/USD, average)	1,215.6	1,260.8	1,314.2	1,458.8	1,576.8

Source: ADB "Key Indicators for Asia and the Pacific 2012"

2.4 Government Finance and External Debt

2.4.1 Government Finance

The total revenue accounted for approximately 20% of GDP in the period from 2006 to 2010. Since the revenue comes mainly from taxes, strong economic growth, a boom in global commodity markets and tax reform improves the performance of government revenue in recent years. The countries in Central Asia have a narrower tax bases as a legacy of the Soviet era. In order to tackle this weakness, the Uzbekistan government made efforts to expand a tax base by reducing tax burden on small business. Based on the official figures, the Uzbekistan government effectively controlled government expenditure within its revenue and maintained state budget surplus in the period from 2006 to 2010.

Table 2.4.1-1 Government Finance

(Unit: billion Sums)

	2006	2007	2008	2009	2010
Total revenue	4,485.4	6,145.0	8,760.8	10,840.2	13,596.7
Current revenue	4,485.4	6,145.0	8,760.8	10,840.2	13,596.7
Taxes	4,184.9	5,666.5	8,132.8	10,224.5	12,740.5
Total expenditure	4,388.4	5,823.8	8,197.1	10,763.9	13,386.9
Overall budgetary balance	97.0	321.2	563.7	76.3	209.8
Total revenue (% of GDP)	21.2	21.8	22.5	22.0	21.8
Total expenditure (% of GDP)	20.8	20.7	21.0	21.8	21.5
Overall budgetary balance (% of GDP)	0.5	1.1	1.4	0.2	0.3

Source: ADB "Key Indicators for Asia and the Pacific 2012"

2.4.2 External Debt

The total debt outstanding and disbursed almost doubled from 2006 to 2010. Nevertheless, because of an economic growth, the external debt over GNI decreased in the same period. Uzbekistan has the second lowest external debt over GNI in Central Asia (Kazakhstan, Kyrgyz, Tajikistan, Turkmenistan, and Uzbekistan) after Turkmenistan. According to a media report in January 2012, the President of Uzbekistan Islam Karimov stated that the total size of external debt did not exceed 17.4% to GDP and 53.7% to the exports volume. ADB's data suggested that debt service (USD 594.5 million) accounted for 5.6% of the merchandize export and 23.9% of the trade surplus in 2010. This suggests that debt service has remained at a manageable level.

Table 2.4.2-1 External Debt

(Unit: million USD)

	2006	2007	2008	2009	2010
Total debt outstanding and disbursed	4,073.9	4,211.1	4,686.1	6,549.7	7,404.3
Long-term debt	3,915.9	4,012.7	4,465.3	6,386.3	7,166.7
Public and publicly guaranteed	3,289.0	3,133.9	3,144.4	3,245.6	3,245.7
External Debt (% of GNI)	24.0	18.8	17.0	20.1	19.0
Total long-term debt (% of total debt)	96.1	95.3	95.3	97.5	96.8
Principal repayment on long-term debt	677.4	649.0	710.5	717.0	470.6
Interest on long-term debt	170.2	167.7	141.0	120.3	118.1
Interest on short-term debt	3.3	7.3	8.0	2.3	5.8

Source: ADB “Key Indicators for Asia and the Pacific 2012”

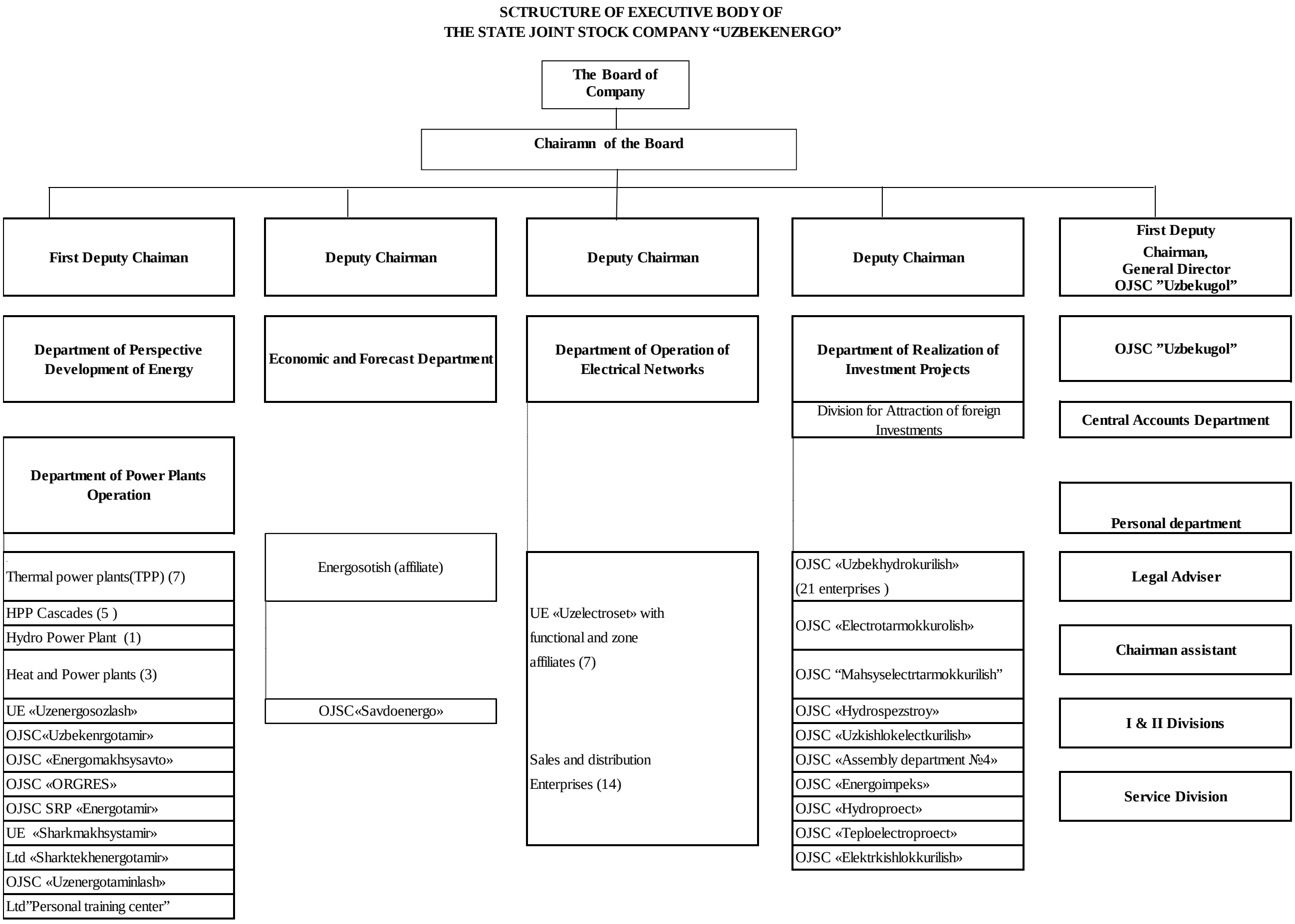
Chapter 3 Overview of the Power Sector in the Republic of Uzbekistan

3.1 Overview of power sector in the Republic of Uzbekistan

3.1.1 Organization

In the Republic of Uzbekistan, there was reorganization in August 2001, and the Ministry of Electric Power and Electrification was changed into the State Joint Stock Company Uzbekenergo (hereinafter referred to as "SJSC Uzbekenergo"). The organization structure of the SJSC Uzbekenergo is shown in Figure 3.1.1-1. SJSC Uzbekenergo includes a power generation company, power transmission company, power distribution company, affiliated company (EnergoSotish, etc), and coal company (Ugol). SJSC Uzbekenergo is run by the board of directors and the council as a higher-level organization. The board of directors consists of the chairman of the board and four deputy chairman of SJSC Uzbekenergo approved by the ministerial conference of the Republic of Uzbekistan. SJSC Uzbekenergo has a payroll of about 40,000. Amid the movement for improved business administration efficiency, the number of the department managers and specialists at the head office of SJSC Uzbekenergo is restricted to 55 according to the decision of the ministerial conference.

The council has jurisdiction over reorganization of the companies including the affiliated company, revision of the articles of association, increase or decrease of capital, and liquidation, and is staffed by eleven members of the council (Vice-president, Vice-chairperson of the national asset committee, Undersecretary of the ministry of finance, Undersecretary of the ministry of macro-economy statistics, and President of SJSC Uzbekenergo).



Source: SJSC Uzbekenergo Booklet, 2008 Version

Figure 3.1.1-1 SJSC Uzbekenergo organization chart

3.1.2 Overview of existing power generation facilities

In 2010, SJSC Uzbekenergo produced 50.158 GWh of electric power, of which 799.2 GWh was exported. In the same year, the SJSC Uzbekenergo imported 898.5 GWh of electric power.
The generation capacity of all the power generation facilities in the Republic of Uzbekistan exceeds 12,400 MW. The thermal power plants accounting for 85.1% and the hydraulic power plant accounting for 11.4% are run by the SJSC Uzbekenergo, and the remaining power generation facilities accounting for 3.5% are run by other organizations.
The SJSC Uzbekenergo anticipates a substantial increase (around 1 to 2%) in electricity demand. To meet this growing demand, the company is planning to maintain the capacity of self support through introduction of new facilities, to improve the reliability and quality of power supply, to save power, and to enhance operation efficiency of fuel and power. Furthermore, to protect the local ecosystem and to enhance global environment, the company is making efforts to develop an on-site power generation technology and renewable energy source. Table 3.1.2-1 and Table 3.1.2-2 show the overview of the existing thermal power plants and hydraulic power plants. Power generation facilities in Uzbekistan consist of ten thermal power plants (of which three are cogeneration power plants) and twenty-eight hydraulic power plants. The overall installed capacity is 12,033MW (10,619MW by thermal power plants plus 1,414MW by hydraulic power plants). Of these, the following four power plants each have an installed capacity of over 1,000MW: These power plants are the Syrdarya thermal power plant (with an installed capacity of 3,000MW), the Navo-Angren thermal power plant (with an installed capacity of 2,100MW),

the Tashkent thermal power plant (with an installed capacity of 1,860MW), and the Navoi thermal power plant (with an installed capacity of 1,250MW). Furthermore, three cogeneration power plants as well as thermal power plants supply heat to thirteen regions.

Many of these power plants have been operating for 40 to 50 years after commencement of commercial operation, and require renewal or replacement due to degradation. However, no plants have been renewed or replaced since commencement of commercial operation of the Talimarjan thermal power plant, unit-1 (having a generation capacity of 800 MW) in 2004, and reinforcement of 300 MW facilities by rehabilitation of the Syrdaria thermal power plant units-7 and -8 in 2005.

Hydroelectric power plants of the company with the installed capacity of 1.4 million kW, are mainly united into cascades of hydroelectric power plants and operate under watercourse.

Table 3.1.2-1 Overview of the facilities in the existing thermal power plants

No.	Name of Plant	Type of Plant	No. of Turbine - Generator Units	Total Installed Capacity (MW)	Type of Fuel	Year of Initial Operation	Total Current Effective Capacity(MW)	Cumulative Operating Hours of All Unit (hours)
1	Syrdarya TPP	Steam Turbine & Boiler	10	3,000	Gas, Oil	1972-1981	2,573.7	185,463 – 238,418
2	Novo-Angren TPP	Steam Turbine & Boiler	7	2,100	Coal, Gas, Oil	1985-1995	1,449.2	56,731 - 110,245
3	Tashkent TPP	Steam Turbine & Boiler	12	1,860	Gas, Oil	1963-1971	1,723	231,542 - 295,138
4	Navoi TPP	Steam Turbine & Boiler	12	1,250	Gas, Oil	1963-1981	980.1	207,387 - 349,429
5	Talimarjan TPP	Steam Turbine & Boiler	1	800	Gas, Oil	2004	-	36,605
6	Takhiatash TPP	Steam Turbine & Boiler	5	730	Gas, Oil	1962-1990	599.7	139,474 - 263,641
7	Angren TPP	Steam Turbine & Boiler	8	484	Coal, Oil, Coal gas	1957-1963	197	158,937 - 288,787
8	Fergana CHP	Steam Turbine & Boiler	7	305	Gas	1954-1979	200	101,051 - 299,183
9	Mubarek CHP	Steam Turbine & Boiler	2	60	Gas	1985-1986	57	71,602 - 128,515
10	Tashkent CHP	Steam Turbine & Boiler	1	30	Gas	1939-1964	-	351,318 - 414,962
	Total			10,619			7,779.7	

Source: SJSC Uzbekenergo

Table 3.1.2-2 Overview of the facilities in the existing hydraulic power plants

No	Name of plant	Type of plant	Place	Number of Unit	Total installed Capacity	Beginning year of operation	Total valid plant capacity (MW)
1	Charvak HPP	Hydraulic Power	Tashkent region	4	600	1970-1972	620.5
2	Khodjikent HPP	Hydraulic Power	Tashkent region	3	165	1976	165
3	Gazalkent HPP	Hydraulic Power	Tashkent region	3	120	1980	120
4	Chirchik GES	Hydraulic Power	Tashkent region	10	190.7	1941-1956	190.7
5	Kadyrya GES	Hydraulic Power	Tashkent region	8	44.6	1933-1946	44.6
6	Nizne-Bozsu GES	Hydraulic Power	Tashkent region	10	50.8	1943-1960	50.8
7	Tashkent GES	Hydraulic Power	Tashkent	10	29	1926-1954	29
8	Farkhad GES	Hydraulic Power	Syrdarya region	4	126	1948-1960	126
9	Sharikhan GES	Hydraulic Power	Andijan region	6	27.8	1943	27.8
10	Samarkand GES	Hydraulic Power	Samarkand region	9	40	1945	40
	Total				1,393.9		1,414.4

Source: SJSC Uzbekenergo

In the meantime, Table 3.1.2-3 and Figure 3.1.2-1 show transition of installed capacity of thermal and hydroelectric power plants. Installed capacity of both power plants remained almost unchanged in the past 10 years.

Table 3.1.2-3 Transition of installed capacity of thermal and hydroelectric power plants

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Thermal Power Plant	10.014	10.000	9.921	10.041	10.041	10.041	10.841	10.841	10.649	9.870	9.870
Hydro Electric Power Plant	1.690	1.690	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.710
Total	**11.704**	**11.690**	**11.631**	**11.751**	**11.751**	**11.751**	**12.551**	**12.551**	**12.359**	**11.580**	**11.580**

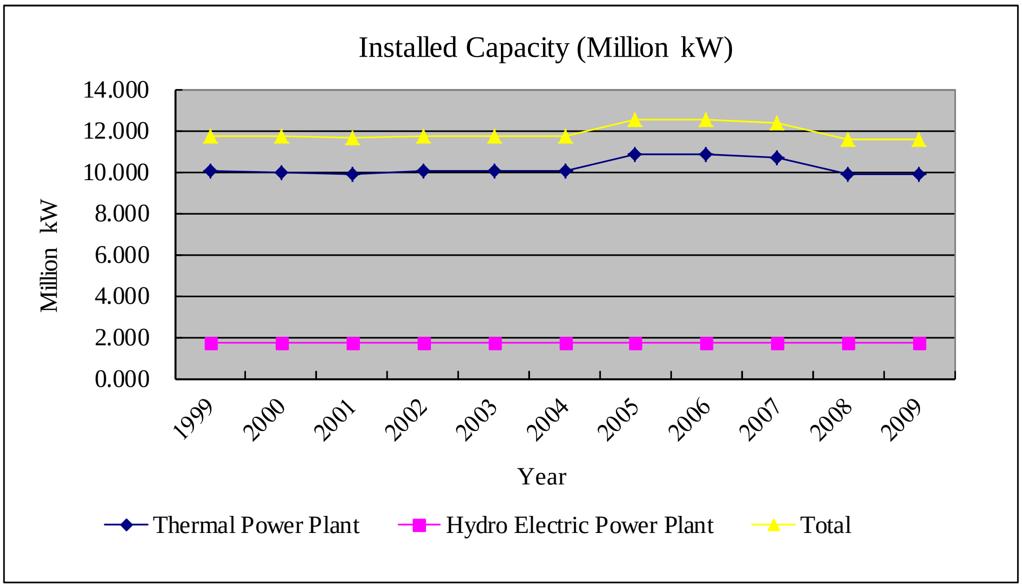


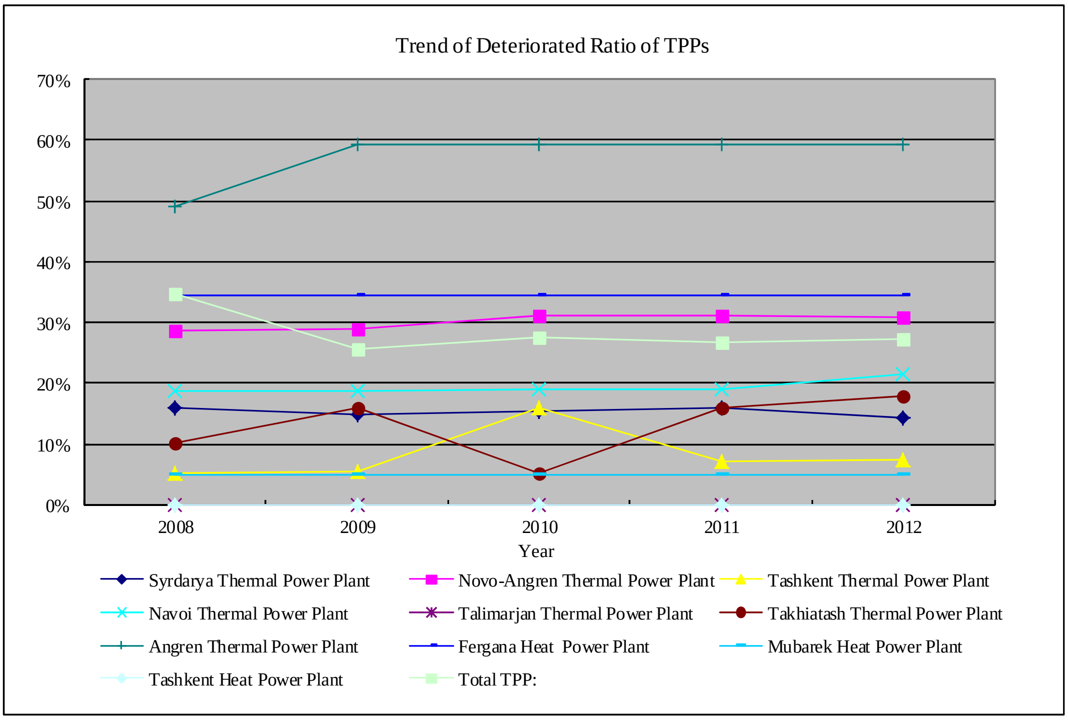
Figure 3.1.2-1 Transition of installed capacity of thermal and hydroelectric power plants

Table 3.1.2-4 shows available capacity of each thermal power plant. As shown in Table 3.1.2-4 and Figure 3.1.2-2, average deteriorated ratio (= (Installed capacity – Available capacity)/Installed capacity x 100) shows around 30%, that is, one third of installed capacity was lost. Largest deteriorated thermal power plant is Angren thermal power plant which shows around 60% of deteriorated ratio, that is, more than half of installed capacity was lost. Recovery of this lost capacity is an urgent issue for power sector in Uzbekistan.

Table 3.1.2-4 Transition of Available Capacity of the existing TPPs

Name of Thermal Power Plant	Available capacities, MW				
	2008	2009	2010	2011	2012
Syrdarya Thermal Power Plant	2,518.1	2,556.5	2,536.0	2,519.3	2,573.7
Novo-Angren Thermal Power Plant	1,497.5	1,491.0	1,448.0	1,448.2	1,449.2
Tashkent Thermal Power Plant	1,763.7	1,755.7	1,562.0	1,724.6	1,723.0
Navoi Thermal Power Plant	1,015.8	1,015.8	1,014.0	1,013.8	980.1
Talimarjan Thermal Power Plant	-	-	-	-	-
Takhiatash Thermal Power Plant	654.8	612.4	692.8	613.4	599.7
Angren Thermal Power Plant	247	197	197	197	197
Fergana Heat Power Plant	200	200	200	200	200
Mubarek Heat Power Plant	57	57	57	57	57
Tashkent Heat Power Plant	-	-	-	-	-
Total TPP:	7,953.9	7,885.4	7,706.8	7,773.3	7,779.7

Source: SJSC Uzbekenergo



Source: SJSC Uzbekenergo

Figure 3.1.2-2 Transition of Deteriorated Ratio of the Existing TPPs

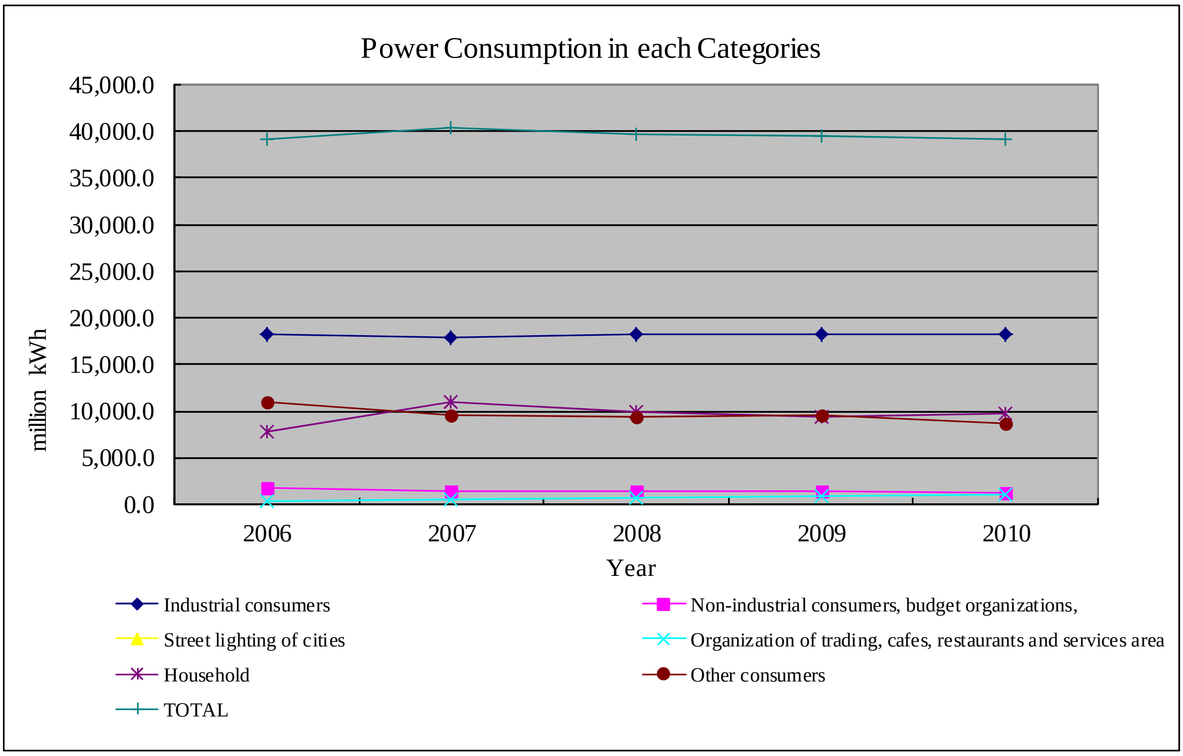
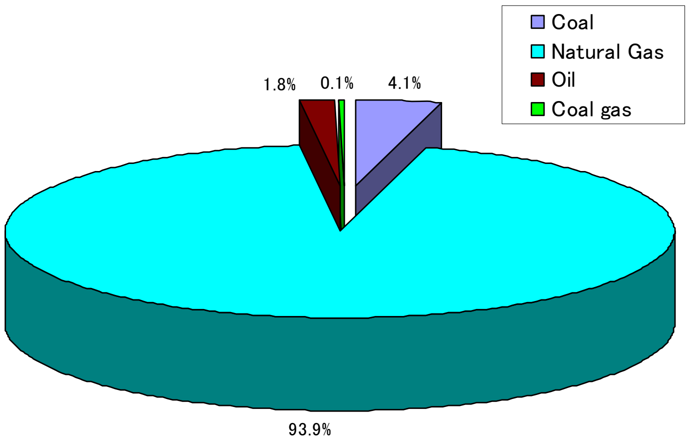


Figure 3.1.2-3 Power Consumption in each Category in the past 5 Years

Figure 3.1.2-4 shows the fuel ratio in thermal power plants in 2008.



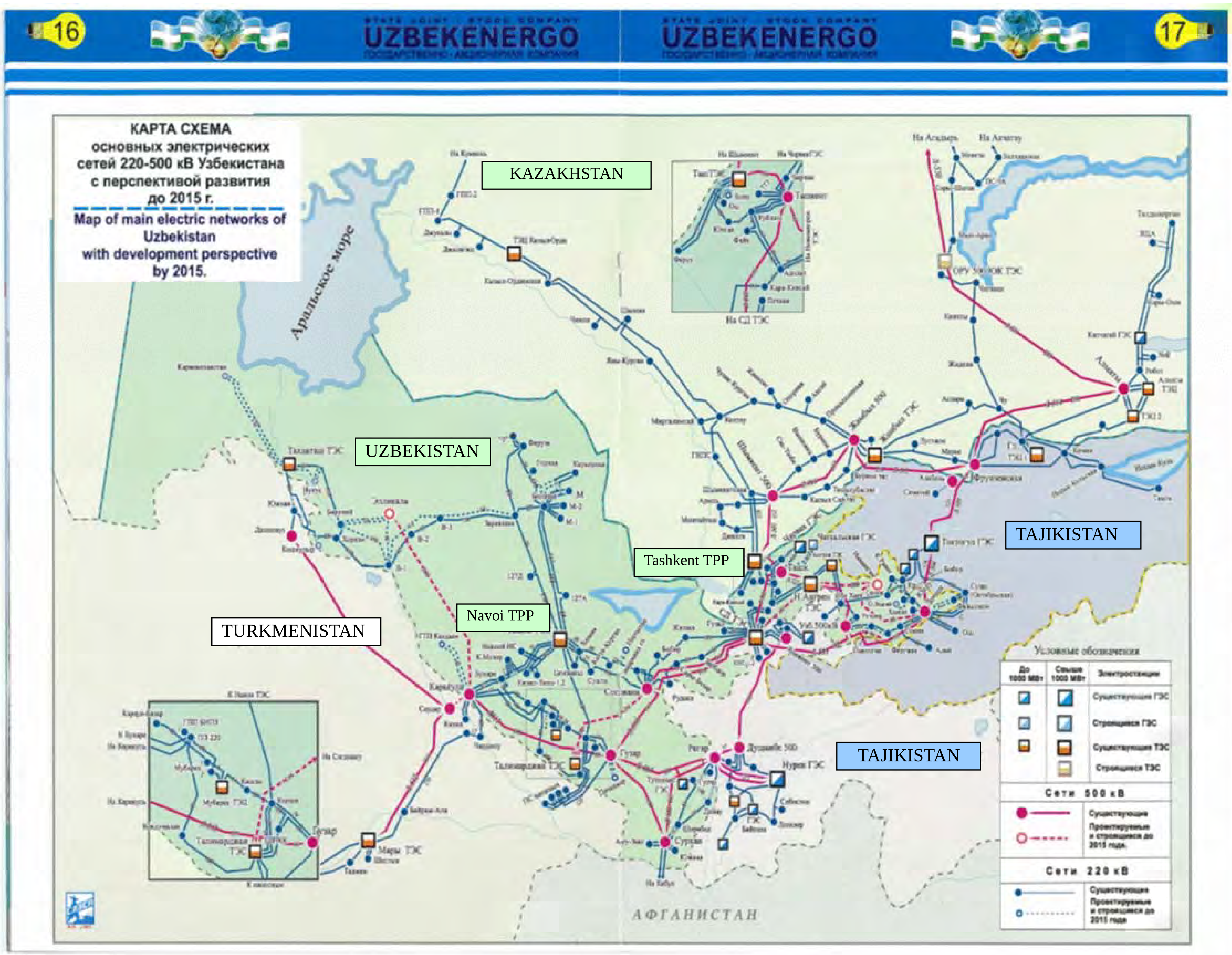
Source: SJSC Uzbekenergo

Figure 3.1.2-4 Fuel ratio in thermal power plants (2008)

3.1.3 Overview of power transmission facilities

(1) Power grid system

The power grid system in the Republic of Uzbekistan was constructed at the time of the former Soviet Union, where five countries including Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan were assumed as constituting one integral area. Thus, after independence of each country, the power grid system constitutes an international linkage system. The 500 kV transmission line is also linked to Russia via Kyrgyzstan and Kazakhstan. Thus, the power grid system is characterized by a large scale system and operation of stable frequency. The 500 kV and 220 kV lines are used in the trunk network, and the 110 kV lines serve for local supply systems. The vast majority of the trunk network consists of one-circuit transmission lines. The outage at the time of transmission line trouble is minimized by parallel operation of the 500 kV and 220 kV circuits.



Source: 2010 Annual Report of SJSC Uzbekenergo

Figure 3.1.3-1 Power grid system for the Republic of Uzbekistan

As will be discussed in Subsection 3.1.4, there has not been much fluctuation in demands for the past ten years. Reinforcement work was not applied to the 500 kV transmission line of the trunk network for some time since 1991, as shown in Table 3.1.3-1 reflecting such demand. However, to meet the requirements for further reduction of transmission loss and subsequent increase in demand, expansion work was performed in 2007 and 2008. As of 2012, the 500 kV transmission line measures 2,331 km, the 220 kV transmission line measures 6,121 km, and the 110 kV transmission line measures 707 km.

Table 3.1.3-1 Overall extension of transmission lines

Year	Length of Transmission Lines / km		
	500kV	220kV	110kV
2003	1,662	5,620	234,847
2004	1,662	6,134	689
2005	1,659	6,158	692
2006	1,659	6,152	692
2007	1,730	6,182	692
2008	1,847	6,173	692
2009	2,043	6,152	692
2010	2,043	6,079	692
2011	2,310	6,121	707

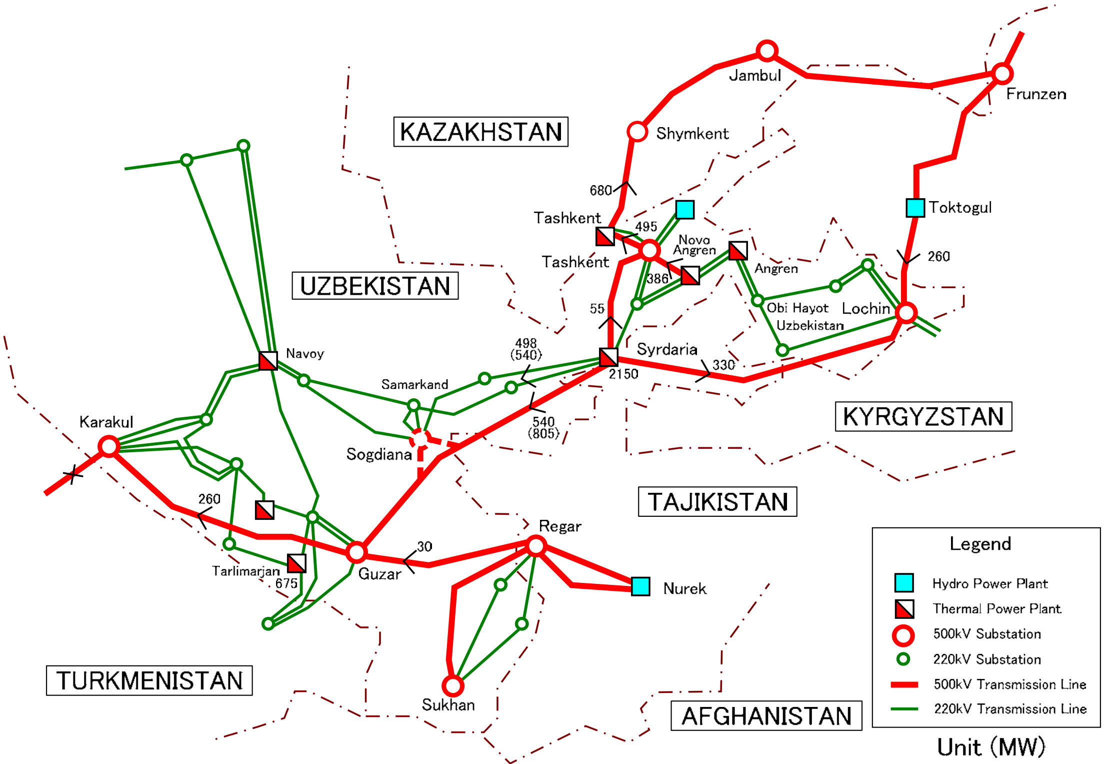
Source: SJSC Uzbekenergo

(2) Power flow

Seventy percent of the power sources including the Tashkent thermal power plant (with a generation capacity of 1,860 MW) located at the center of demand, the Novo Angren thermal power plant (with a generation capacity of 2,100 MW), and Syrdarya thermal power plant (with a generation capacity of 3,000 MW) are located in the northern district. The major power flow goes from north to southwest. The overall power transmitted from the Syrdarya thermal power plant at the time of maximum demand in December 2003 was 1,345 MW -- 805 MW via the 500 kV transmission line, and 540 MW via the 220 kV transmission line (Figure 3.1.3-2).

However, in the south of the Republic of Uzbekistan, the Talimarjan thermal power plant (having a generation capacity of 800 MW) commenced commercial operation in 2004. This reduced the power flow to the southwest. The result was a total of 1,038 MW power transmission capability -- 540 MW via the 500 kV transmission line and 498 MW via the 220 kV transmission line.

Furthermore, the excessive load on the 220 kV transmission line in the center of the Republic of Uzbekistan with the major center located in Samarkand was reduced by the new construction of the 500 kV Sogdiana substation in July 2005. The power grid system characteristics have been greatly enhanced by the implementation of these measures.



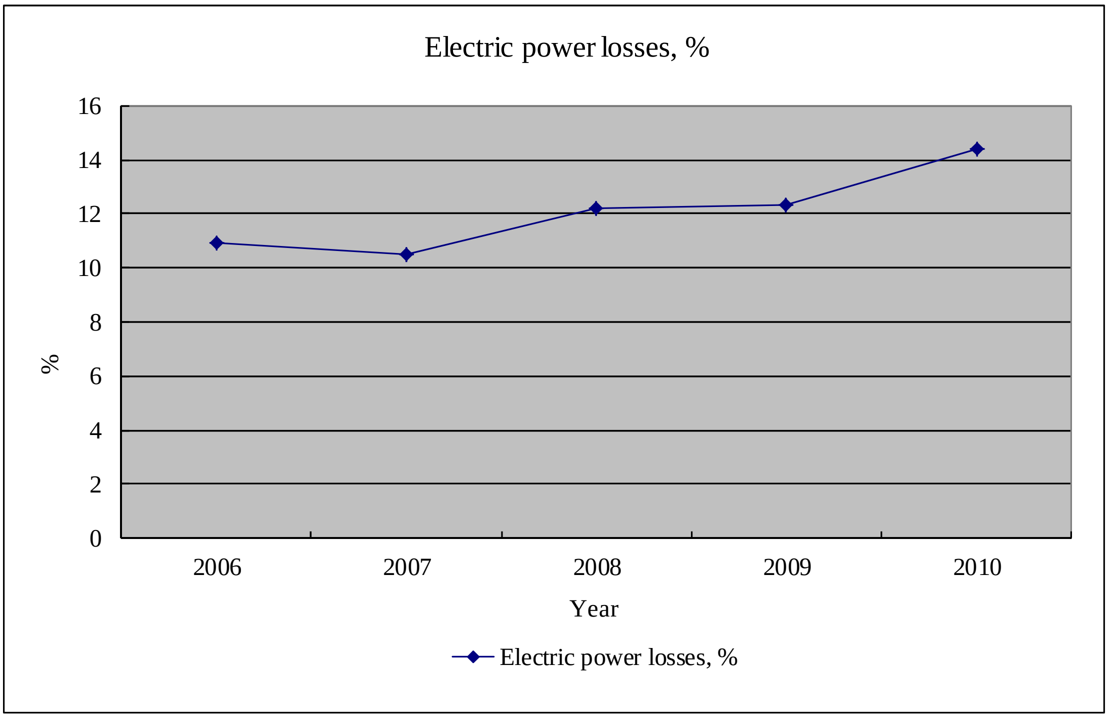
Power Flow at Peak Demand Time on Dec. 2004 (Dec. 2003)

Source: Sector Study for Power Sector in Uzbekistan (2004, JBIC)

Figure 3.1.3-2 Power flow in the Uzbekistan power system

(3) Loss in power transmission and distribution

The loss in power transmission and distribution can be divided into technical loss and non-technical loss. The technical loss rate of Figure 3.1.3-2 shows a transition of about 10 % up to the year 2010 from 2006. After that, a rapid increase can be observed. This may have been caused by the degradation of power transmission and distribution facilities. However, the reason for a rapid increase amid the stagnation of the overall demand is not yet clear. The reduction in the loss rate is effective in reducing the amount of primary energy used, hence in protecting the global environment. It is necessary to examine the reasons in greater detail and to take required measures.



Source: SJSC Uzbekenergo

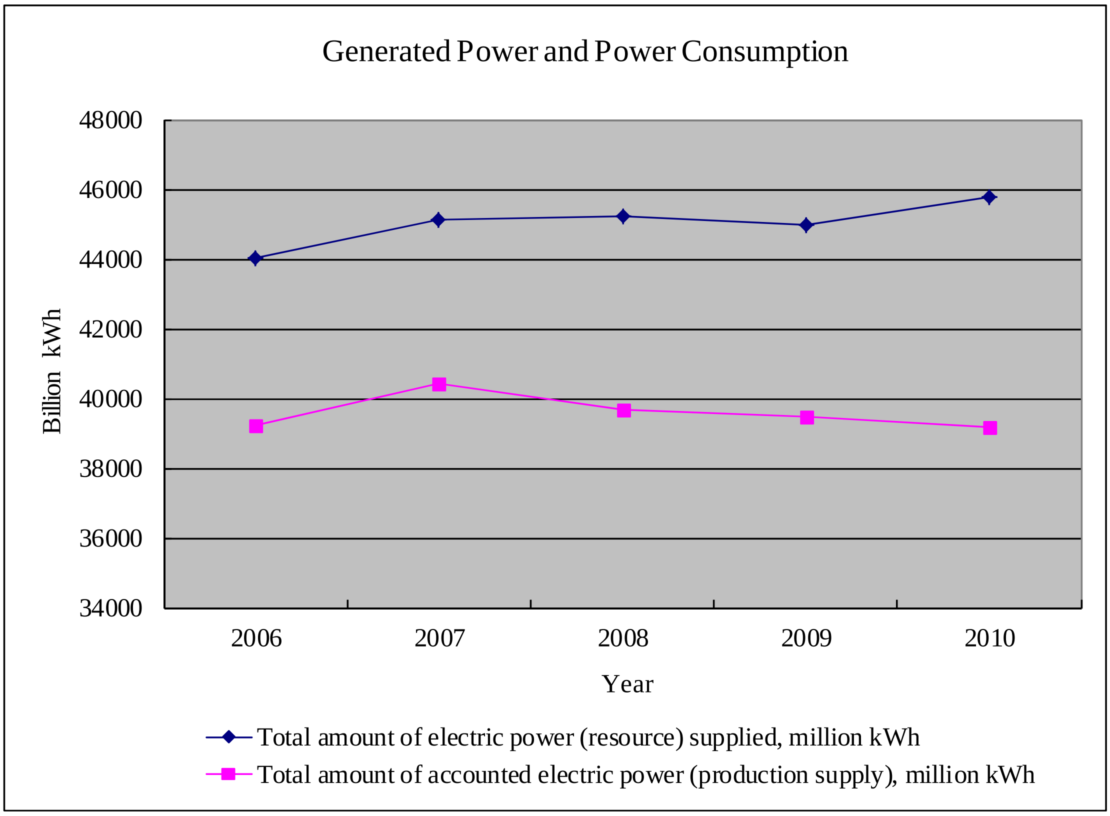
Figure 3.1.3-2 Transition of power transmission and distribution loss rate

3.1.4 Power demand

Figure 3.1.4-1 shows the transition of the generation and consumption of power in the last 5 years. The overall demand for electric power in the Republic of Uzbekistan had exhibited annual reduction for ten years after independence in 1991 due to economic confusion and stagnation of industrial activities. However, economy has been on an upward trend after that, and the overall demand for electric power is also on an upward trend, even though this trend is very slow.

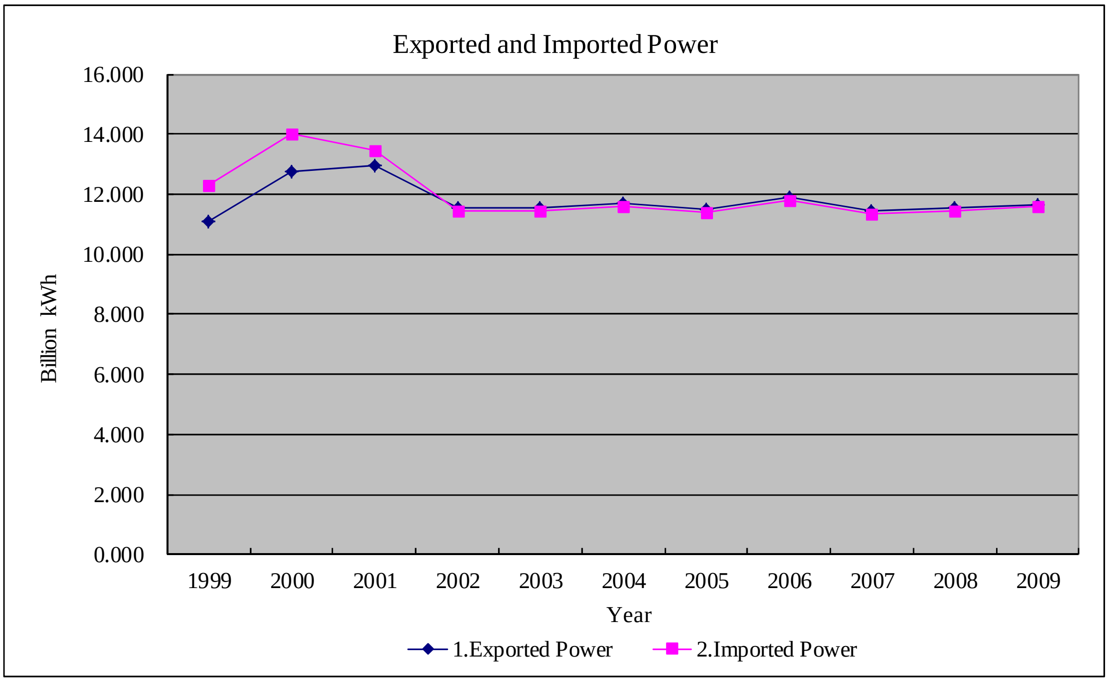
Figure 3.1.4-2 shows the transition of the imported and exported electric power. As described above, electric power is exchanged among Uzbekistan and the surrounding countries. The export and import power exhibits a slight fluctuation from 1999 to 2002, while both are generally stabilized from 2003 to 2009. The possible cause is that the electricity rate is not yet determined for exchange of electric power among the surrounding countries, and transaction of water, electricity and natural gas is performed on a barter basis.

Figure 3.1.4-3 shows the transition of the maximum demand for electric power and generation capacities in the last ten years. The demand for electric power in Uzbekistan registered a level of 8,608 MW in 1991 during the age of the Soviet Union. The demand had been on a downward trend since independence in the same year to reach a level as low as 7,379 MW in 1995. After that, reflecting the economic recovery, there was a slight increase in the demand, but the record for 2008 is 7,727 MW, without the maximum record of the past being surpassed. Furthermore, in comparison with the generation capacity, the reserve margin in the generation capacity at the time of maximum demand (calculated from the percentage between maximum demand and effective capacity, although the value corresponding to the shutdown due to maintenance and other work is subtracted, where this value was omitted for the sake of simplification) was 21 % in 2005. By contrast, this percentage was increased to 28 % in 2008, exhibiting a satisfactory transition level.



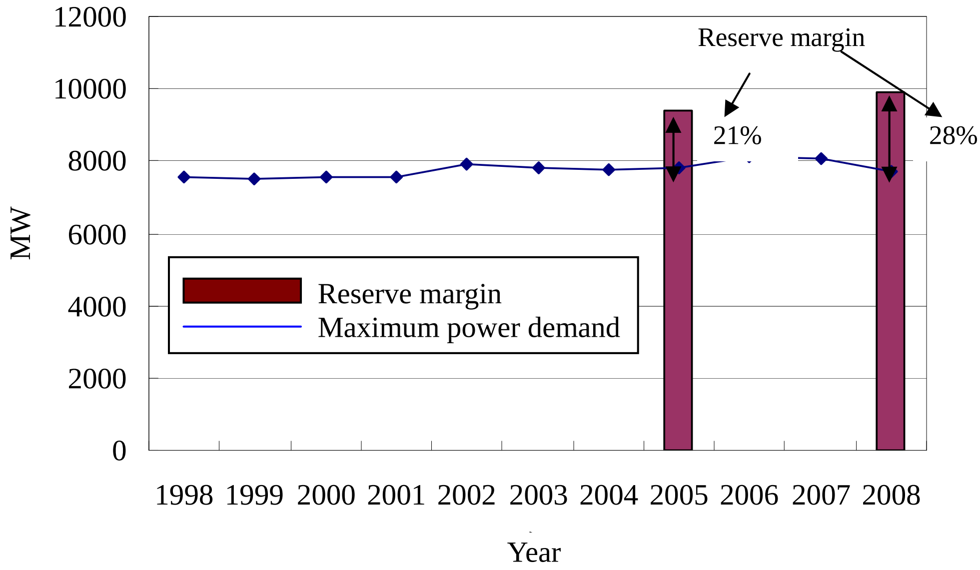
Source: SJSC Uzbekenergo

Figure 3.1.4-1 Transition of electricity generation and electricity consumption in the last 5 years



Source: SJSC Uzbekenergo

Figure 3.1.4-2 Transition of the imported and exported electric power in the last ten years



Source: SJSC Uzbekenergo

Figure 3.1.4-3 Transition of the maximum power demand and reserve margin

3.1.5 Power generation development plan

In the Republic of Uzbekistan, the position of the most important national investment items for gas development, electric power development and others has been clearly defined by the Executive Order of the President in an effort to ensure a sustainable development of economy. According to Power Generation Development Plan up to 2015 made by SJSC Uzbekenergo; expansion of the Talimarjan thermal power plant, expansion of the Navoi thermal power plant, expansion of the Novo-Angren thermal power plant and modernization of the Tashkent heat supply power plant are approved as the important projects for electric power development in that time period. For the funds of these projects, the SJSC Uzbekenergo depends mainly on the loans from JICA and other international cooperation agencies.

In this context, the Navoi CHP Plant is located at the south-east of the Navoi Province, and is evaluated as the major power source as well as the important heat supply source. Accordingly, if the modernization project of this power plant is financed as a Japanese ODA Loan project and is implemented as planned, a significant contribution is anticipated to be made to a stable supply of heat and electricity in Uzbekistan as well as Navoi.

Table 3.1.5-1 Power generation development plan up to 2015

No.	Name of plants	Type of plants	Installed capacity, MW	Type of fuel	Year of launching
1	Construction of CCGT at Navoi TPP	Combined cycle gas turbine	478	Natural gas	2012
2	Construction of gas turbine plant at Tashkent Heat Power Plant	Gas turbine plant	3x27	Natural gas	2013-2015

No.	Name of plants	Type of plants	Installed capacity, MW	Type of fuel	Year of launching
3	Construction of two CCGT at Talimarjan TPP	Combined cycle gas turbine	2x450	Natural gas	2014
4	Construction of power generating unit at Angren TPP	Thermal power plant	150	Coal	2014
5	Construction of CCGT at Tashkent TPP	Combined cycle gas turbine	370	Natural gas	2014
6	Expansion of Mubarek Heat Power Plant with installation of GTP	Gas turbine plant	140	Natural gas	2014
7	Expansion of Navoi TPP with installation of second CCGT unit	Combined cycle gas turbine	450	Natural gas	2015

(Note) TPP: Thermal Power Plant, CHP: Combined Heat and Power
Source: SJSC Uzbekenergo

3.1.6 Power demand forecast

SJSC Uzbekenergo planned power generation by their Thermal Power Plant from 2012 to 2020 is shown in Table 3.1.6-1. During the term its growth rate will be around 1.0% per year.
As described in item 3.1.2, the available capacity of the existing thermal power plants is reduced to 70% of their installed capacity in 2012. Therefore, new installation or modernization of power plant is necessary to cover such gap between maximum power demand and available capacity. On the other hand, 2,569MW generation capacity is planned to be developed, as shown in Table 3.1.5-1. This figure includes the capacity by replacement of the existing power plants. Therefore, to keep the stability of power supply to correspond to increasing power demand, it is necessary to implement said power generation development plan steadily.

Table 3.1.6-1 Power Demand Forecast up to 2020

Unit: Billion kWh

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electric Power Demand	50.5	50.7	51.2	51.7	52.2	52.7	53.3	53.8	54.4
Growth Ratio (vs. previous year)	-	0.40%	0.99%	0.98%	0.97%	0.96%	1.14%	0.94%	1.12%

Source: SJSC Uzbekenergo

3.1.7 Activity for Developing Renewable Energy by SJSC Uzbekenergo

In Uzbekistan the complex of works on the environment protection and an establishment of corresponding normative requirements are carried out in full conformity with laws of the Republic of Uzbekistan.
“About Protection of Nature”, “About Air Protection”, “About Rational Using of Energy”, “About Ecological Expertise”, in line with the documents accepted at the international level concerning ecological and nature protection problems.

SJSC Uzbekenergo having observed requirements of the nature protection legislation of the Republic of Uzbekistan provides realization of necessary measures in the area, directed to

- Reduction of pollutant emission to atmosphere and discharges in water basins ;
- Rational utilization of water resources ;
- Waste utilization ;
- Disturbed soils re-cultivation ;
- Dimensioning emissions and discharges up to the technically reasonable values.

3.1.8 Renewable Energy in Uzbekistan

SJSC Uzbekenergo is promoting Renewable Energy in Uzbekistan to diversify fuel and energy balance, SJSC Uzbekenergo plans to implement the following projects.

(1) Solar power plant
- Capacity : 50MW
- Period of construction ; 2016 to 2018
- Power generation : 110 mil. kWh per year
- Saving natural gas volume : 36 mil. m^3 per year
- Project cost : 250 mil. USD
- Source of finance : Own finance and foreign investment

(2) Pilot wind power plant
- Capacity : 0.75MW
- Period of construction ; 2011
- Power generation : 1.28 mil. kWh per year
- Saving natural gas volume : 0.4 mil. m^3 per year
- Project cost : 2.87 mil. USD
- Source of finance : Own finance

(3) Wind power units
- Capacity : 100MW
- Period of construction ; 2016 to 2018
- Power generation : 210 mil. kWh per year
- Saving natural gas volume : 68 mil. m^3 per year
- Project cost : 250 mil. USD
- Source of finance : Own finance and foreign investment

3.2 Electricity and Heat Tariff

3.2.1 Electricity Tariff

In Central Asia, Uzbekistan is one of the countries where cross-subsidy is relatively small. In the period of 2002-2004, tariff reform was initiated. This effort brought a significant reduction of cross-subsidy to the power sector by the mid-2000s[1]. Retail tariff of electricity has increased at 8-10% higher than annual rate of inflation for the period of 2004-2011[2]. As a result, a direct subsidy to cover production cost is not provided to electricity. In the current tariff table, there are ten types of customer category. Cheaper tariff for large industrial customers shows that tariff setting remains economically rational.

On retail prices of electricity, SJSC Uzbekenergo submits a tariff petition to the Ministry of Finance which is in charge of review and approval of electricity tariff. The retail prices of electricity have been revised twice or three times per year for the period of 2010-2012. The data obtained from SJSC Uzbekenergo show that average price of electricity tariffs has margin over production cost, which includes fuel cost, maintenance cost, depreciation and interest payment. The weighted average price of electricity sales was 83.53 sum/kWh in 2011 and surpassed the production cost for the same year. For the period of 2010-2011, the supply cost has been lower than tariff rates in most customer categories except large industrial users, a customer category which is offered the most inexpensive tariff rate but charged an additional fee. With the current level of electricity tariff, it is plausible that SJSC Uzbekenergo obtains revenue sufficient for recovery of both investment and operation costs for power generation.

The Final Report for Central Asia Economic Cooperation Power Sector Master Plan, which is funded by ADB, estimates cost recovering tariff level at USD 0.07/kWh or 137.2 sum/kWh. However, the estimated cost is based on efficiency of existing gas-fired power plants and export price of natural gas which is higher than the price of natural gas in the domestic market. The estimated cost fairly shows a hypothetical production cost in the case that fuel price would reach international level but it is somewhat immoderate as actual production cost. According to the aforementioned master plan, the Uzbekistan government is likely to support capital costs for investment in electricity. The Ministry of Finance in Uzbekistan currently supports SJSC Uzbekenergo in recovery of investment cost by maintaining electricity tariff at appropriate level and deducting taxes and duties. In the view point of beneficiary payment principle, continuing tariff revision above inflation is appropriate to ensure sufficient investment in the power sector in the long run.

Table 3.2.1-1 Electricity Tariff by Customer Category

（Unit: Uzbekistan Sum）

Cat.	Customer	Apr-10	Oct-10	Dec-10	Apr-11	Oct-11	Apr-12	Oct-12
1	Industrial (connected load >750 kW)*	55.50	60.45	60.45	65.80	71.70	76.50	81.90
2	Industrial (connected load <750 kW)	70.50	76.80	76.80	83.60	91.10	97.50	104.40
3	Industrial Agriculture	70.50	76.80	76.80	83.60	91.10	97.50	104.40

[1] ADB (2005), “Electricity Sectors in CAREC Countries”
[2] WB (2011), “Project Appraisal Document for Talimarjan Transmission Project”

Cat.	Customer	Apr-10	Oct-10	Dec-10	Apr-11	Oct-11	Apr-12	Oct-12
4	Electrified Railway	70.50	76.80	76.80	83.60	91.10	97.50	104.40
5	Non-industrial consumers	70.50	76.80	76.80	83.60	91.10	97.50	104.40
6	Commerce	72.00	78.40	78.40	85.40	93.00	99.50	106.50
7	Residential**	70.50	76.80	76.80	83.60	91.10	97.50	104.40
8	Air conditioning and Hot water	70.50	76.80	76.80	83.60	91.10	97.50	104.40
9	Advertisement and Illumination	110.00	110.00	110.00	110.00	110.00	110.00	110.00
10	Usage of power system	70.50	76.80	76.80	83.60	91.10	97.50	104.40
	Average	65.84	68.14	73.10	78.65	78.65	84.64	91.24

Source: SJSC Uzbekenergo
* Based on maximum load, additional fee is charged.
**Houses with electric stoves have preferential tariff.

Table 3.2.1-2 Production Cost of Electricity

	2007	2008	2009	2010	2011
Power Generation (GWh)	40,417.9	39,698.3	39,460.7	39,179.5	40,512.2
Total Production Cost (million sum)	1,483,508.1	1,882,782.0	2,130,853.6	2,428,727.4	2,493,510.0
Production Cost (Sum/kWh)	36.70	47.43	54.00	61.99	61.55

Source: SJSC Uzbekenergo

3.2.2 Heat Tariff

Heat, both steam and hot water, is a major byproduct of electricity generation and used for both household and industrial purposes. Based on the data obtained from SJSC Uzbekenergo, heat revenue surpassed production cost including fuel cost, maintenance cost, depreciation and interest payment. While the weighted average price of heat sales was 20,733.46 sum/Gcal in 2011, the supply cost was 18,778.1 sum/Gcal in the same year. It is concluded that heat tariff is at or above cost recovery level.

Table 3.1.8-1 Production Cost of Heat

	2007	2008	2009	2010	2011
Usable Heat (Gcal)	9,638,062.2	9,043,909.4	8,174,272.1	7,677,624.1	7,937,008.7
Total Cost (million sum)	91,120.8	102,105.7	106,644.3	118,324.5	149,041.9
Unit Cost (Sum/Gcal)	9,454.27	11,290.00	13,046.34	15,441.61	18,778.10

In the Navoi area, SJSC Uzbekenergo provides heat to its customers including chemical plants and residents via Navoi TPP. Billing of both steam and hot water is calorie-based under the same tariff table. Consumed amounts of steam and hot water are converted to calories. Heat tariff is revised every year as Navoi TPP submits a tariff petition to the Ministry of Finance with production cost data once a year. The Ministry of Finance is in charge of review and approval of heat tariff as well. A direct subsidy is not provided to heat. In the tariff table of Navoi TPP, there are four types of customer category. Profitability of heat production can provide indirect evidences on cost recovery. The profit of heat production in Navoi TPP had been positive for the period of 2007-2010. This may imply that heat production covered production costs required directly for its operation.

Table 3.2.2-2 Tariff Table of Heat for Navoi TPP in October 2012

Cat.	Customer	Price (Sum/Gcal)
1	Consumers except whole sellers and greenhouses	30,838
2	Whole sellers and greenhouses	26,349
3	Usage under SJSC Uzbekenergo system	23,248
4	Residential	16,961

Source: Navoi TPP

Table 3.2.2-3 Gross profit of heat production in Navoi TPP

	2007	2008	2009	2010
Heat power Production (000 Gcal)	2,862.0	2,759.0	2,235.0	2,329.5
Heat power sales (000 Gcal)	2,749.9	2,650.2	2,149.0	2,234.8
Profit from heat sales (million sum)	33,773.3	35,643.5	32 281.3	34,384.2

Source: Preliminary F/S for “The construction of the second CCGT Unit of 450MW at the Navoi thermal power station” (2012)

Chapter 4 Survey of Navoi Power Plant Facilities

4.1 Site situation

4.1.1 General

Uzbekistan is characterized by typical continental climate consisting of a very hot summer, comparatively cold winter, a great temperature difference between daytime and night time, and dry weather with little precipitation.
The planned project site is adjacent to the existing Navoi thermal power plant located in the suburbs of Navoi of Uzbekistan approximately 360 km west-southwestern (WSW) of Tashkent, capital of Uzbekistan.
The Navoi thermal power plant and the candidate construction site are located on the left bank of the Zarafashan River.
The CCCGP No.2 (450MW) power plant is considered to require a site area of approximately 9.0 Ha.

4.1.2 Site selection

The planned candidate construction site for the CCCGP No.2 (450MW) power plant is adjacent to the Navoi thermal power plant approximately 7 km northwest of Navoi city (city hall).
Table 4.1.2-1 illustrates the comparison between candidate sites A and B.

Table 4.1.2-1 Comparative table of construction sites

Item	Candidate site A	Candidate site B	Remarks
Installation position	West of CCCGP No.1 under construction	North of the existing Navoi thermal power plant	
Site acquisition	Possible to acquire the area for the CCCGP No.2 site measuring approximately 9.0 Ha	Difficult to acquire the area for the CCCGP No.2 site and the site required for construction	
Site conditions	The power transmission steel tower (currently being used) must be relocated. The existing structures (ground-based structures) other than the power transmission tower (currently being used) have already been removed.	The groups of garages and National Vacation Villages must be relocated.	
Access	A railway and access road are constructed up to the southern point of the planned site. However, the need for extending the access road width and others must be studied.	A new access road must be constructed. The existing power plant will be split by the access road.	

Item	Candidate site A	Candidate site B	Remarks
Workability	There seems to be no problem except for the problem of relocating the power transmission steel tower (currently being used).	The existing power plant structures must be removed to construct a new access road.	
Security	No security problem for the existing power plant as a result of constructing the CCCGP No.2.	Security problem will arise to the existing power plant because the existing plant will be split by the construction of a new access road.	
Others	Close to the existing power plant, fuel supply, water supply and heat supply. Smaller impact of the construction of the CCCGP No.2 upon the existing power plant.	Requires construction of a gas pipeline that splits the existing power plant.	
Evaluation	OK (accepted)	NG (rejected)	

Source: Study Team

The above Table suggests that candidate site A is superior to candidate site B as a candidate construction site for a new power plant.
Thus, candidate side A is recommended as a construction site for a new power plant.

4.1.3 Site condition

4.1.3.1 Site preparation

In the planned construction site for CCCGP No.2 (candidate site A), approximately 9 hectares of the site required for power plant construction has been prepared almost completely. However, the transmission lines of the four series and their foundations have not been removed. Thus, the transmission lines of the four series and their foundations must be removed or relocated.
The prepared ground level of candidate site A is BSL + 330.0m to +336.5m (BSL: Baltic Sea level).
It should be noted, however, that construction of the power plant requires a survey of the existing underground structures. If the existing underground structures are left unremoved, they must be relocated or removed.

4.1.3.2 Physiographical and Geological condition

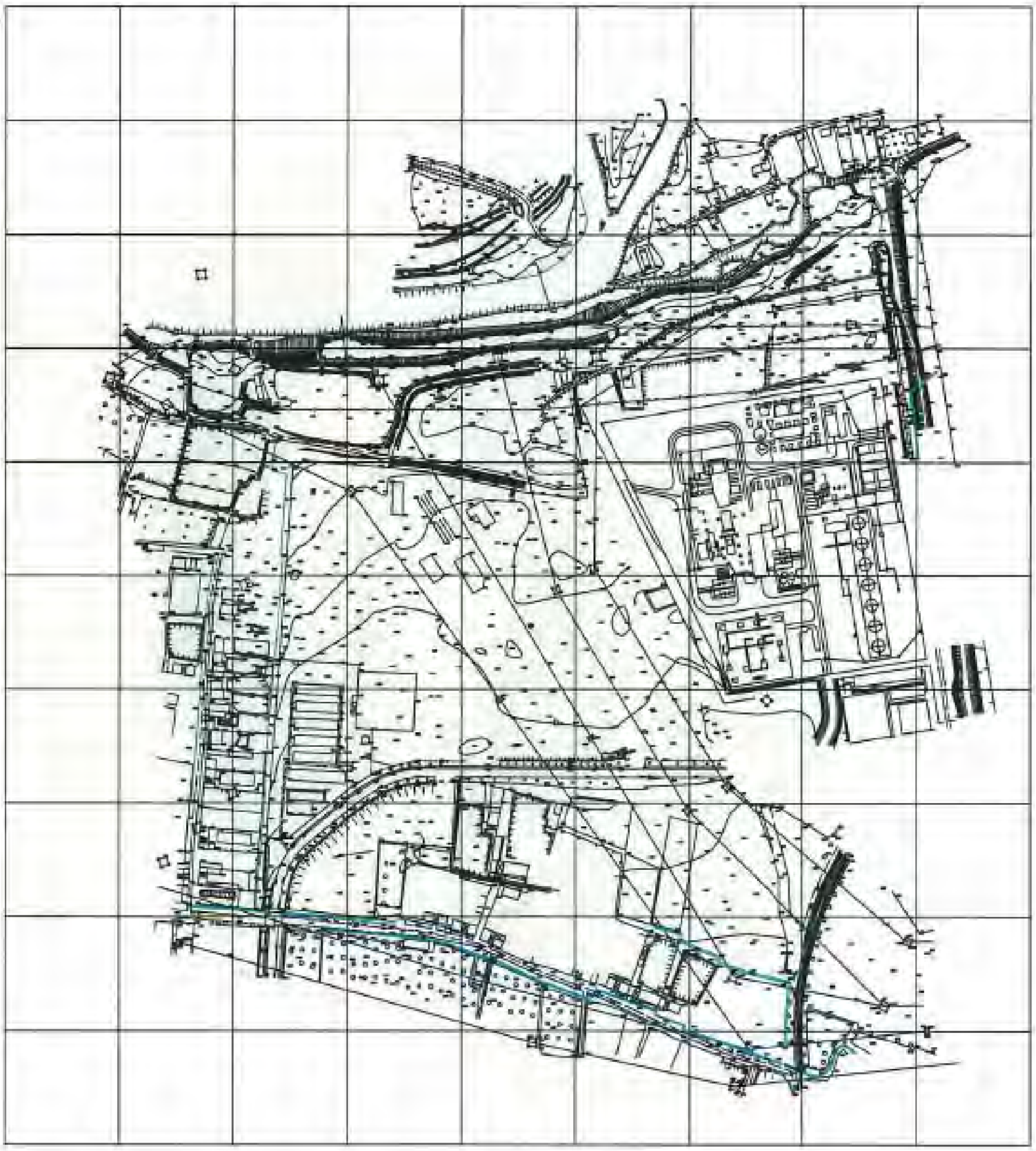
Physiographic location of the project site is on a left bank of the river Zeravshan in its middle course.
The Valley of Zeravshan River within the limits of the considered district extends in latitudinal direction. In the north the valley is confined by smooth hill slopes of Nuratin Mountains, in the south - by foothills of Zeravshan range (Zerabulak- Zihayetdin Mountains).
The width of the valley in the described valley achieves from 3-4 to 12-14 km.
The region is characterized by a long hot summer and comparatively warm winter.

Geologically in the valley of Zeravshan river the following river terraces are distinguished:

First terrace above flood-plain was mainly developed in the right bank part of the valley, where its width achieves 1-2 km, in the left bank part it stands out in a form of a narrow strip of 50-m width, being traced along the current riverbed.
Second terrace above flood-plain is also traced, mainly, on the right bank of the river.
Third terrace above flood-plain in the survey area is the most developed, it takes the greatest part of Zeravshan river valley.
On the surface of a third terrace above flood-plain, mainly, all the settlements, industrial enterprises are located, including Navoi thermal power plant (TPP).

Terrace cusp above water level in the river is 4-6 m.

Figure 4.1.3-1 shows the topographic map.



Source: SJSC Uzbekenergo

Figure 4.1.3-1 Topographic map.

4.1.3.3 Soil condition

The construction site for the CCCGP No.2 is composed of stratums of quaternary depositions of the barren complex represented by alluvial and proluvial loams and sandy loams of grayish-brown color. They are followed by wood-detrital soils and gravel.
The first from surface natural lithologic horizon consists of a loamy layer with the inclusion of a soil-vegetable layer and silt. The thickness of this layer may vary from 0.5 to 4.5 meters. Loams have the color from dark gray to yellowish-gray and gray-field. Loams are loess-like pulverescent and are of firm consistency.
Below this, the layer of a grussy soil occurs, which consists of fragments of clay slates with sandy-loam filler.
Under the layer of a grussy soil, the loamy sediments of alluvial origin of yellowish-gray to gray color occur.
Loamy soils of the first and second layers, along with their similarity, also have very close values of physical and mechanical properties.
Loamy soils of the first layer according to the extent of slumping from their own weight when soaked refer to the first type of collapsibility. Loamy soils of the second layer are not collapsible.
Soils are slightly saline.
Type of soil is salinity – hydrocarbonate-sulfate-calcium. Soils, as the environment, are strongly aggressive against Portland cement.
Clay soils are underlain by gravel-pebble depositions (layer 3) at a depth of 5.7-6.0 meters.
Pebbles are mostly of medium size, they are well-rounded, but there are also not well-rounded fragments.
The filtration properties of these depositions are characterized by the coefficient of filtration – 15.9 m/day.

4.1.3.4 Groundwater condition

The hydrogeological conditions are characterized by the development of ground water confined to quaternary depositions of the Zarafshan river valley, and within the study area they receive an additional feeding through infiltration of irrigation water and inflow of groundwater from the foothills.
The groundwater table is at the level of 5.5-6.0 meters. The long-term monitoring over the groundwater levels shows that the amplitude of their fluctuations is about 1.2 - 1.3 meters.
The groundwater mineralization reaches values from 1.2 to 2.05 g/l; they are characterized by sulfate aggressiveness in relation to concretes from standard cement grades.

4.1.3.5 Zero mark of the site

The zero mark of the project (0.000) corresponds to +332.910 above the sea level.

4.1.3.6 Construction area characteristics

The normative value of the snow cover weight for the 1st district is 0.50 (50) kPa (kgf/m2) (according to KMK 2.01.07-97 “Loads and effects”).
The normative wind dynamic pressure for the 1st district is 0.38 (38), kPa (kgf/m2) (according to KMK 2.01.07-97 “Loads and effects”).
The seismicity of the area according to KMK 2.01.03-96 is 8 points.
The maximum possible seismic accelerations are within 0.28 – 0.40 g.

4.1.3.7 Meteorological condition

Absolute maximum ambient temperature is +47 °C in July, absolute minimum ambient temperature is -28 °C in January and average annual ambient temperature is +14.3 °C.
Monthly mean ambient temperature in the hottest month is +28.2 °C in July.
Monthly mean ambient temperature in the coldest month is 0.2 °C in January.

The highest monthly mean humidity is 75% in January.
The lowest monthly mean humidity is 36% in July.

Average duration of frostless season is 221 days, the depth of freezing of soil is 40 cm, and maximum height of blanket of snow is 12 cm.

Prevailing wind direction is eastern, average wind speed is 1.8 to 2 m/sec.

Uzbekistan has two rainy seasons, from January to May and from October to December.
Annual average rainfall is 405 mm.

Annual snowfall is assumed 350 mm similarly in Tashkent.

4.1.3.8 Cooling water

The possible CCCGP No.2 cooling methods are:

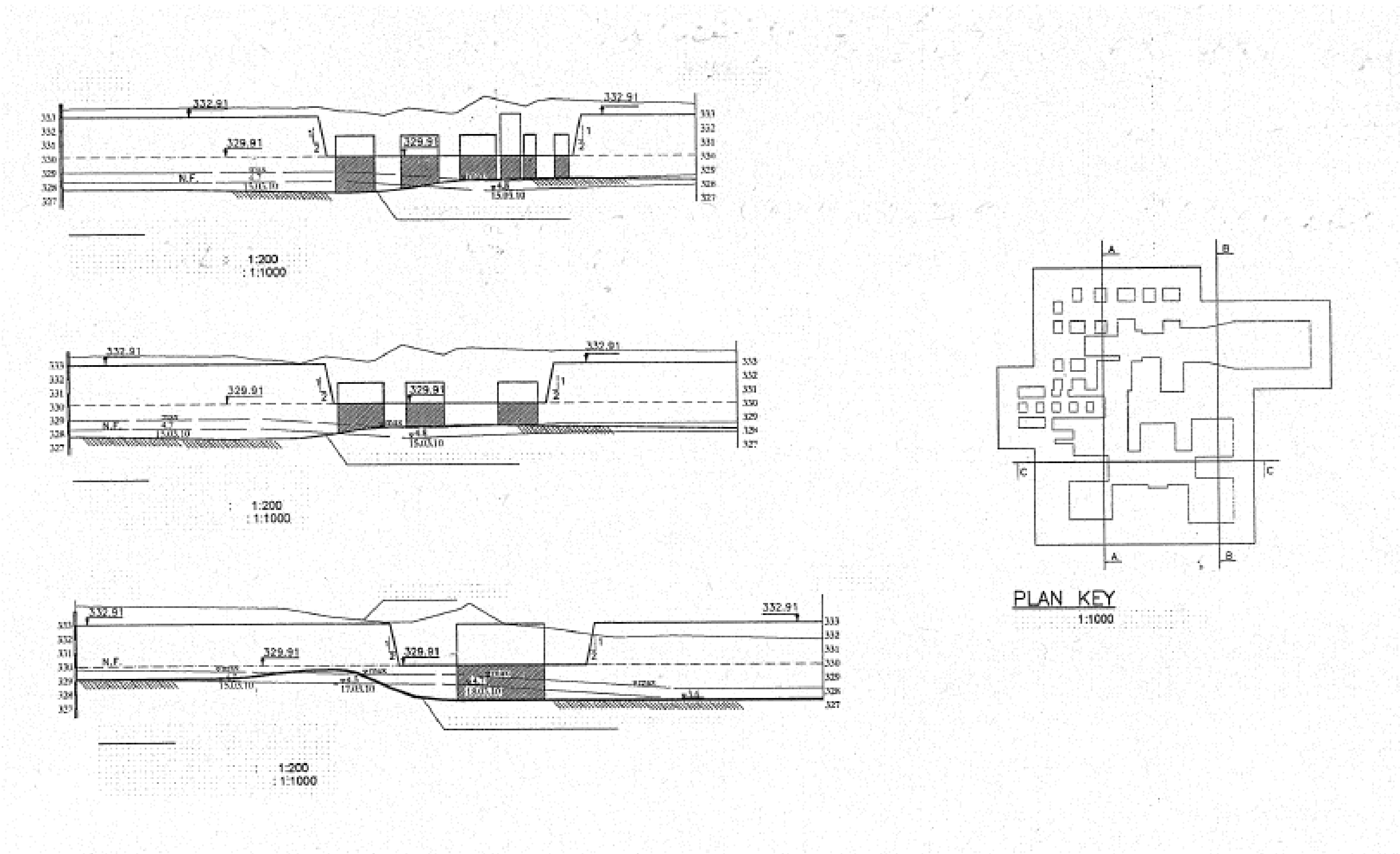
- Once-through cooling method
- Mechanical draft cooling tower cooling method
- Mechanical draft air cooling method

The existing Navoi thermal power plant depends on a mixtured of the once-through cooling method and the cooling tower cooling method using the cooling water supplied from the Zarafashan River. However, the water of the Zarafashan River is characterized by poor water quality. High maintenance costs and labor are required to repair the trouble caused by deposition of scales inside the condenser heat exchanger tube.
Further, the mechanical draft air cooling method has an advantage in that the use of cooling water is not required. However, the mechanical draft air cooling method has a disadvantage in that the plant performance deteriorates by the increase in the pressure of exhaust gas in the steam turbine.
Therefore, we would like to adopt the mechanical draft cooling tower cooling method as the CCCGP No.2 cooling method, where makeup water is supplied from the Zarafashan River after pre-treatment.

4.1.3.9 Foundation design

The soil quality at the planned CCCGP No.2 construction site is relatively good. For the major structures of the adjacent CCCGP No.1, the foundation structures are built directly without using any pile.
The foundation of the major structure of CCCGP No.2 in close proximity to CCCGP No.1 is considered to be based on the direct foundation structure, the same as that of the major structure of CCCGP No.1. When the type of CCCGP No.2 structure foundation is to be determined, a detailed ground survey of the planned CCCGP No.2 construction site will be implemented.

The foundation type will be determined after detailed designing has been performed based on the result of this survey.
Figure 4.1.3-2 illustrates the major structures of CCCGP No.1 and the cross section of soil.



Source: SJSC Uzbekenergo

Figure 4.1.3-2 Section of main structures and soil stratum

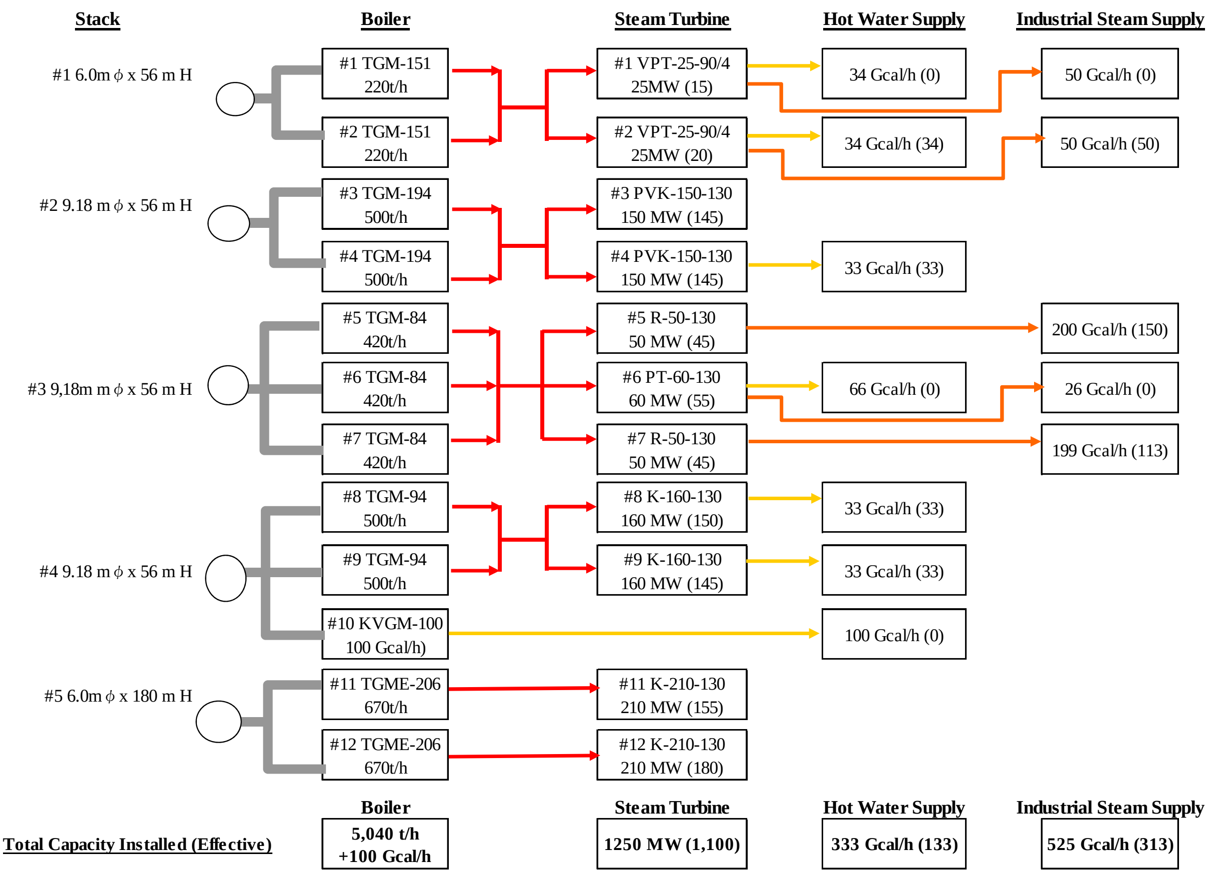
4.2 Existing facilities

4.2.1 Overview of the existing equipment in Navoi Thermal Power Station

(1) System configuration

The overview of the existing power and heat supply system of Navoi Thermal Power Station is as shown in Figure 4.2.1-1. The Power Station is consisted of 12 boilers and 11 steam turbines. No. 1 through No. 9 boilers and steam turbines, which are heat and electricity cogeneration type units, have their common main steam lines with adjacent unit(s) and the number of operating units is changed according to power and heat demand, resulting in high operational reliability. No. 10 boiler is installed for the purpose of hot water heating. On the other hand, No. 11 and 12 units are used exclusively for electricity generation. Five sets of stacks are installed for the 12 boilers. Flue gas ducts from two or three boilers are connected to each stack. The equipment in Navoi Thermal Power Station consists of electricity generation plants as well as steam supply system for neighboring industries and hot water supply system for district heating.

Figure 4.2-1 Heat and power supply system of Navoi Thermal Power Station



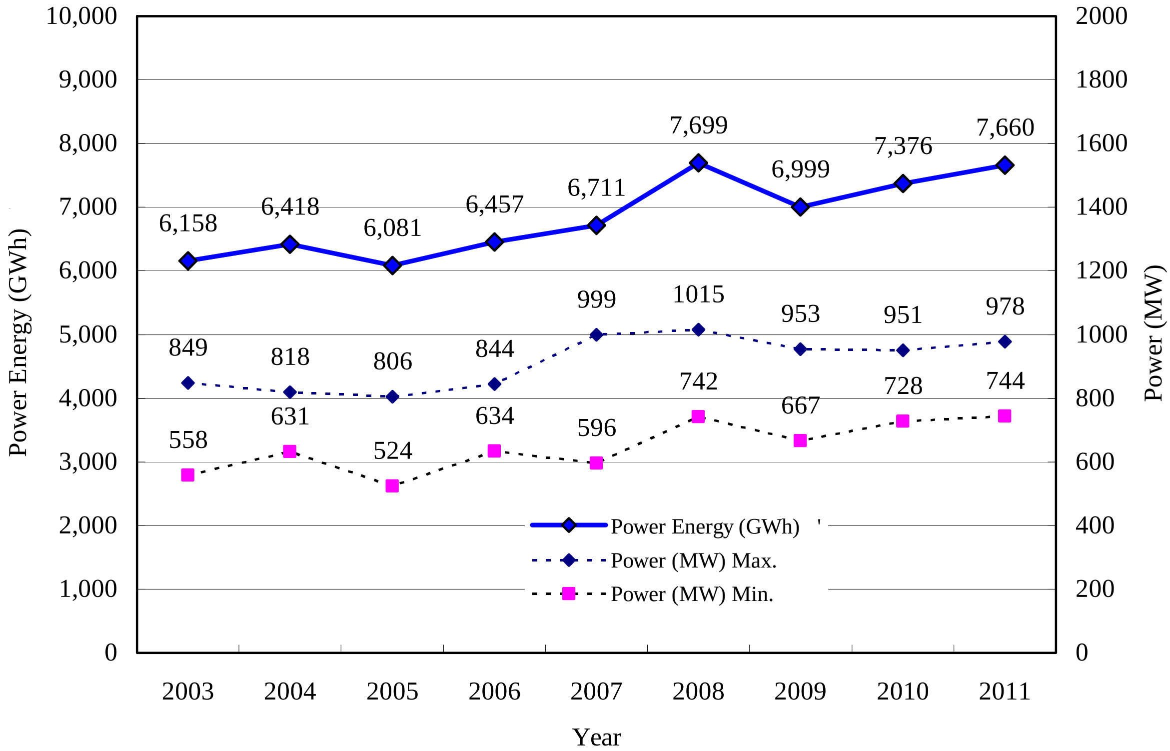
Source: SJSC Uzbekenergo

Figure 4.2.1-1 Heat and power supply system of Navoi Thermal Power Station

(2) Electric power supply

Navoi Thermal Power Station is the central plant in Navoi city, and is bearing the electric power supply to local residents and surrounding factories.

The transition of annual power generation (MWh) as well as the transitions of electric power (MW) of this plant for the past ten years is shown in Figure 4.2.1-2. The annual electric power generation was increasing by 2.5 to 3.3 % a year constantly from 2003 to 2011. Like the annual power generation, the maximum and minimum electric powers were also increased steadily.



Source: SJSC Uzbekenergo

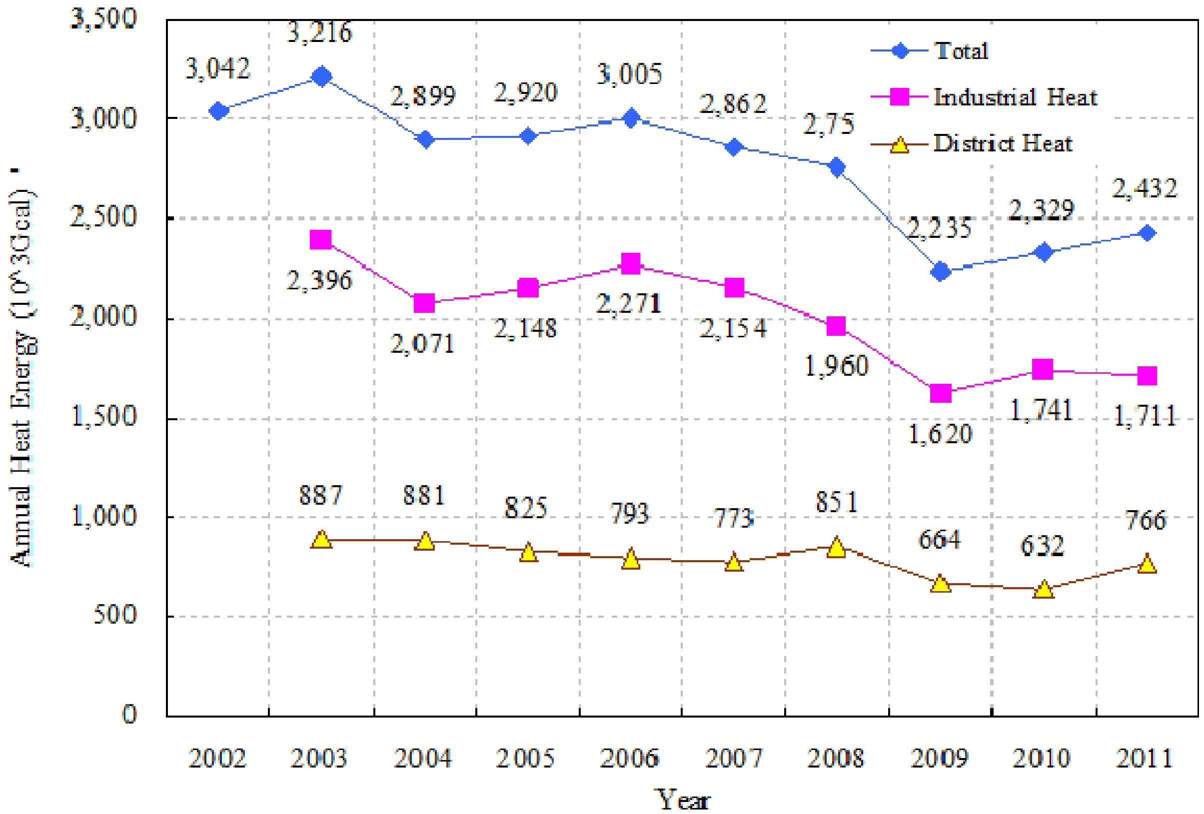
Figure 4.2.1-2 Annual power generation and max/min power for the past ten years

(3) Industrial steam and hot water supply

Navoi Thermal Power Station supplies not only electric power but also industrial steam for neighboring factories and hot water for district heating. Since it is the one and only supplier of these heat energies in the area, the Navoi Power Station has become indispensable for the important heat sources. The heat produced in the power station is in the form of steam and hot water. Steam is sent to neighboring factories, and hot water is sent to each home in Navoi city.

The heat currently supplied by steam from Navoi Thermal Power Station is sent to two chemical factories at a distance of four kilometers from the power station. Annual supply quantity of industrial steam in 2011 is 1711 Tcal/year. The heat supply from hot water in 2011 totals 766 Tcal.

The annual heat supplies for the past ten years are shown in Figure 4.2.1-3. Unlike the electric power generation, the industrial steam supply and hot water supply are descending from 2003 through 2009, and from 2009 to 2011, they are stable or slightly increasing.



Source: SJSC Uzbekenergo

Figure 4.2.1-3 Annual industrial steam and hot water supply for the past ten years

(4) Supply pattern of power and heat

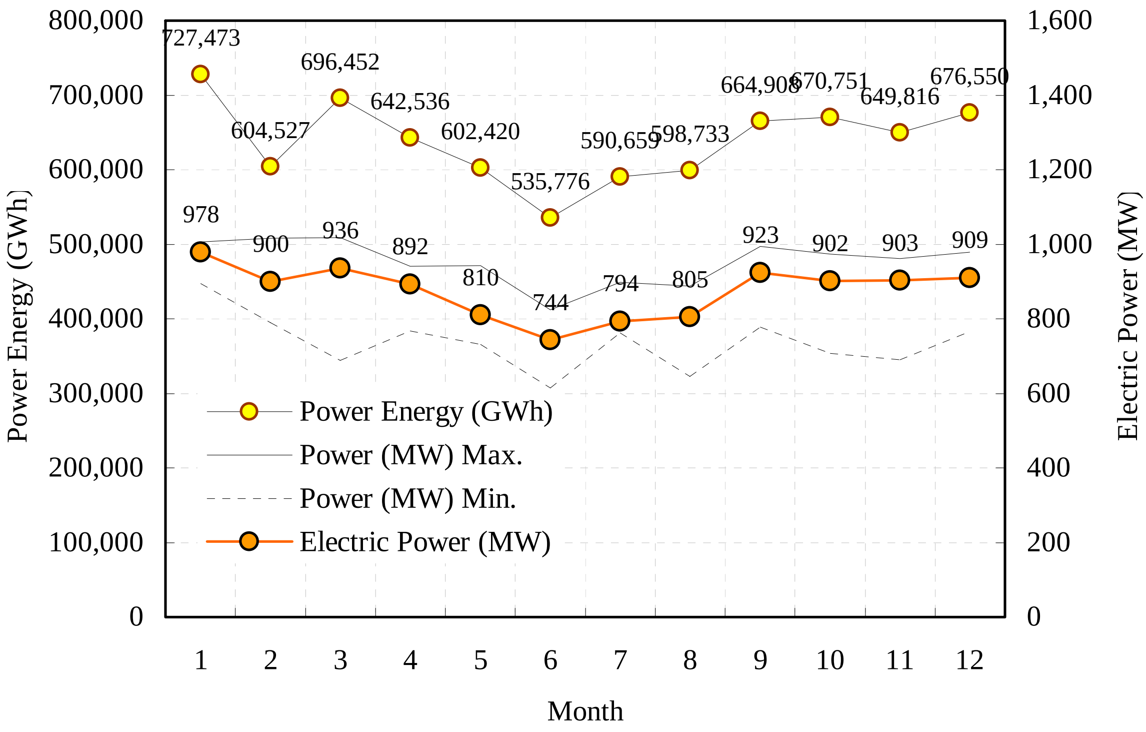
Table 4.2.1-1, Figures 4.2.1-4 and 4.2.1-5 show the record of monthly power and heat supply in Navoi Thermal Power Station in 2011. The amounts of electric power, industrial steam, and hot water supplied have a tendency of increasing in winter and decreasing in summer, but specifically the hot water supply shows the strongest tendency.

Total thermal efficiency of the existing facilities of Navoi Thermal Power Station is calculated as 63.7%. This data shows the ratio of the heat input (fuel consumption) and output (total supply of heat and power).

Table 4.2.1-1 Record of Monthly Power and Heat Supply in 2011

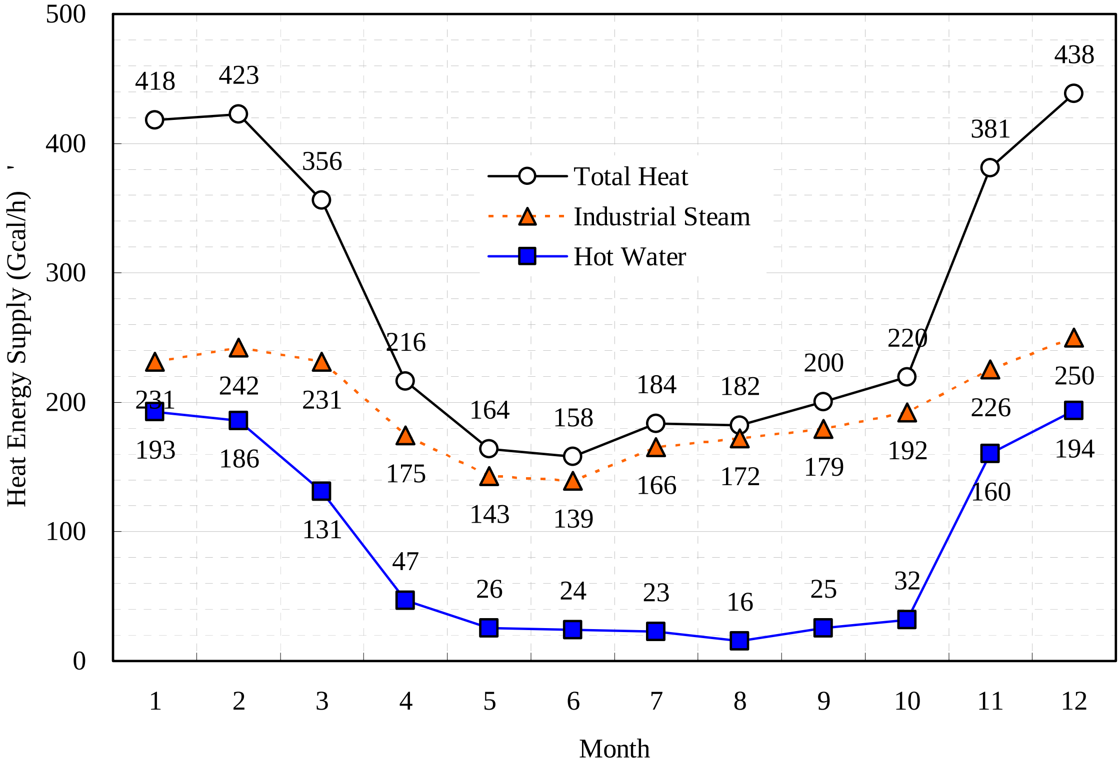
Month	Power (MW)		Power Energy (GWh)	Heat Energy (10^3Gcal)		
	Max.	Min.		District Heat	Industrial Heat	Total
1	1,006.0	894.4	727,473	143,426	172,226	310,897
2	1,016.2	789.4	604,527	124,827	162,945	283,939
3	1,018.6	688.2	696,452	97,464	171,979	264,992
4	940.2	768.0	642,536	33,896	125,709	155,724
5	943.2	731.5	602,420	19,125	106,366	122,087
6	824.8	615.2	535,776	17,244	100,327	113,807
7	897.2	761.8	590,659	17,085	123,149	136,533
8	887.8	645.3	598,733	11,551	128,049	135,548
9	993.7	778.5	664,908	18,332	129,075	144,341
10	973.5	707.9	670,751	23,763	143,056	163,373
11	961.7	690.4	649,816	115,407	162,402	274,509
12	979.0	765.0	676,550	144,062	186,103	326,209
Total	-	-	7,660,601	766,182	1,711,386	2,431,959

Source: SJSC Uzbekenergo



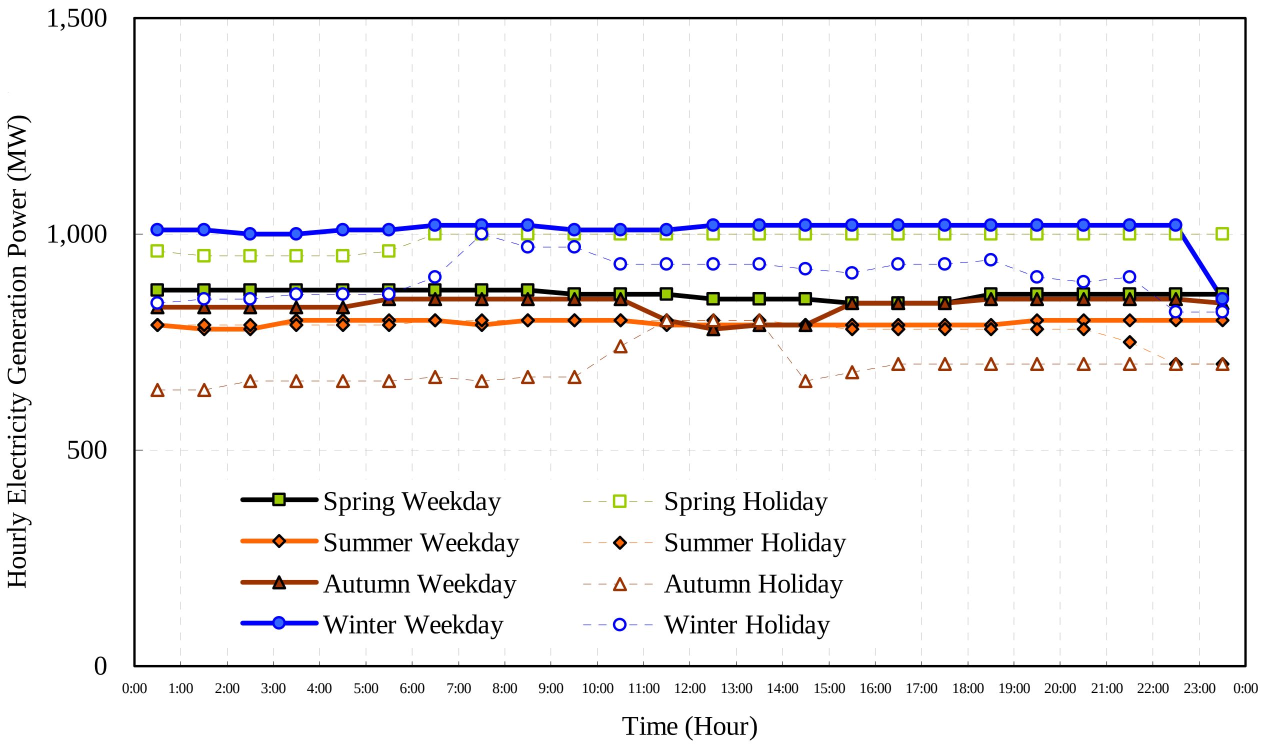
Source: SJSC Uzbekenergo

Figure 4.2.1-4 Monthly Electric Power Generation in 2011



Source: SJSC Uzbekenergo

Figure 4.2.1-5 Record of Monthly Heat Supply in 2011



Source: SJSC Uzbekenergo

Figure 4.2.1-6 Power supply pattern of Navoi Thermal Power Station in 2011

4.2.2 Situation of the existing equipment

Power generation units of Navoi Thermal Power Station consist of 12 boilers, 11 turbines, and 11 generators, and, the amount of rated generating steam is 5,040 t/h and the rated power generation output is 1,250 MW. Operation of Unit No.1 was commenced in 1963 with 49 years having passed. Total operation hours of the units until now are about 220,000 to 360,000 hours, and degradation by operation is also progressing considerably in addition to aged deterioration.

Table 4.2.2-1 Operating Record of Navoi Thermal Power Plants

Unit №	Type of Plant	Installed (Effective) Capacity			Start-up Year	Operating Hours	Service Factor (%)(1)
		Power (MW)	Heat Supply (Gcal/hr)				
			Hot water	Industrial steam			
1	Heat and Power	25 (15)	34 (0)	50 (0)	1963	316,680	73.7
2	Heat and Power	25 (20)	34 (34)	50 (50)	1963	362,468	84.4
3	Power	150 (145)	-	-	1964	349,172	83.0
4	Heat and Power	150 (145)	33 (33)	-	1965	308,577	74.9
5	Heat and Power	50 (45)	-	200 (150)	1966	339,774	84.3

6	Heat and Power	60 (55)	66 (0)	26 (0)	1967	311,919	79.1
7	Heat and Power	50 (45)	-	199 (113)	1971	314,936	87.6
8	Heat and Power	160 (150)	33 (33)	-	1968	326,414	84.6
9	Heat and Power	160 (145)	33 (33)	-	1969	317,604	84.3
10	Heat	-	100 (0)	-	1972	238,353	68.0
11	Power	210 (155)	-	-	1980	231,961	82.7
12	Power	210 (180)	-	-	1981	222,739	82.0
Total	-	1,250 (1,100)	333 (133)	525 (313)	-	-	-

Note (1): Averaged Service Factor (%) = The total operating hours/the total calendar hours from start-up to present time ×100.
Source: SJSC Uzbekenergo

Chapter 5 Fuel Supply Plan

5.1 Natural gas reserves in Uzbekistan

The proven natural gas reserves in Uzbekistan register an abundant figure of 1.603 trillion cubic meters (hereinafter referred to as "Tcm"), as of December 2011. This figure puts Uzbekistan in 5th place in the Eurasian region in terms of natural gas reserves, and in 25th place in the world. The gas fields are concentrated in the Amu Darya Basin in the southwest of the country and in the Central Ustyurt plateau west of the Aral Sea.
The following illustrates the transition of the proven natural gas reserves in Uzbekistan.

Table 5.1-1 Amount of proven natural gas reserves in Uzbekistan

Unit: Tcm

	At end 2001	At end 2010	At end 2011
Proved reserves	1.700	1.600	1.603

Source: BP Statistical Review of World Energy 2012

Table 5.1-2 shows the natural gas development projects in Uzbekistan. Projects are currently being implemented by the Russian companies and Asia companies based on the license of exploration for natural gas. The development of these gas fields are expected to increase the proven natural gas reserves in Uzbekistan.

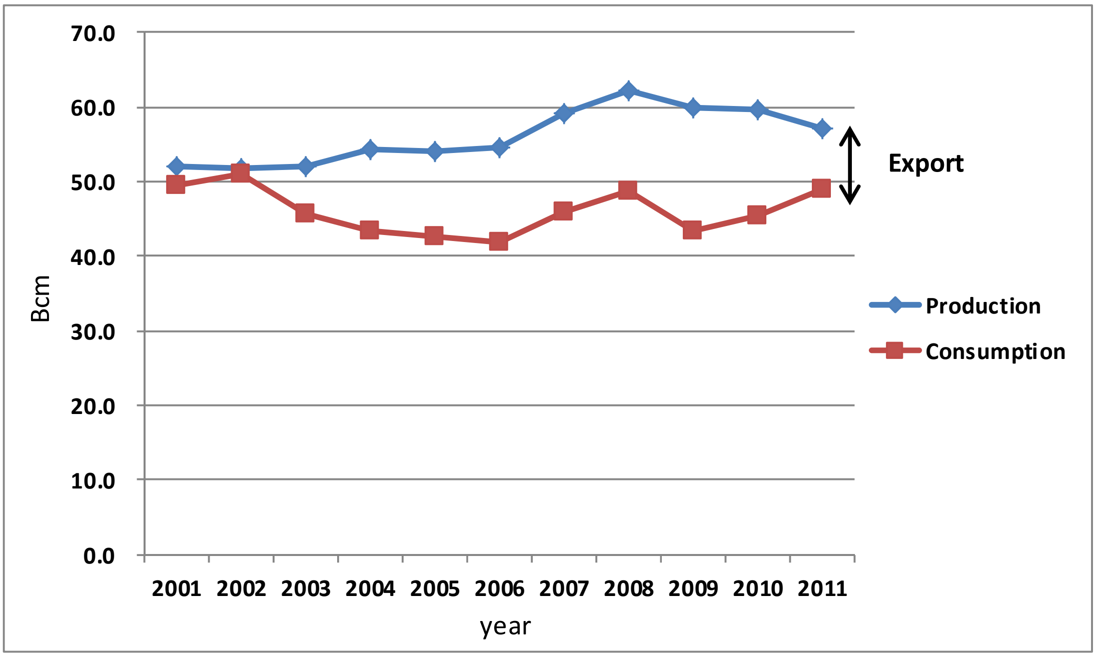
Table 5.1-2 Natural gas development projects in Uzbekistan

Field	Target production volume	Target reserves
Southwest Gissar and central Ustyurt region (7 fields)	3 Bcm/year	0.1Tcm
Western Ustyurt region (4 fields)	-	1Tcm
Khauzak and Kandym fields in Bukhara-Khiva and Gissar regions	4 Bcm/year	0.25Tcm
Aral Sea Surgli field	0.08 Bcm/year	-
Surkhandarya region Baisun field	2.2 Bcm/year	-
West Urga / Western Ustyurt region (3 fields)	0.7 Bcm/year	-

Source: Global Insight IEA and trade press

5.2 Production and consumption volumes of natural gas in Uzbekistan

The following describes the proven production and consumption volumes of natural gas in Uzbekistan during the period from 2001 to 2011. The natural gas production volume registers a gradual increase after 2001 to reach a peak value in 2008. This is followed by a slight decrease every year. The figure registered in 2011 was 57.0 Billion cubic meters (hereinafter referred to as "Bcm"). In the meantime, the consumption of natural gas in 2011 registers 49.1Bcm, the same value as that of 2001. Further, since Uzbekistan does not import natural gas, the difference between production and consumption volumes indicates the amount of export. The export volume in 2011 was 7.9 Bcm, accounting for approximately 14 percent of the total production.



Source: BP Statistical Review of World Energy 2012

Figure 5.2-1 Proven production and consumption volumes of natural gas (2001-2011)

Table 5.2-1 shows the R/P obtained by calculation based on the reserves of natural gas and its consumption. R/P ratios represent the length of time that those remaining reserves would last if production were to continue at the previous year's rate. It is calculated by dividing remaining reserves at the end of the year by the production in that year. The R/P is an index that shows how many years natural gas can be produced continuously in the future.

As a result, the R/P in Uzbekistan is 28.1 years as of present 2011, predicting a slight increase of over 26.8 years at the end of 2010. This is estimated to be due to an increase in the proven natural gas reverses achieved by the development of the gas field currently under way. When consideration is given to the continued development of gas fields in future, sufficient reserves can be estimated, even if the life time of this project is assumed to be 25 years.

Table 5.2-1 Reserves / Production Ratio of Natural Gas

	Unit	At end 2001	At end 2010	At end 2011
Proved reserves	Tcm	1.700	1.600	1.603
Production	Tcm	0.0520	0.0596	0.0570
R/P ratio	Year	32.7	26.8	28.1

Source: BP Statistical Review of World Energy 2012

5.3 Possibility of gas supply to CCCGP No.2

5.3.1 Verification of natural gas supply agreement

An agreement was signed with the JSC Uztransgaz for the supply of the natural gas of the Navoi Thermal Power Plant. This company is a subsidiary of the NHC Uzbekneftegaz in charge of overall management of the petroleum and gas sectors in Uzbekistan, and is mainly engaged in the transportation of natural gas. The agreement between the Navoi Thermal Power Plant and JSC Uztransgaz for the supply of natural gas is updated every year. The annual contracted volume for 2012 is 2,876.080million m^3N/year. This annual contracted natural gas volume is determined by the Navoi Thermal Power Plant estimating the amount of natural gas used in the following year and requesting the JSC Uztransgaz. This procedure allows the Navoi Thermal Power Plant to secure the natural gas on a priority basis.

At present, the Navoi Thermal Power Plant uses two types of natural gas; a natural gas containing sulfur content and a natural gas with minimal sulfur content. CCCGP No.2 is planning to use the natural gas with minimal sulfur content used in CCCGP No.1. The volume that can be supplied amounts to 419,300m^3N/h (450,000m^3/h at 20 degrees Celsius). The following describes the properties of the natural gas used in CCCGP No.1 and CCCGP No.2.

Table 5.3.1-1 Specifications of Natural Gas

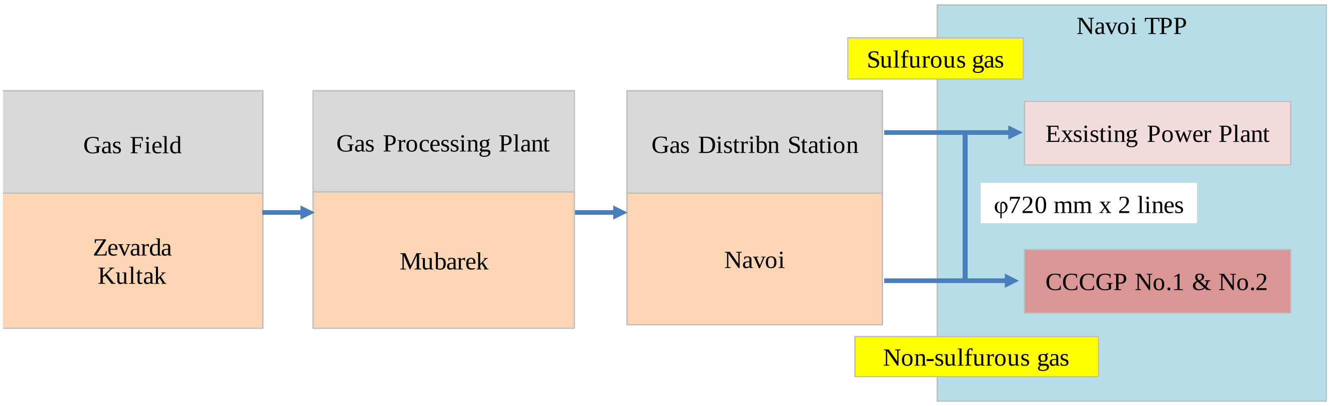
Components	Unit	Value
Methane	mol %	93.69
Ethane	mol %	3.07
Propane	mol %	0.64
i-Butane	mol %	0.09
n-Butane	mol %	0.14
i-Pentane	mol %	0.04
n-Pentane	mol %	0.04
Hexane	mol %	0.04
Oxygen	mol %	n/a
Nitrogen	mol %	0.42
Carbon dioxide	mol %	1.83
Total	mol %	100.00
Absolute water content	g/m^3	0.200
Lower Heating Value (20°C, 760mmHg)	kcal/m^3	8,150
Density (20°C, 760mmHg)	kg/m^3	0.722
Weight content of hydrogen sulfide	g/m^3	0.007
Weight content of mercaptan sulfur	g/m^3	0.016

Source: Navoi TPP

The natural gas supplied to the Navoi Thermal Power Plant is supplied from the Zevarda gas field and the Kultak gas field located in the Amu Darya Basin in the south of Uzbekistan. The following illustrates the locations of the Zevarda gas field and Kultak gas field, and the approximate transportation route from the gas fields to the Navoi Thermal Power Plant. The natural gas produced in the Zevarda gas field and Kultak gas field is refined in the Mubarek Gas Processing Plant (hereinafter referred to as "Mubarek GPP"), and is supplied to the Navoi Thermal Power Plant through the Navoi Gas Distribution Station (hereinafter referred to as "Navoi GDS").

Source: Study Team

Figure 5.3.1-1 Location of Natural Gas Field



Source: Navoi TPP

Figure 5.3.1-2 Approximate transportation route from the gas field to the Navoi Thermal Power Plant

5.3.2 Verification of the adequacy and feasibility of the project from the viewpoint of gas supply

Table 5.3.2-1 illustrates the consumption of the natural gas at the time of rated output in CCCGP No.1 and CCCGP No.2. The natural gas with minimal sulfur content used in CCCGP No.1 and CCCGP No.2 can be supplied in the volume of 419,300m^{3}N/h. By contrast, a total of natural gas consumption in CCCGP No.1 and CCCGP No.2 is 189,057m^{3}N/h. This shows that the natural gas can be supplied to the Navoi Thermal Power Plant.

Table 5.3.2-1 Hourly natural gas consumption of each unit at rated output

Unit : m^{3}N/h

Unit No	Fuel Consumption	Remark
CCCGP No.1	90,000	-
CCCGP No.2	99,057	-
Total	189,057	< 419,300 (450,000 m^3/h at 20 °C)

Source: Navoi TPP

Table 5.3.2-2 shows the annual consumption of natural gas in the Navoi Thermal Power Plant. The average annual consumption of natural gas in the last five years is 2,903.3 million m^{3}N. In the meantime, the annual natural gas consumption volumes at CCCGP No.1 and CCCGP No.2 are estimated at 720 million m^{3}N and 792.5 million m^{3}N, respectively, if the plants are operated for 8,000 hours every year. When the operation of CCCGP No.2 commences, existing power plants Nos. 3, 6, 8 and 10 in addition to existing power plants Nos. 1 and 2 will be shut down. When the natural gas with minimal sulfur content is used in all the units, the volume of natural gas that can be supplied every year will be 3,673 million m^{3}N (= 419,300 m^{3}N/year x 8,760h). By contrast, the annual consumption of natural gas in the Navoi Thermal Power Plant subsequent to commencement of commercial operation in CCCGP No.2 will be 3,361.5million m^{3}N/year. This indicates that the Navoi Thermal Power Plant can be supplied with natural gas.

Table 5.3.2-2 Annual natural gas consumption of each boiler unit for last 5 years

Unit : million m^3N/year

Unit No	2007	2008	2009	2010	2011	Average	Future
1	15.5	57.8	69.6	61.0	41.7	49.1	0
2	59.8	67.1	63.8	86.7	65.9	68.7	0
3	342.7	339.1	272.7	366.7	365.6	337.4	0
4	42.0	356.6	374.6	373.1	393.5	308.0	308.0
5	136.8	160.7	145.0	108.7	92.8	128.8	128.8
6	163.2	181.6	132.9	123.2	115.5	143.3	0
7	177.0	159.5	151.2	117.2	118.1	144.6	144.6
8	346.2	303.0	363.2	380.1	322.6	343.0	0
9	521.4	360.8	549.3	330.6	382.6	428.9	428.9
10	86.0	133.7	108.4	113.8	122.5	112.9	0
11	388.9	467.0	435.7	401.0	471.8	432.9	432.9
12	454.4	440.2	250.8	408.7	475.1	405.8	405.8
CCCGP No.1	-	-	-	-	-	-	720.0
CCCGP No.2	-	-	-	-	-	-	792.5
Total	2,733.9	3,027.1	2,917.2	2,870.8	2,967.7	2,903.3	3,361.5

Source: Navoi TPP

5.4 Order of priority for gas supply in the event of gas insufficiency at the Navoi Thermal Power Plant

There has been no public disclosure of the proven natural gas reserves and production volume in the Zevarda gas field and Kultak gas field that supply natural gas to the Navoi Thermal Power Plant. Since supply of electricity and hot water is essential to public life, the Government of Uzbekistan is required to ensure that natural gas is supplied to the Navoi Thermal Power Plant on a priority basis. Should there be any shortage of natural gas supply to the Navoi Thermal Power Plant, CCCGP No.2 will be operated on a priority basis as it is characterized by high power generation efficiency and capable of generating a greater volume of heat.

Chapter 6 Basic Design

6.1 Conceptual Design

6.1.1 Design Conditions

Design conditions shall be specified to complete the feasibility study for this project. However, all the detailed design conditions are still undecided because of less time schedule for discussion and study during the period of preparation of the feasibility study. Some design conditions may be tentatively specified or assumed at this feasibility study stage and will be revised or finalized at the further detailed design stage of this project. The following table 6.1.1-1 shows the design conditions necessary for completion of the feasibility study on Navoi Thermal Power Plant Modernization Project.

Table 6.1.1-1 Design Conditions and Specifications

Description	Conditions and/or Specifications	
(1) Basic Design Conditions	**Rated**	**Range**
a. Dry bulb temperature (^{o}C)	15.0	- 28.0 to 47.0
b. Barometric pressure (kPa)	97.4	
c. Altitude (m)	332.91	
d. Relative humidity (%)	60.0	20.0 to 80.0
e. Wet bulb temperature (^{o}C)	10.9	- 21.0 to 36.6
f. Temperature of cooling water	18.9	As per design of cooling tower
g. Type of fuel	Specified natural gas	
h. Supply pressure of natural gas at terminal point (MPa)	1.2	1.0 to 1.2
i. Supply temperature of natural gas at terminal point (^{o}C)	15.0	-5.0 to 22.0
j. Export heat (Gcal/hr) 1.20 MPa steam	100	0.0 to Max.
0.25 MPa steam	100	0.0 to Max.
k. Maximum export heat capability	Dependable on model of GT, site ambient conditions, and design concept of manufacturer	
l. Conditions to define the maximum capability of bottoming and electrical systems	Ambient conditions: Dry bulb temperature 0.0 ^{o}C Relative humidity 20.0 % Wet bulb temperature -4.6 ^{o}C Duct firing temperature: 750 °C Export heat amount: 0 Gcal/hr	
m. Economically operable service life	25 years with reasonable repair and/or replacement of consumable and/or normal wear and tear parts	
n. Make-up water for process	Demineralized Zarafshan River water	
o. Make-up water for cooling tower	Treated Zarafshan River water	
p. Make-up water for hot water	Treated tap water	
(2) Specification of Main Equipment		
1) Plant		
a. Type of shaft arrangement	Multi-shaft arrangement with a bypass	

Description	Conditions and/or Specifications
	stack
b. Type of control system	Micro-processor based DCS type
c. Type of steam turbine condenser cooling system	Mechanical draft wet type cooling tower
2) Gas turbine	
a. Supplier	Original equipment manufacturer
b. Application standards	ISO 3977 Part 3 or equivalent
c. Type of configuration	Open cycle, single shaft, heavy duty, Natural gas fired, cold end drive, axial exhaust type
d. Type of installation	Indoor installation with sound attenuation enclosure
e. Rating	Continuous base load rating with the load weighing factor of 1.0 for EOH calculation
f. Rotating speed	3,000 rpm
g. Type of coupling	Directly coupled with generator by integrated solid coupling
h. Shaft strength	To be designed to withstand the transient torque due to short circuit or out-of-phase synchronization, whichever is greater.
i. Temperature class	F-class with a wealth of commercial operating experience specified in Gas Turbine World Handbook 2010
j. Shaft lateral vibration	As per ISO 7919-Part 4 "Gas Turbine Sets"
k. Allowable speed variation range on continuous load operation	3,000 rpm ±3 %
l. Dry low NOx combustion system for natural gas	Yes
m. Inlet air cooling system	No
n. Type of starting device	- A synchronous generator/motor with a thyristor frequency converter or - A squirrel cage motor with a torque converter
o. Compressor on-line and off-line cleaning device	Yes
p. Wet type air compressor cleaning device	Yes
q. Pre-heater of natural gas fuel	As per manufacturer's option
r. Type of inlet air filter	Three stage or self-cleaning type with a dust removal efficiency of more than 99.5 % for ISO fine dust.
s. Bypass stack	Yes
3) HRSG	
a. Application standard	Relevant ASME Pressure Vessel Codes or equivalent
b. Type of configuration	Lateral or vertical gas flow type with evaporation drum and natural circulation
c. Type of cycle	Triple-pressure, reheat
d. Flue gas exit temperature	Higher than 100 °C in consideration of

Description	Conditions and/or Specifications
	impact on environment
e. Type of installation	Indoor installation
f. Supplementary duct firing temperature	Max. 750 °C
g. Flue gas stack	Stand alone type fabricated with steel plates supported by steel structures with a height of 90 m in consideration of impact on environment
h. Flue gas velocity at flue gas stack exit	not more than 25 m/s
4) Steam turbine	
a. Application standard	ISO 14661 or equivalent
b. Type of configuration	Two (2)-casing, three (3)-admission, two (2)-extraction, sliding pressure, full condensing, downward exhaust, low pressure turbine end drive type
c. Type of cycle	Triple-pressure, reheat
d. Type of pressure control of extraction steam	Internal pressure control type
e. Type of installation	Indoor installation with sound attenuation cover
f. Rotating speed	3,000 rpm
g. Minimum allowable speed variation range on continuous load operation	3,000 rpm ±3 %
h. Type of coupling	Directly coupled with generator by integrated solid coupling
i. Shaft strength	To be designed to withstand the transient torque due to short circuit or out-of-phase synchronization, whichever is greater.
j. Shaft lateral vibration	As per ISO 7919-Part 2 "Large Land-based Steam Turbine Generator Sets"
k. Steam bypass	Yes
l. Condenser	Shell and tube surface cooling type
5) Cooling tower	
a. Type	Mechanical draft wet type
b. Heat load	218 Gcal/hr
c. Circulating water flow rate	27,300 m^3/hr including water for auxiliary systems
d. Approach temperature	8 °C
e. Cooling range	8 °C
f. Temperature difference	5 °C
6) Hot water production system	
a. Type	Heat exchange type between water and Extracted steam
b. Capacity	100 Gcal/hr
c. Hot water supply temperature	110 °C
d. Return water temperature	55 °C
7) Generators	
a. Application standard	IEC 60034-3 or equivalent
b. Type	Horizontally mounted, cylindrical rotor, rotating field, air or hydrogen cooled

Description	Conditions and/or Specifications
	synchronous type
c. Rated voltage	22 kV
d. Type of exciter	Static or brushless type
e. Coil temperature rise	IEC B class
f. Insulator temperature limit	IEC H class
8) Main transformer	
a. Type of cooling	Oil natural and air forced type
b. Primary voltage	22 kV
c. Secondary voltage	220 kV
(3) Operational Requirements	
1) Type of operation	
a. Type of basic operation	Continuous base load operation
b. Anticipated range of plant controllable power load without steam bypass	30 to 100 %
c. Speed droop power load operation	Yes
d. Constant power load operation irrespective of heat export demand	Yes
e. Frequency control operation	Yes
f. Constant gas turbine inlet temperature operation	Yes
g. Gas turbine simple cycle operation	Yes
h. Operation manner	LCD operation in remote control room with keyboard and mouse
i. Blackout start	No
o. Isolated operation of gas turbine from network in an any emergency	Yes
2) Time required for start-up to full power after pushing start-up button (time for purge and synchronization is not included)	
a. Cold start	At longest 4 hours
b. Warm start	At longest 3 hours
c. Hot start	At longest 2 hours
d. Very hot start	At longest 1 hours
3) Voltage rating of auxiliary equipment power source	
a. AC power	
a) 200 kW≦P	AC 6,300 V
b) 3 kW≦P< 200 kW	AC 400 V
c) P< 3 kW	AC 200 V
b. DC power	DC 220 V
c. Lighting	AC 200 V
d. Instrumentation	AC 200 V
e. Control power	AC 100 V
f. Control signal	DC 24 V
(4) Basal Conditions for Arrangement of Main Equipment	
1) Gas and steam turbine generators	To be installed inside the gas and steam turbine separate buildings with a

Description	Conditions and/or Specifications
	ventilation system, an overhead travelling crane and laydown bay for carrying in and out of bulky components and maintenance spaces.
2) HRSG	To be installed inside building on the same center axis as the gas turbine generator.
3) Arrangement of axes of gas and steam turbine generators	To be arranged in parallel
4) Gas turbine air filter	To be located as high as possible above ground level
5) Control and monitoring and electrical equipment	To be located in the rooms integrated with the gas turbine building
(5) Emission	
1) Exhaust gas emissions (dry, 15 % O_2 basis) (75 - 100% load of gas turbine under duct firing operation over specified all ambient conditions)	
a. NOx	< 51 mg/Nm^3 as NO_2 (25 ppmv)
b. SOx	Changeable depending on sulfur content
c. CO	< 10 ppmv
d. PM_{10}	< 5 mg/Nm^3
2) Airborne noise emission on steady state conditions without background noise	
a. Sound pressure level at a height of 1m on station boundary	< 55 dB(A) : Daytime < 45 dB(A) : Nighttime
b. Sound pressure level at a height of 1 m and a distance of 1m from equipment or enclosure	< 80 dB(A)
(6) Properties of Fuel Gas	
a. Temperature	Max. 22 °C, Min. -5 °C
b. Pressure	1.0 ~ 1.2 MPa
c. Composition	Performance point
CH_4	93.69 %
C_2H_6	3.07 %
C_3H_8	0.64 %
i-C_4H_{10}	0.09 %
n-C_4H_{10}	0.14 %
i-C_5H_{12}	0.04 %
n-C_5H_{12}	0.04 %
C_6H_{14}	0.04 %
O_2	n/a
N_2	0.42 %
CO_2	1.83 %
Total	100.00 %
d. Absolute water content	0.200 g/m^3
e. Lower Heating Value (20°C, 760mmHg)	8,150 kcal/m^3
f. Density (20°C, 760mmHg)	0.722 kg/m^3
g. Weight content of hydrogen sulfide	0.007 g/m^3
h. Weight content of mercaptan sulfur	0.016 g/m^3

Description	Conditions and/or Specifications
(7) Make-up Water for Bottoming System a. Type of water b. Temperature e. Available flow rate	 Demineralized river water __10__°C to __30__ °C Max.__300__m^3/hr
(8) Make-up Water for Hot Water a. Type of water b. Temperature e. Available flow rate	 Tap water __10__°C to __30__ °C Max.__180__m^3/hr
(9) Make-up Water for Mechanical Draft Cooling Tower a. Type of water b. Temperature e. Available flow rate	 Treated river water __10__°C to __30__ °C Max. __560__m^3/hr
(10) Operation and Maintenance 1) Gas turbine 2) Other equipment 3) Trainning of O & M staff at EPC contractor's works 4) Three(3) resident engineers (mechanical, electrical and control) of EPC contractor during defect liability period for operation and maintenance support 5) Inspection intervals of gas turbine on an EOH basis a. Combustion inspection b. Turbine inspection c. Major inspection 6) Inspection intervals of other equipment 7) Replacement intervals of filter elements	 Spare parts including consumed parts for two (2) years operation are to be included in scope of supply ditto Yes Yes Min. __8,000__hours Min. __16,000__hours Min. __48,000__hours As per recommendation of manufacturer More than 8,000 hours for ISO fine dust
(11) Guarantee Items 1) Plant net power output with specified heat export 2) Plant net thermal efficiency with pacified heat export 3) Exhaust gas emissions at 75 - 100 % load of gas turbine at max. duct firing temperature over all specified ambient conditions a. NOx b. CO c. PM_{10} 4) Airborne noise emissions on steady state conditions under all specified operating conditions a. Sound pressure levels at a height of 1 m on the station boundary limit b. Sound pressure level at a distance of 1m and a height of 1 m from equipment or	 Yes Yes Yes Yes Yes Yes Yes

Description	Conditions and/or Specifications
noise attenuation cover	
5) Successful completion of two (2) weeks Reliability run	Yes
6) Shaft vibration of gas and steam turbine sets based on related ISO standards during the reliability run	Yes

6.1.2 Outline of Cogeneration System

This plant is a combined cycle cogeneration plant (CCCGP) which concurrently produces both heat and power energies. The plant is comprised of the following main components; a gas turbine, a gas turbine generator, an HRSG with a supplementary duct firing facility, a steam turbine, a steam turbine generator, a fuel gas compressor station, a water pre-treatment facility for exported steam, a water pre-treatment facility for export hot water and a hot water production system.

The plant shaft configuration is of multi-shaft type where the gas and steam turbine shafts are separated.

The gas turbine is of a large capacity F class type which is available in the world market with a wealth of commercial operating experience.

The HRSG is of triple-pressure and reheat cycle type. The F class gas turbine is commonly coupled with the triple-pressure and reheat cycle HRSG to elevate the plant thermal efficiency.

Without any supplementary firing in the duct between the gas turbine exhaust and the inlet to the HRSG, the heat and power requirements for this project could not be met by the bottoming system coupled with F class gas turbine. For the purpose, this plant is equipped with the supplementary duct firing system.

The steam turbine is of triple-admission, dual-extraction of medium and low pressure steams and condensing type. The medium pressure steam is extracted from the IP steam turbine section and exported to adjacent companies as industrial steam as it is. The low pressure steam from the LP steam turbine section is supplied to the production system of the district hot water. The pressure of the extracted steam is controlled with the PC valve integrated in the steam turbine.

The hot water production system consists of a water storage tank, water pre-treatment facilities, deaeration facility, steam to water heat exchangers and a hot water storage tank.

The Figure 6.1.2-1 is the simplified schematic diagram of the cogeneration system of this project.

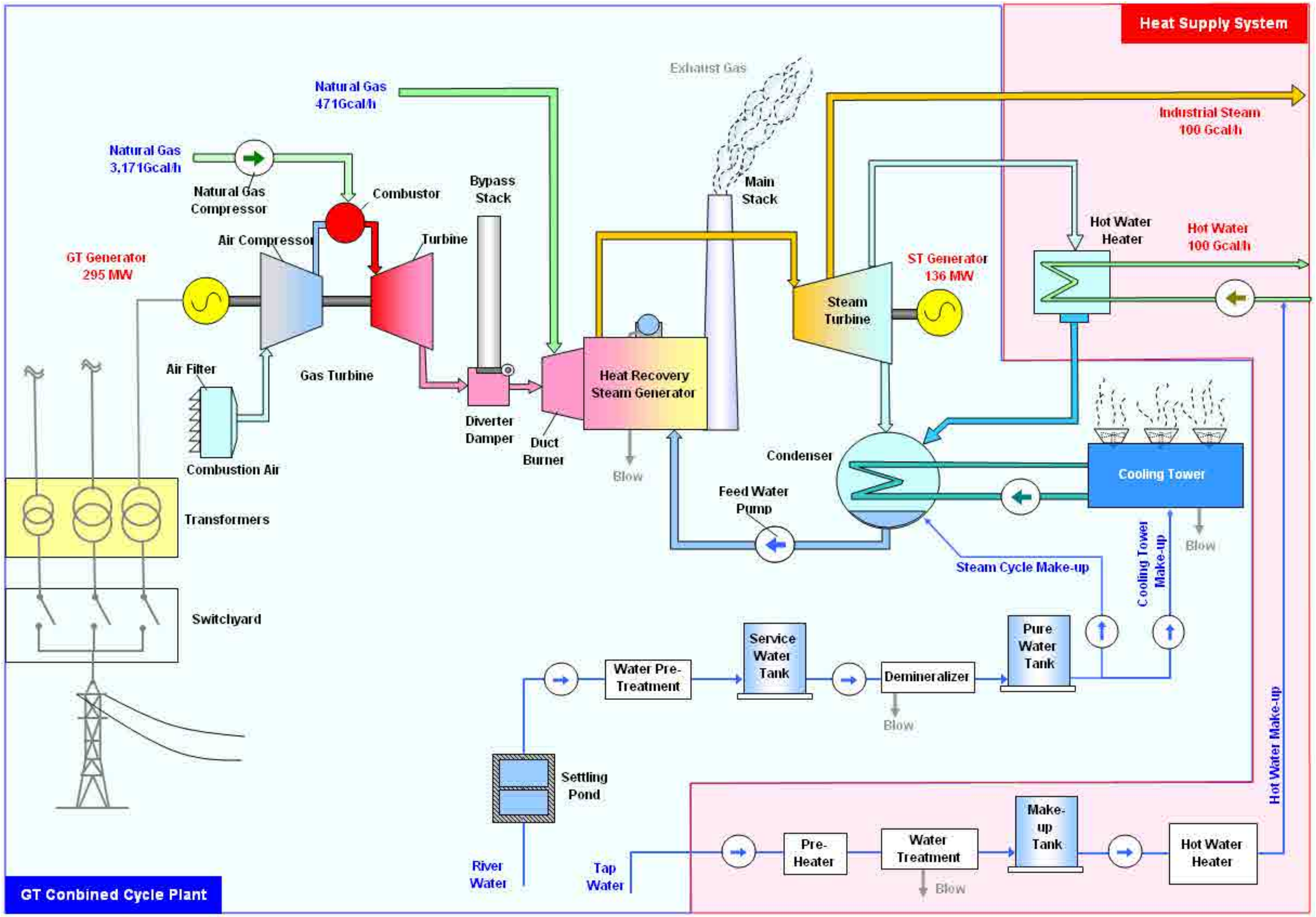


Figure 6.1.2-1 Simplified Schematic Diagram of Total Cogeneration System

6.1.3 Study on Shaft Configuration

(1) Type of Shaft Configuration

The following is a comparison study on the type of the shaft configuration of the combined cycle cogeneration plant (hereinafter to be collectively called as CCCGP) comprised of the one (1) gas turbine, one (1) heat recovery steam generator with a duct supplementary firing system (hereinafter to be collectively called as HRSG), one (1) steam turbine and generator(s).

Basically, there are two (2) types of shaft configurations. One is called single-shaft configuration where the gas turbine, a steam turbine and a generator are connected on the same shaft. The other is called multi-shaft configuration where the gas turbine/generator shaft and the steam turbine/generator are separate.

The single-shaft configuration is classified into two (2) types of configurations depending upon whether with or without a SSS clutch and a bypass system. In case of the former configuration, the power train is arranged in order of the gas turbine, the generator and the steam turbine. The SSS clutch is of auto-engagement and disengagement type and is located between the generator and the steam turbine. In case of the latter configuration, the power train is commonly arranged in order of the gas turbine, the steam turbine and generator.

In case of the multi-shaft type, two (2) types of CCCGP configurations with and without the bypass system could be considered. These four (4) types of CCCGP shaft configurations are as depicted on the Figure 6.1.3-1.

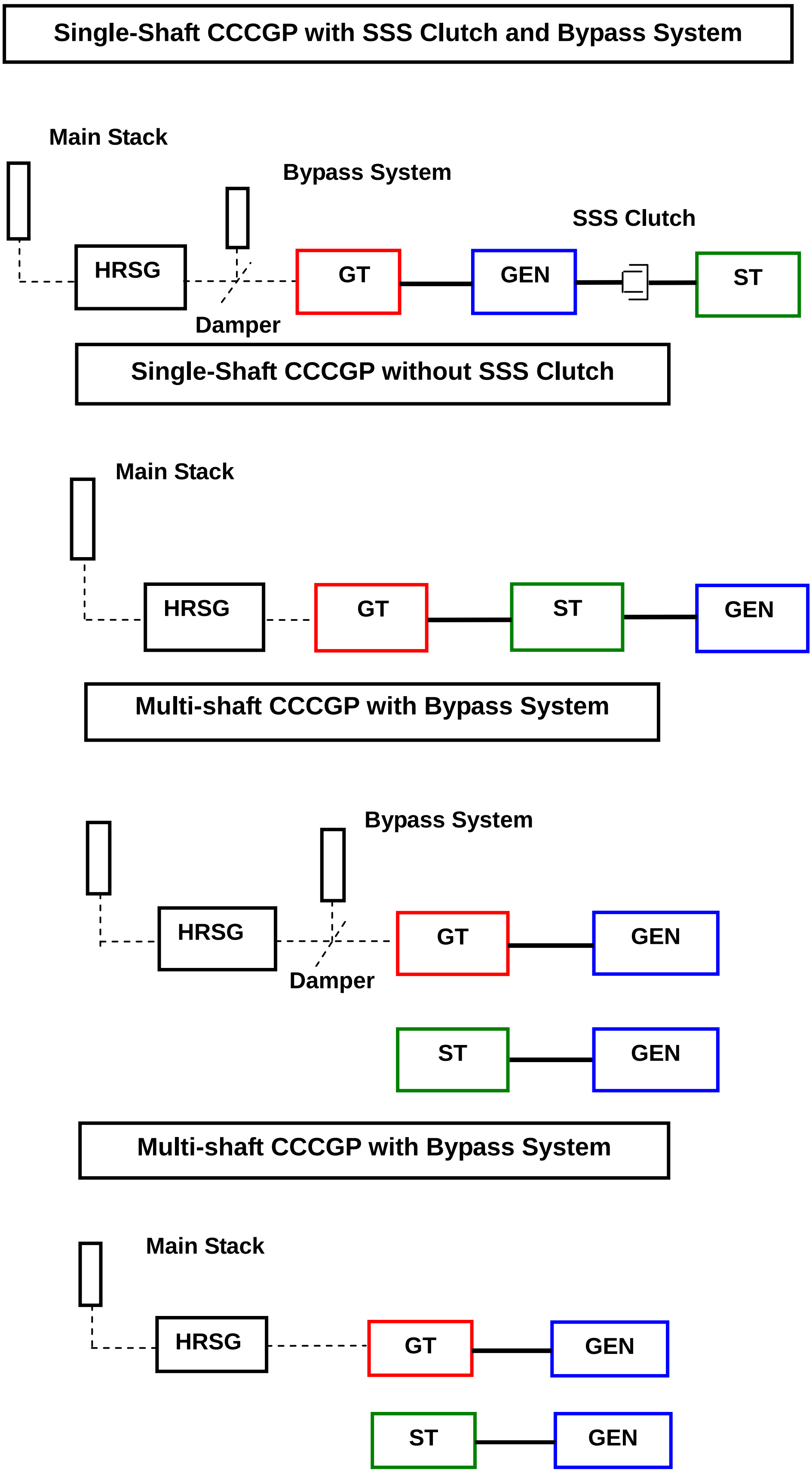


Figure 6.1.3-1 Shaft Configuration

As shown above, in case of the single-shaft CCCGP, one (1) large capacity generator common to both gas and steam turbines is employed. While in the case of the multi-shaft CCCGP, two (2) generators are individually employed for the gas and steam turbines. In this case, one is the plant configuration with the bypass system consisting of a bypass stack and a damper, which are installed between the gas turbine and HRSG to allow for the gas turbine/generator to operate as a simple cycle. The other one is the plant configuration without the bypass system.
The comparison study is performed from the viewpoints of thermal efficiency, operational flexibility, operability, start-up steam and auxiliary power requirement, application experiences, operating reliability, maintainability, installation footprint area requirement, construction cost, generation cost and transportation among above four (4) types of CCCGP shaft configurations.

(2) Plant Thermal Efficiency

The single-shaft configuration is equipped with one (1) larger size generator, while two (2) smaller sizes of generators are employed in the multi-shaft configuration. In case of the configuration with the bypass system, the leakage from the bypass system of the exhaust gas will influence the plant efficiency. It is reportedly said that the leakage over the life time of the plant is 0.5 to 1.5 %. This means that the steam turbine efficiency drops by 0.5 to 1.5 %. Consequentially, the thermal efficiency of the plant with the bypass system drops by 0.17 to 0.50 % compared with the plant without it. Therefore, the plant thermal efficiencies of the four (4) configurations are as estimated below considering that the efficiency of the larger capacity generator is higher by some 0.1 %. The heat loss due to the clutch is considered to be negligibly small.

Type of Configuration	SS CCCGP w SSS and BS	SS CCCGP w/o SSS and BS	MS CCCGP w BS	MS CCCGP w/o BS
Plant Thermal Efficiency (%)	Δ0.17~0.50	100	Δ0.27~0.60	Δ0.1

Where,

SS CCCGP w SSS and BS	Single-shaft CCCGP with Clutch and Bypass System
SS CCCGP w/o SSS and BS	Single-shaft CCCGP without Clutch and Bypass System
MS CCCGP w BS	Multi-shaft CCCGP with Bypass System
MS CCCGP w/o BS	Multi-shaft CCCGP without Bypass System

(3) Operational Flexibility

In case of the single-shaft CCCGP without the clutch, the plant could not be operated unless the components of the gas turbine, the heat recovery steam generator, steam turbine and the generator are all healthy. While, the single-shaft CCCGP with the clutch and bypass system could be operated on a simple cycle mode with isolation of the steam turbine by disengaging the clutch even if any components of the bottoming system consisting of a HRSG, a steam turbine and a steam turbine generator is out of order due to any reasons. The exhaust gas from the gas turbine can be discharged into atmosphere through the bypass system.

In case of the multi-shaft configuration, if the bypass system is equipped, the gas turbine/generator could be operated as a simple cycle similarly to the single-shaft configuration CCCGP with the clutch.

Unless the bypass stack is equipped, the plant behaves as if it were of a single-shaft type without the clutch. However, the plant could be operated on a simple cycle mode by exporting some parts of the generated steam externally as heat energy and dumping the remaining parts into the condenser in the situation whereby the HRSG and the condenser are both in healthy conditions even if the steam turbine is out of service. This is a specific feature of a multi-shaft configuration without a bypass stack.

Thus, the CCCGP with the bypass system, whichever the shaft configuration is, will be more flexible in terms of operability than without the bypass system. There is always no difference in terms of operational flexibility between both types of shaft configurations without the bypass system.

(4) Operability

The CCCGP could be operated only by automatic adjustment of the fuel flow into the gas turbine and the operation cycle of start-up, steady operation and shut-down could be fully automated irrespective of the type of the shaft configuration. The SSS clutch is of a self-shift and synchronous type. There is, therefore, no essential difference with the operability between both types of shaft configurations. The operational sequence of the multi-shaft CCCGP may be slightly complicated compared to the single-shaft CCCGP because of more numbers of components.

(5) Start-up Steam and Auxiliary Power Requirements

In case of the multi-shaft CCCGP or the single-shaft CCCGP with the clutch, the gas turbine can be started up together with the HRSG separately from the steam turbine/generator. After a certain period of the time, the necessary steam for start-up can be available from the HRSG and then the steam turbine/generator can be started up with own steam for flow passage cooling and gland sealing.

In case of the single-shaft configuration without the clutch, however, the steam for the flow passage cooling and gland sealing of the steam turbine which must be started up together with the gas turbine is required from any external sources. For the purpose, any auxiliary steam from the existing boilers or a standalone auxiliary boiler will be needed.

In case of the single-shaft configuration without the clutch, the power requirement for the starting device is approximately 2.5 % of the gas turbine power output, while it is approximately 2.0 % in cases of other three (3) types of CCCGPs.

There is no difference with the auxiliary power requirements among the types of CCCGPs except for the starting device of the shaft train.

(6) Application Experiences

There are many application experiences with both shaft configuration types of CCCGPs. It is understood that both types of shaft configurations are technically feasible without any technical difficulties.

(7) Operating Reliability

The plant operating reliability of each type of CCCGP could be evaluated by the plant reliability factor to be calculated with the reliability factors of the main equipment which are assumed as shown below:

Gas turbine:	A1 = 97.5 %
Bypass system:	A2 = 97.5 %
Heat recovery steam generator:	A3 = 98.0 %

Steam turbine:	A4 = 98.5 %
Gas turbine generator and transformer:	A5 = 99.0 %
Steam turbine generator and transformer:	A6 = 99.0 %
SSS clutch:	A7 = 99.0 %

The following calculations are the theoretically calculated plant operating reliabilities on an hourly basis operation of the single-shaft CCCGP without the clutch as $PORH_S$ and with the clutch as $PORH_{SS}$, the multi-shaft CCCGP without the bypass system as $PORH_M$ and the multi-shaft CCCGP with the bypass system as $PORH_{MB}$.

$PORH_S = A1 \times A3 \times A4 \times A5 = 0.9318 = 93.18\ \%$

$PORH_{SS} = A1 \times A2 \times A3 \times A4 \times A5 \times A7 + A1 \times A2 \times A5 \times A7 \times (1-A3 \times A4) = 0.9317 = 93.17\ \%$

$PORH_M = A1 \times A3 \times A4 \times A5 \times A6 = 0.9224 = 92.24\ \%$

$PORH_{MB} = A1 \times A2 \times A3 \times A4 \times A5 \times A6 + A1 \times A2 \times A5 \times (1-A3 \times A4 \times A6) = 0.9411 = 94.11\ \%$

By the above calculation results, the following relationship could be predicted among operating reliabilities on an hourly basis of the four (4) types of CCCGPs.

$PORH_{MB}$ (94.11 %) > $PORH_S$ (93.18 %) = $PORH_{SS}$ (93.17 %) > $PORH_M$ (92.24 %)

It is found from this relationship that the plant operating reliability of the multi-shaft CCCGP with the bypass system ($PORH_{MB}$) is slightly higher compared with other types of CCCGPs.

The PORH is the plant operating reliability on a basis of the operating hours. However, when the gas turbine is operated on a simple cycle mode, the plant total power output could be reduced to some two thirds. Therefore, the plant operating reliability on a basis of power energy (PORE) has to be evaluated. The PORE of each shaft configuration can be calculated as shown below.

$PORE_S = A1 \times A3 \times A4 \times A5 = 0.9317 = 93.17\ \%$

$PORE_{SS} = A1 \times A2 \times A3 \times A4 \times A5 \times A7 \times (2/3+1/3 \times 0.995) + A1 \times A2 \times A5 \times A7 \times (1-A3 \times A4) \times 2/3$
$= 0.9194 = 91.94\ \%$

$PORE_M = A1 \times A3 \times A4 \times A5 \times A6 = 0.9224 = 92.24\ \%$

$PORE_{MB} = A1 \times A2 \times A3 \times A4 \times A5 \times A6 \times (2/3+1/3 \times 0.995) + A1 \times A2 \times A5 \times (1-A3 \times A4 \times A6) \times 2/3$
$= 0.9257 = 92.57\ \%$

Therefore, the priority order of the PORE of each shaft configuration can be expressed as shown below:

POREs (93.17 %) > $PORE_{MB}$ (92.57 %) > $PORE_M$(92.23 %) ≥ POREss (91.94 %)

(8) Maintenance Cost

Compared with the single-shaft CCCGP, the multi-shaft CCCGP is equipped with additional components such as a generator, a step-up transformer, a lubricating and control oil systems, a bypass stack, a bypass stack silencer, and an exhaust gas damper. Therefore, it is envisaged that the maintenance of the multi-shaft CCCGP needs more man-hour requirement and is costly.

(9) Footprint Area for Instruction

As mentioned in the previous paragraph, since the multi-shaft CCCGP is equipped with more facilities than the single-shaft CCCGP, more footprint area is needed for their installation. In addition, the space utilization effect is inferior because the gas turbine/generator and steam turbine/generator are severally installed. It is foreseen from our experiences that the footprint area for installation of the multi-shaft CCCGP power train is more or less larger by 15 ~ 25 % than the single-shaft CCCGP depending upon installation of the bypass system.

The larger footprint area for installation of equipment means larger amount of civil, architectural and erection works, which in turn means higher cost. The Figure 6.1.3-2 and 6.1.3-3 attached hereon show the typical plan drawings of single-shaft CCCGP power train without the clutch and multi-shaft CCCGP power train with bypass system using F-class gas turbine.

In case of the single-shaft CCCGP power train with the clutch and bypass system, the length in the longer direction is supposed to be longer by some 20 m compared to the layout shown with Figure 6.1.3-1. Therefore, the footprint area for installation comes close to that of the multi-shaft CCCGP power train with bypass system.

(10) Phased Construction

The multi-shaft configuration with the bypass system has the special feature that the phased construction can be available. The completion time of the gas turbine package is normally faster than the bottoming system, which means that it will be put into commercial operation in advance. This feature is more advantageous for the project which must cope with steeply increasing power demand.

(11) Construction Cost

The multi-shaft CCCGP is constituted of a higher number of components than single shaft CCCGP as mentioned in previous paragraphs. Therefore, it is easily predicted that its construction cost will be higher compared with the single-shaft CCCGP. According to the construction estimation results by computer software, the relative cost difference between them could be shown below as referential values for this study.

SS CCCGP w/o SSS and BS	100 % (Base)
SS CCCGP w SSS and BS	plus 2.2 %
MS CCCGP w/o BS	plus 4.2 %
MS CCCGP w BS	plus 6.1 %

(12) Power Generation Cost

The power generation costs of other three (3) types of CCCGPs against the SS CCCGP w/o SSS and BS could be calculated as shown below. In this calculation, the heat supply amount shall not be considered.

1) Fuel cost

Fuel cost (fuel consumption) is proportional to the plant operating reliability on an hourly basis. Therefore, fuel costs of other three (3) types of CCCGPs against the SS

CCCGP w/o SSS and BS are estimated as tabulated below:

SS CCCGP w SSS and BS	minus 0.01 % (=93.18 – 93.17)
MS CCCGP w/o BS	minus 0.93 % (=93.17 – 92.24)
MS CCCGP w BS	plus 0.98 % (=93.17 – 94.11)

2) Capital recovery cost

The capital recovery cost proportional to the construction cost can be estimated as shown below referring to the results in the previous sub-section (11). Therefore, the relative values of other shaft configurations against the SS CCCGP w/o SSS and BS can be expressed as below:

SS CCCGP w SSS and BS	plus 2.2 %
MS CCCGP w/o BS	plus 4.2 %
MS CCCGP w BS	plus 6.1 %

3) Power energy sales

The power energy sale is proportional to the plant operating reliability on a power energy basis. Therefore, the relative values of other shaft configurations against the SS CCCGP w/o SSS and BS can be expressed as below:

SS CCCGP w SSS and BS	minus 1.24 % (=93.18 – 91.94)
MS CCCGP w/o BS	minus 0.94 % (=93.18 – 92.24)
MS CCCGP w BS	minus 0.61 % (=93.18 – 92.57)

Therefore, the power generation cost of SS CCCGP w SSS and BS against the SS CCCGP w/o SSS and BS can be calculated to be higher by 2.7 % (= ((1–0.0001)×1/3 + (1+ 0.022)×2/3))/(1 – 0.0124) – 1.0) = 0.027). In this case, the ratio of the fuel cost to the capital recovery cost is assumed to be 1.0 to 2.0. The generation costs of other two (2) types of CCCGPs can be similarly calculated. The calculation results are as follows:

MS CCCGP w/o BS	plus 3.5 %
MS CCCGP w BS	plus 5.0 %

(13) Inland Transportation

The site is located adjacent to the existing Navoi Thermal Plant in the southern part of Uzbekistan, referred to as a double-locked country. It is not easy to transport the large dimensioned and heavy cargos to the site.

The weights and dimensions of the generator and step-up transformer are different due to type of the shaft configuration, while other components are common irrespective of shaft configuration. The capacity size of the single-shaft CCCGP is larger by approximately 1.5 times that of the multi-shaft CCCGP. The heaviest cargo is deemed to be the generator being common for both types of shaft configurations depending upon the design of manufacturers. The gas turbine can be transported split into three (3) components of a rotating part, a lower casing and an upper casing. Therefore, the generator which is the heaviest cargo in case of the single shaft configuration is heavier by 1.5 times that of the multi-shaft configuration. Therefore, as far as the transportation is concerned, multi-shaft configuration is advantageous.

In this connection, the Study Team is told that large dimensioned and heavier cargos of No. 1 CCCGP have been transported to the site by road from Turkmenbasi on Caspian Sea coast in Turkmenistan. The similar transportation manner will be employed for No. 2 CCCGP, if the shaft configuration is of multi-shaft type.

(14) Study Summary and Recommendation

The study results described above are summarized in the Table 6.1.3-1 on the next page. The yellow colored cell shows that the shaft configuration of the cell is preferred in terms of the related comparison item. As shown in this table, the single shaft configuration without the clutch and bypass stack has the most priorities in terms of comparison items.

The multi-shaft configuration with the bypass stack has many priorities next to the shaft configuration stated above. This configuration is ranked highest in terms of the operating reliability on an operating hourly basis and is advantageous in more comparison items than the multi-shaft configuration without the bypass stack. In addition, this shaft configuration has a specific feature allowing for phased construction and that simple cycle operation can be done. For such reasons as stated above, the Study Team recommends the multi-shaft configuration with the bypass stack.

Table 6.1.3-1 Summary of Comparison Study Results on Shaft Configuration of CCCGP

Comparison Item		Single-shaft CCCGP		Multi-shaft CCCGP	
		Without a SSS clutch	**With a SSS clutch and a bypass stack**	**With a bypass stack**	**Without a bypass stack**
1. Thermal Efficiency		Base (100 %)	Δ 0.17 ~Δ 0.50 %	Δ 0.27 ~Δ 0.60 %	Δ 0.10 %
2. Operational Flexibility (Simple Cycle Operation)		Base (No)	More flexible (Yes)	More flexible (Yes)	Similar (No)
3. Operability		Base	Similar	Slightly complicated due to operation of more equipments	
4. Start-up Requirement	**Steam**	External auxiliary steam	Own steam	Own steam	External auxiliary steam
	Power for Starting device	App. 2.5 % of GT capa.	App. 2.0 % of GT capa.	App. 2.0 % of GT capa.	App. 2.0 % of GT capa.
5. Application Experiences		Base	Similar	Similar	Similar
6. Operating Reliability	**PORH**	Base (100 %)	Δ 0.0 %	+ 0.9 %	Δ 0.9 %
	PORE	Base (100 %)	Δ 1.2 %	Δ 0.6 %	Δ 0.9 %
7. Maintenance Cost		Base	Similar	Slightly higher because of more equipments	
8. Footprint Area of Power Train		Base (100 %)	+ 15 %	+ 25 %	+ 10 %
9. Phased Construction		No	No	Yes	No
10. Construction Cost		Base (100 %)	+ 2.2 %	+ 6.1 %	+ 4.2 %
11. Power Generation Cost		Base (100 %)	+ 2.7 %	+ 5.0 %	+ 3.5 %
12. Inland Transportation		Base	Similar	Better	Better

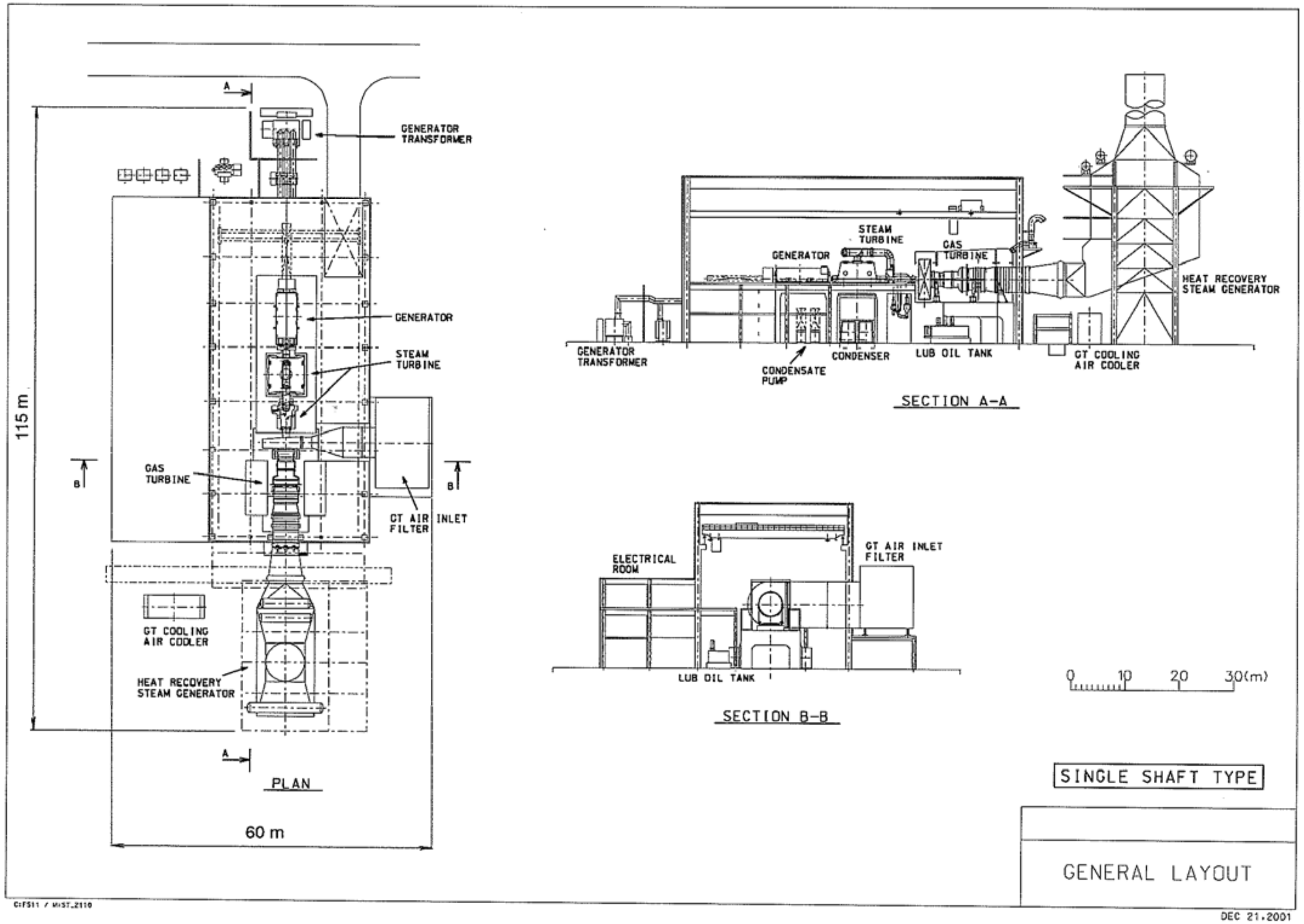


Figure 6.1.3-2 Typical Layout of Single-shaft Arrangement Combined Cycle Power Plant

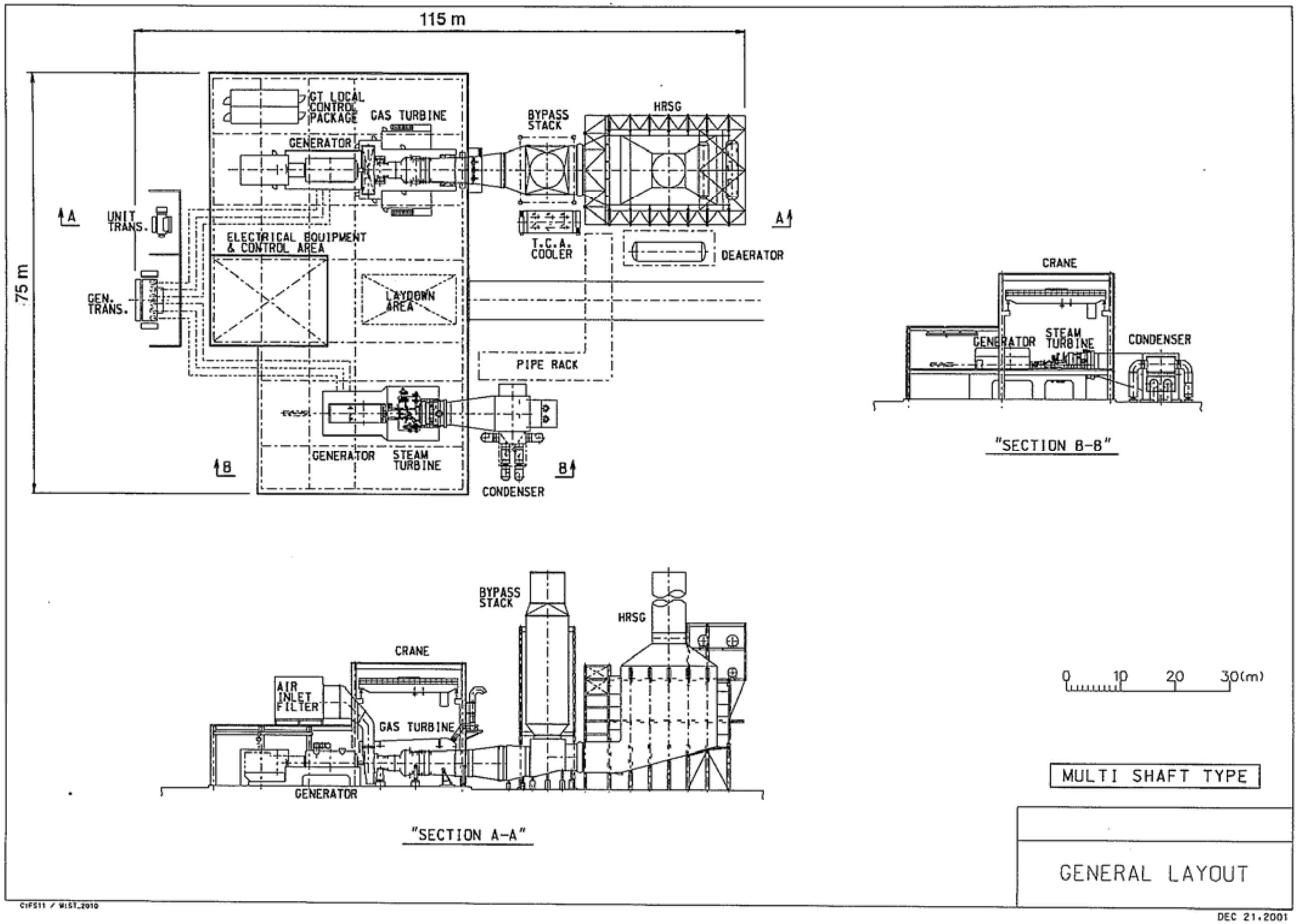


Figure 6.1.3-3 Typical Layout of Multi-shaft Combined Cycle Power Plant

6.2 Scope of the Project

6.2.1 General

The scope of this Project includes the design, manufacture, transportation and delivery to the Site, construction at the Site, testing and commissioning, and maintenance for a period of one (1) year after Taking Over of the plant herein described.

The combined cycle cogeneration plant to be installed shall be of nominal 450MW highly efficient combined cycle block in a one on one multi-shaft configuration comprising one (1) low-NOx gas turbine, one (1) triple pressure reheat, indoor type heat recovery steam generator (HRSG) equipped with duct firing burners, one (1) reheat, two-extraction, condensing type steam turbine, two (2) electric generators, and miscellaneous auxiliary equipment.

The cooling water system for the condenser of steam turbine and for the closed circuit cooling water of plant auxiliary equipment shall be of mechanical draft wet cooling tower type.

The gas turbine and duct firing system shall be designed for natural gas exclusive firing. Gas supply is from Navoi Gas Distribution Station to the site at 1.0~1.2 MPa (g) at the terminal point. Booster gas compressors shall be included in the scope of work, to boost the pressure to the required pressure in the gas turbine combustion chamber. The plant does not need to be capable of starting on blackout condition.

Transmission lines for CCCGP No. 2 to the existing Navoi substation and 220kV bay and bus to be installed in the existing Navoi substation shall be included in the scope of this project. Furthermore, a part of the existing transmission lines which are passing the area of CCCGP No.2 shall be reconstructed as a scope of this project.

The power plant shall supply the industrial steam of 0.8~1.3 MPa (abs) and 300ºC for neighboring chemical companies and the steam of 0.07~0.25 MPa (abs) and 170 ºC to heat the hot water for district heating. These steam supplies shall be extracted from the steam turbine and their heat capacities shall be 100Gcal/h and 100 Gcal/h respectively. The industrial steam supply system and the hot water supply system including steam and hot water piping to the connection points with the existing main piping as well as their make-up water treatment systems shall be included in the scope of this project.

6.2.2 Scope of works

The facility and equipment, as described herein, shall include the following:

(1) Power generation equipment
- (a) One set of Gas Turbine and Auxiliaries and Flue Gas Exhaust System including HRSG Bypass Stack, Dampers, Silencer, etc.
- (b) One set of Steam Turbine, Condenser, and Auxiliaries
- (c) One set of Heat Recovery Steam Generator and Auxiliaries
- (d) One set of Gas Turbine Generator and one set of Steam Turbine Generator, and their Step-up Transformers, Unit Transformer, Auxiliary Transformer and Auxiliaries
- (e) One set of Main Stack
- (f) 220kV Substation, Interconnections and Auxiliaries

(2) Transmission Lines and Substation
- (a) 220kV Transmission lines to the existing Navoi Sub-station
- (b) 220kV bay and bus in the existing Navoi substation
- (c) Reconstruction of existing 220kV transmission lines

(3) Heat supply system
- (a) Industrial steam supply system
- (b) Hot water supply system
- (c) Hot water supply and return piping and valves
- (d) Water treatment system for hot water make-up water

(4) Mechanical Equipment of Auxiliaries and Balance of Plant (BOP)
- (a) Cooling water system for steam turbine condenser and auxiliary cooling system.
- (b) Gas skid and instrument air facilities
- (c) Gas pipe from metering station to plant and booster compressor station
- (d) River water supply facilities
- (e) Water treatment plant
- (f) Waste water treatment facilities
- (g) Cranes and miscellaneous hoist
- (h) Fire fighting protection and detection system
- (i) Heating, Ventilation, and Air Conditioning (HVAC) system
- (j) General service air system and instrument air system
- (k) Workshop and chemical laboratory equipment and miscellaneous items
- (l) Service and potable water system

(5) Electrical Equipment of Auxiliaries and Balance of Plant (BOP)
- (a) Station electrical supply system comprising unit and station transformers, bus duct connections, medium/low voltage boards, auxiliary transformers, motor control centers, etc.
- (b) 110V station DC supply system
- (c) 240V AC station UPS system
- (d) Distributed control system (DCS)
- (e) Station earthing / grounding system
- (f) Telecommunication system
- (g) Lightning protection system
- (h) Emergency diesel generator
- (i) Cathodic protection system
- (j) Lighting and small power supply system including emergency lighting
- (k) Compound / perimeter lighting system
- (l) External lighting

(6) Civil and Building Works
- (a) Preliminary works comprising soil investigation, hydraulic and hydrographic survey and model studies, site survey and setting out, etc.
- (b) Demolition works (if necessary)
- (c) Piling works (if necessary)
- (d) Foundation and superstructure works
- (e) Construction of the administration building, the gas turbine building including the central control room, steam turbine building, HRSG building, and other buildings
- (f) Building of shower for staff

(g) Canteen for staff
(h) Storage for spare parts, tools, etc.
(i) Miscellaneous civil works

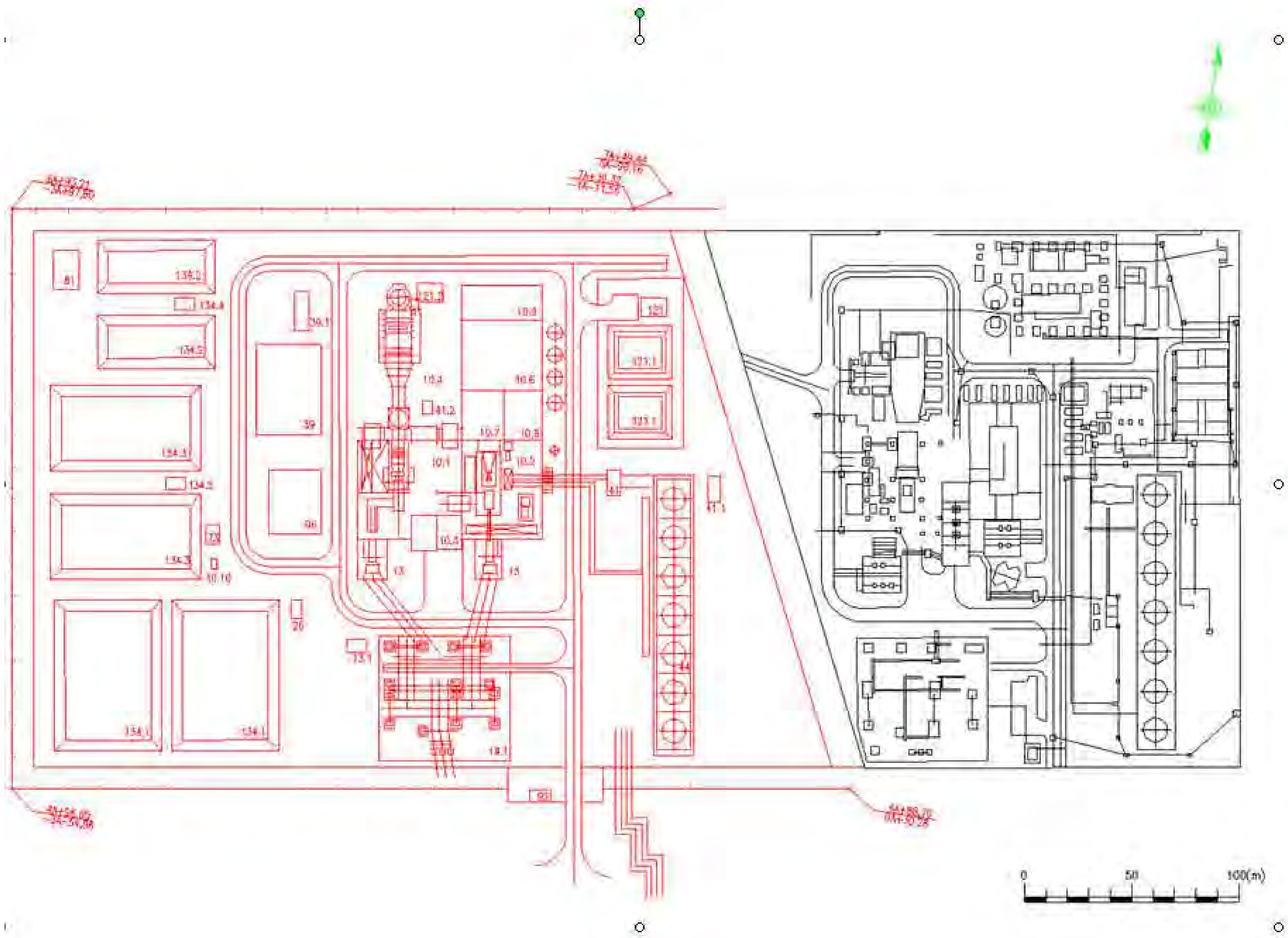
(7) Environmental
(a) On-line emission continuous monitoring system
(b) On-line ambient air continuous monitoring system
(c) Sampling and analysis
(d) Other equipment
(e) Landscaping and environmental blending

(8) Miscellaneous
The scope of this Project also includes the following:
(a) Tools and appliances
(b) Spare parts for two (2) years continuous operation
(c) First fill of oils and greases, and flushing oil and chemicals.
(d) All consumable items for the one (1) year maintenance period.
(e) Fire barrier installation conforming to the Fire Services Department requirement
(f) Training of Power Plant’s staff
(g) Keys and key cabinets system for all plant and equipment
(h) Supply of operation and maintenance (O & M) manuals
(i) Air pollution study and determination of stack dimensions
(j) Statutory and local authorities approval

6.3 Plot Plan

Candidate site is situated in the area adjacent to the west side of the CCCGP No.1 in the west of the existing Navoi thermal power plant.

The conceptual arrangement of CCCGP No.2 is as shown in Figure 6.3-1.



Number	Equipment/Facility Name
	[10. Main Building]
10.1	Gas turbine
10.2	Steam turbine
10.3	Electrical equipment
10.4	Heat recovery steam generator (HRSG)
10.6	Water treatment and wastewater treatment
10.7	Deaerator, Boiler feed water pump, condensate make-up pump, and chemical dosing pump
10.8	Heater and deaerator for hot water supply system
10.9	Utility building
10.10	Emergency turbine lubrication tank (underground)
11.	Stack
13.	Step-up transformers (GT & ST)
19.1	220 kV switchyard
26.	Emergency diesel generator
39.	Natural gas boost-up compressor
39.1	Natural gas distribution station
41.	Circulating water pump station
41.1	Cooling tower blow down tank
41.2	Drainage pump
44.	Cooling tower (7 units)
73	Air compressor with receiver
81.	Electro hydraulic control (EHC) station
92.	Security gate
96.	Oil storage (oil in packages)
121.	Fire pump station
121.1	Reserve water tanks for fire fighting (2 tanks)
121.2	Boost-up station for fire fighting
	[134. Sludge dump area for waste water treatment system]
134.1	Evaporating pond for hot water heater chemical wash
134.2	Sludge dump for oil contaminated water (2 sections)
134.3	Sludge dump for waste water treatment (2 sections)
134.4	Treated water return pump station for oil contaminated water
134.5	Pump station for chemical water treatment

Figure 6.3-1 Plot plan

6.4 Basic Systems for Plant Design

6.4.1 Gas Turbine System

(1) Design Codes and Standards

The gas turbine system shall be basically designed as per ISO 3977-3 “Gas turbines-Procurement-Part3: Design requirements” and ISO 21789 “Gas turbine applications-Safety”

(2) Gas Turbine

The gas turbines shall be of single shaft configuration, open cycle, heavy duty F class temperature level type with dry low NO_x design suitable for the specified natural gas.

The gas turbine design shall be with a minimum number of bearings, and shall be located on a steel frame or on adequate steel structures and concrete foundation, so sized as to withstand the transient torque imposed on the shaft in case of short circuit of the generator or out-of-phase synchronization, whichever is larger. The power output shall be taken out at the cold end of the shaft.

Any type of power augmentation due to the inlet air cooling shall not be considered.

The gas turbine shall be complete with all auxiliary systems such as starting system, lube oil supply system, inlet air filtration system, inlet air anti-icing system, fuel gas supply system, turning device, control and monitoring equipment necessary for safe, reliable and efficient operation with the fuel specified. The gas turbine shall be designed for indoor installation in an enclosure suitable for specified noise requirements.

The gas turbine shall be designed for continuous base load operation according to the manufacturer’s standard, burning the natural gas with the specified composition range. The gas turbine shall be capable of start-up, loading and shut down on the specified natural gas.

The gas turbine shall be provided with an automatic start-up and control system capable of being operated from the central control room of the Plant.

The control system of the gas turbine shall be such that is capable of performing the following operations as a simple and combined cycle:

- Constant load operation at all loads between the minimum and full loads regardless of variation of heat export amount
- Governor free (droop) operation
- Turbine inlet temperature constant operation
- No load operation for certain periods of time without being synchronized as a simple cycle
- Minimum load operation not more than 30% of the full load as a combined cycle on the full power of the steam turbine keeping all the bypass valves closed.
- Automatic purging cycle to ensure that specified natural gas is removed from the gas turbine and entire exhaust system up to the exit of the stacks. Purging time shall be adjustable.
- The load rejection from the full load without tripping for easy re-synchronization.

The gas turbine shall be of horizontally split case construction for convenience of maintenance and shall permit easy access to stationary and moving blades without undue difficulties.

The entire gas turbine casing shall be heat and sound insulated in such a manner so as to allow easy removal and replacement for overhaul and inspection. The insulation material shall be of asbestos free non-combustion and chemically inert material and shall be covered by sheet metal. The design of the heat and sound insulation shall be in a manner so as to avoid that the lube oil from soaking in.

Around the gas turbine there shall be working space of at least 0.8 m width without any interference by piping, cabling, walls etc.

The journal bearings shall be of sleeve bearing type. The axial thrust force shall be oriented in one direction during all steady state operating conditions and shall be absorbed by an adjusted axial thrust bearing. All main bearings of hydrodynamic type shall be equipped with bearing oil outlet temperature indicators and monitors and vibration indicators and monitors. The monitors shall be capable of actuating alarm and/or trip as per manufacturers' practices.

Borescope ports for inspection of all critical inner parts shall be provided.

Figure 6.4.1-1 shows the longitudinal section of the typical F-class gas turbine which may be applicable to this project.

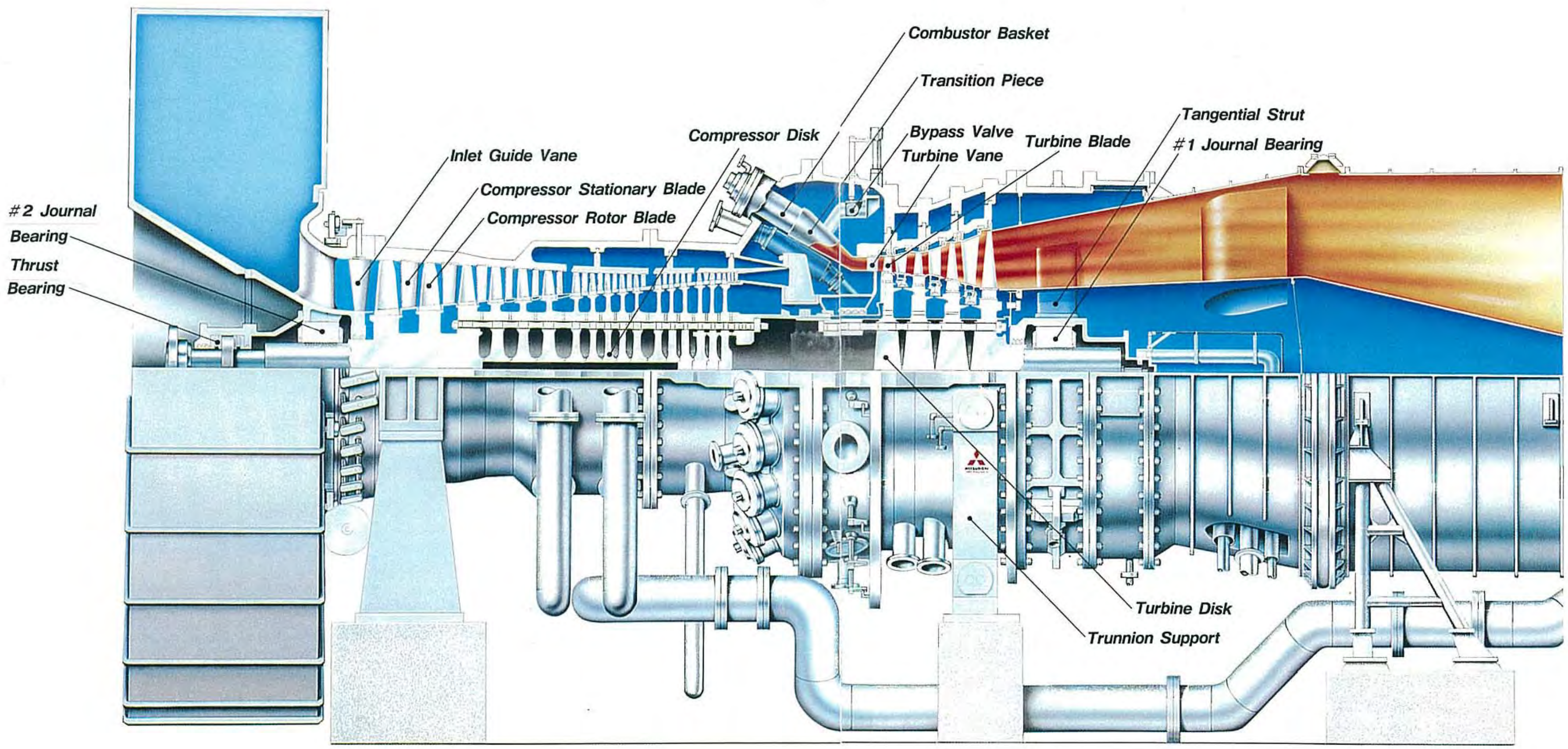


Figure 6.4.1-1 Longitudinal Section Drawing of Typical F-class Gas Turbine

(3) Starting System

The starting device and associated power supply equipment shall be suitable for the acceleration of the gas turbine/generator and the extended operation during purge and compressor cleaning cycles. The rating of the starting device shall be determined so as to produce the starting and acceleration torque with a proper margin to allow for the gas turbine/generator to accelerate to the rated speed from standstill within 25 minutes (excluding the purge and synchronization time) on all machine state conditions without any difficulties throughout the specified ambient temperature range. The starting device and starting power supply capacity shall be minimized as long as the train will be accelerated within the specified time.

The following two (2) types of starting devices can be conceivable for such a large capacity gas turbine and generator of the separate shaft type CCCGP as required for this plant.

- a synchronous generator/motor with a static frequency converter
- a squirrel cage type motor with a torque converter

The starting system should preferably be rated without limit on the number of starts attempted in succession and without restricting the rate of starting.

Interlocks shall be provided to prevent the gas turbine/generator from starting in case the lube oil pressure is not sufficient to rotate the gas turbine/generator rotor.

Any starting device shall disengage automatically and shut down before its reaching to the maximum allowable speed. The starting device is normally disengaged at the self-sustaining speed or idle speed and is at rest during operation. Failure of the disengagement shall automatically abort the starting sequence.

The gas turbine/generator shall be capable of starting instantaneously from any standstill conditions as long as it is on reserve condition.

The starting control system, including any pre-start actions such as turning, shall be of manual and automatic as defined below:

Manual start:	The start-up sequence shall be held and advanced at the events such as cranking, purging, firing and at the minimum governor setting speed.
Automatic start:	The start-up sequence shall be automatically advanced to the minimum governor setting speed or the readiness to synchronizing or to the pre-set load.

The starting control system shall be provided with an automatic purge function to ensure safe operation.

(4) Lube Oil Supply System

The lube oil supply system shall be basically designed as per the requirements of the latest version of API 614. Any a complete lube oil system shall be provided and shall be fully integrated with jacking oil system (if applicable), oil purification system and dirty oil drains for the gas turbine/generator. The lube oil system shall have sufficient capacity to accommodate the requirements of the systems that will be supplied with the lube oil.

The system shall include sufficient standby equipment to allow any items of equipment within the lube oil system to be taken out of service for maintenance without restricting in operation of the plant.

The lube oil system shall be preferably separated from that of the steam turbine/generator.

The retention time of the oil reservoir shall not be less than eight (8) minutes based on normal flow rate of oil and the retention capacity which is the total volume below the minimum operating level.

Alarms shall be at least made on occurrence of following situations:

- Lube oil supply pressure low
- Lube oil reservoir level low
- Lube oil discharge temperature high
- Lube oil supply temperature high
- Lube oil filter differential pressure high

All bearing drain lines and oil wells are to be provided with visual indicators capable of being observed from a local platform or operating floor level.

The outlets of relief valves shall be routed to the oil reservoir tank.

In the event of AC power failure, the emergency DC oil pump to be operated for rundown of the rotating shafts and bearing cool-down shall be automatically put into operation. A combined AC/DC tandem motors-driven pump shall not be accepted.

Where oil is supplied from a common system to two or more machines, the characteristics of the oil shall be specified by the Contractor. The Contractor shall ensure that the specified oil meets the requirements of the different machines and is locally procurable.

(5) Fuel Gas Supply System

The gas turbine combustion system shall be of a single fuel design so that the specified natural gas indigenous in Uzbekistan can be fired without any difficulties.

The natural gas pipe line terminal point is located adjacent outside the boundary fence in the north-east direction of the plant site. The pressure at the terminal point is specified at 1.0-1.2 MPa (g). The nominal size of the branch pipe is 20 inches. The dust particle distribution data necessary for design of the pre-treatment facility will be examined in due course of time.

The fuel gas supply system shall be such that it can supply the gas turbine with the specified natural gas on the acceptable conditions to it with a proper pre-treatment and necessary pressurization of supplied natural gas.

The fuel supply system shall cover all the equipment required for the start-up, shutdown and continuous operation of the gas turbine. A gas compressor station, flow metering devices, a pre-treatment system, and a gas pressure-regulating device, but not limited to them, shall be also included in the scope.

Any fuel gas heating facility where the fuel gas may be heated with hot air extracted from the gas turbine compressor as a turbine cooling media for improvement of the thermal efficiency of the plant may be provided depending upon the gas turbine manufacturer.

Any other conditions necessary for design shall be examined at the detailed design stage. In case of firing the specified natural gas, the NOx concentration level shall not be more than 25 ppmv 15 % O_2 on dry conditions without injection of water or steam.

(6) Air Intake System

1) General

The air supply for a gas turbine shall be taken from a high-level atmospheric air inlet external to the gas and steam turbine building. The air intake shall also be positioned to avoid the ingress of exhaust gases from the main stack of the heat recovery steam generator.

The design of the hood shall permit ready access to the air filtration system. After filtration the air shall be directed to the inlet flange of the gas turbine compressor.

The intake system shall be complete with inlet screen and louvers, filters, airtight duct from filters to compressor inlet, foreign object damage protection screen, sound attenuators and all controls and instrumentation necessary for safe control.

The number of access points and penetrations into the air inlet system for maintenance and inspection shall be minimized. Any door or hatch shall be capable of being securely locked, and interlocks shall be provided to prevent any attempted start with any door or hatch not properly closed.

2) Air Filtration System

The air intake filtration system shall be accomplished by a multi-stage dry system. The filter elements shall be preferably of washable reuse type to minimize the industrial waste. The air filtration system shall be so designed that its dust collection efficiency will not fall below 99.5 % in the weighing method for ISO fine dust while in service and shall be such that particles remaining in the filtered air shall not exceed 5 microns diameter.

The replacement interval of filter elements shall not be shorter than 6,000 hours for use of ISO fine dust.

The air intake shall be equipped with a silencer downstream of the filtration system and the whole of the ducting shall be sealed to avoid ingress of unfiltered air.

The air filters chosen shall be suitable to reduce the sand, dust and salt content in the atmospheric air to a level which is not detrimental to the life of the gas turbine unit and under the most adverse atmospheric conditions of the site.

A self-cleaning type air filtration system shall be acceptable as an alternative. The filter system shall be composed of high efficiency media filter cartridges, which can be cleaned automatically by reverse pulses of compressed air taken from the intermediate stage of the gas turbine air compressor. The sound pressure level during the reverse cleaning operation shall not exceed 80 dB (A) at the distance of 1 m from the system.

The design shall minimize the inlet system pressure drop. The instrumentation and control equipment shall also be kept to a minimum but must include a differential pressure monitor across every stage of the filtration system.

3) Air Inlet Ductwork

The ductwork shall be complete with all the necessary expansion joints, guide vanes, supports and supporting steelwork, vibration isolators, flanges, silencing equipment, cladding and any other items necessary to complete the system.

The expansion joint shall be such that no loads or forces are transmitted to the gas turbine inlet flange.

Sliding joints shall not be used in the ductwork. All expansion joints shall be flanged for removal without disturbing the main sections of the ductwork.

No entrapped nuts, bolts or rivets shall be used inside the ductwork downstream of the filtration system.

Bypass doors shall be provided in the ductwork to allow the air filtration system to be bypassed in the event of excessive differential pressure across the filtration system. The construction of the bypass door shall be preferably of a counter weight type. An alarm in the control room shall be initiated on high filter differential pressure. On further increase in differential pressure, a further alarm shall be initiated together with automatic opening of the bypass doors.

4) Silencer

The silencer shall be provided to control the noise from the air compressor to the specified level. The silencer acoustic panels shall be designed for the service life of 30 years at the full load condition of the gas turbine. The silencer shall be capable of being removed from the ductwork without dismantling or removing any other ductwork than that containing the silencer. The silencer acoustic panels shall be constructed from stainless steel. The infill and panels shall be fully resistant to the worst atmospheric conditions anticipated on the site. Precautions shall be taken to prevent settling or packing of the infill material. The infill material shall be vermin proof.

5) Foreign Object Damage (FOD) Protection Screen

Since there is a possibility of foreign objects entering the gas turbine and causing any damage to rotating parts, the FOD protection screen shall be installed at the compressor inlet to reduce the size of objects that can enter to a size that is not liable to cause such damage. The location of the screen shall be sufficiently upstream to avoid the potential for large objects to cause significant localized flow blockage that may induce blade failure.

6.4.2 Steam Turbine System

(1) Design Codes and Standards

The steam turbine system shall be basically designed as per the latest version of ISO 14661 “Thermal turbines for industrial applications” or equivalent codes and standards.

(2) Steam Turbine

The steam turbine shall be of a reheat, three-admission, two-extraction, two-casing, condensing type directly connected to the generator. The steam shall be downward exhausted to a surface condenser which is cooled by fresh circulating water which is in turn cooled with a mechanical draft wet type cooling tower. The steam turbine shall be of a three (3) pressure-level turbine with HP, IP and LP sections. The medium pressure level of steam may be extracted from the IP section for export to adjacent industrial companies. The low pressure level of steam may be extracted from the LP section for production of hot water for district heating.

The steam turbine and ancillary systems shall be designed to run continuously under all specified conditions over the specified lifetime of the plant.

The steam turbine maximum capability shall be defined so as to cope with such parameters as steam pressure, temperature, flow rate to be developed by the HRSG under conditions of full condensing with no steam extraction and maximum allowable supplementary duct firing temperature when the gas turbine is operated on the maximum capability ambient temperature.

The steam turbine shall be complete with all auxiliary systems such as a steam condenser, a lube oil supply system, a control oil supply system, admission steam stop and throttling valves, a governing system, a steam bypass system, a turning device, control and monitoring equipment necessary for safe, reliable and efficient operation. The steam turbine shall be designed for indoor installation in an enclosure suitable for specified noise requirements.

The steam turbine design shall be with a minimum number of bearings, and shall be located on a steel frame or on adequate steel structures and concrete foundation, so sized as to withstand the transient torque imposed on the shaft in case of short circuit of the generator or out-of-phase synchronization, whichever is larger. The power output shall be taken out at the LP turbine section side.

The turbine blading shall be designed so that it withstands the continuous operation under any loads at any network frequency from 48.5 to 51.5 Hz with any allowable time limitation for under frequency less than 48.5 Hz.

Blades shall be thoroughly protected against erosion from moisture. The last stage blades shall be protected against erosion by flame hardening or by erosion shields of satellite or other suitable material. Other erosion protection provisions such as drain grooves on the last few stator blades and turbine casing will also be considered if such provisions are proven to be effective.

The steam turbine shall be designed so that the expected life expenditure of the main components shall not exceed 75% of the expected lives of them through the specified service hours when it will be operated on the specified conditions.

The turbine shall be provided with necessary number of borescope ports to inspect the conditions of the blades at periodical intervals.

The steam turbine shall be designed with proven materials having a wealth of commercial operating experiences on the similar operating conditions. Especially, special attention shall be paid to the material of integrated single rotor where operating conditions are different at front and rear parts of it.

As for design of the casing and its pipe connections, it shall be taken into account that the most severe conditions of pressure and temperature may simultaneously act upon them. In addition to the calculated minimum thickness of the casing, allowance shall be made for corrosion if the casing is not of a corrosion-resistant material.

The rotor shall be designed to be safe against the speed at least 10 % above the momentary speed which may happen under the maximum operating temperature. If the rotor is of built-up construction, the disc shall remain secure at the speed mentioned above.

The figure 6.4.2-1 is a longitudinal section of typical steam turbine which may be applicable for this project.

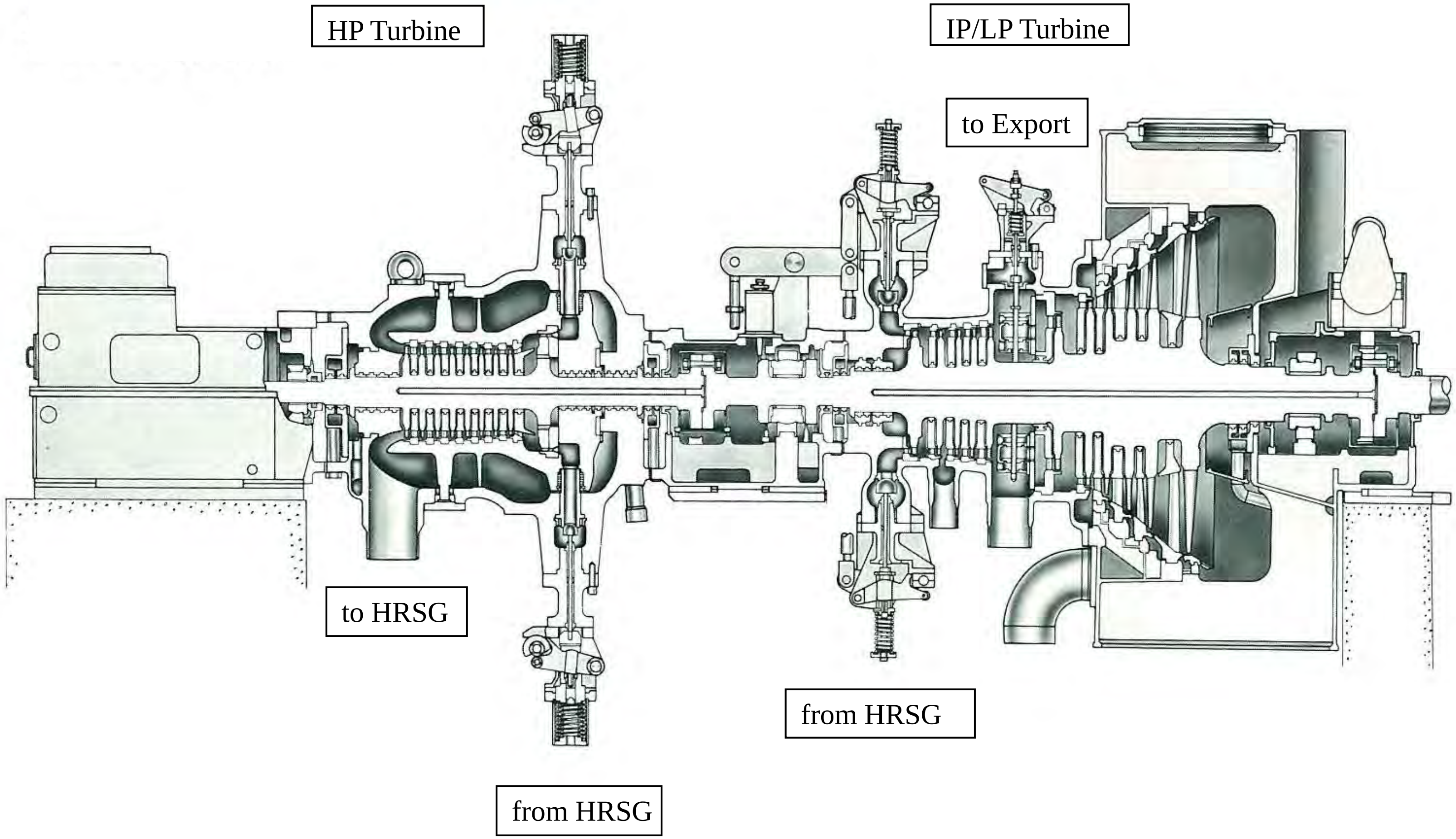


Figure 6.4.2-1 Longitudinal Section of Typical Steam Turbine

6.4.3 Heat Recovery Steam Generator (HRSG) System

(1) Introduction and Scope

This part of the specification covers the one Heat Recovery Steam Generator (HRSG) complete with ducting, mountings, integral valves and pipes, and other specified items associated with the one gas turbine generator of the combined cycle block.

The HRSG shall be of the fired, three-pressure, natural or forced circulation, reheat type of proven design in accordance with the requirements of BS 1113 or equivalent, where applicable.

The HRSG shall be designed to accept the maximum exhaust gas mass flow from a gas turbine at base continuous output with minimum specified ambient temperature and the heating surfaces shall be designed to take into account, the variation on the temperature/flow profile which will occur in the gases leaving the gas turbine under differing loads and ambient conditions.

The HRSG shall be capable of following the inherent rapid start-up and shut down of the gas turbine without undue thermal stress.

The HRSG shall be designed to operate on the exhaust gas of the gas turbine fired with natural gas. Furthermore, the HRSG shall be designed to operate with a duct burning system fired with natural gas. The purpose of the duct firing system is to maximize the quantities of extraction steam from the steam turbine for the industrial steam supply system and the hot water supply system especially in the winter season. The capacity of the duct firing system shall be determined carefully by the manufacturer taking into consideration the maximum allowable temperature of the hot gas duct as well as adverse effects on HRSG steam temperature control and others, however, the maximum firing rate shall be limited to the flue gas temperature rise to 750 °C.

An exhaust gas bypass system with bypass stacks shall be incorporated to improve flexibility of combined cycle operation.

In the case of steam turbine trip, the HRSG shall be able to continue operation using the steam turbine bypass system and supply the heating steam instead of the steam turbine extraction steam.

The HRSG design shall be such as to minimize the back-pressure on the gas turbine while maintaining the rated output and steam conditions.

The HRSG should be constructed of large, factory-tested, shippable modules to reduce installation time. Following heat transfer modules shall be considered, as applicable, for the HRSG design:

- High Pressure Superheater Section
- High Pressure Evaporator Section
- High Pressure Economizer Section
- Reheater Section
- Intermediate Pressure Superheater Section
- Intermediate Pressure Evaporator Section

- Intermediate Pressure Economizer Section
- Low Pressure Superheater Section
- Low Pressure Evaporator Section
- Low Pressure Economizer Section
- Condensate Preheater (if required)

To minimize the outage time for inspection and maintenance, provision shall be made to allow ready access to the flue gas path, tubing, and other pressure parts. Access doors with integral seals to prevent gas leakage to atmosphere shall be provided.

The HRSG shall be designed for indoor installation to protect both personnel and equipment from the external environment and in particular offer freeze protection during the winter season.

The steam drums shall be sized sufficiently large to accommodate water level variations during start-up and during operating transient conditions without resorting to wasteful water dumping or risk of carry over. The drum capacity shall also be sufficient such that tripping of any one operating boiler feed water pump shall not cause HRSG trip prior to standby feed water pump reaching its operating load. Particulars of the general layout of the water circulating system including the number and internal diameter of feeders and mains for each circuit shall be provided.

The HRSG shall be arranged with the total pressure parts comprising steam drums, superheaters, reheaters, evaporators, economizers, headers, down comers and integral pipe work in the form of a self-contained unit supported by its own steel structure. This structure is to be quite independent of any building except for normal points of interconnection with access galleries, platforms, or stairways.

The design of the HRSG and associated ancillary and auxiliary systems shall have been developed for both base load and cycling service in particular where component material stress and structural design are concerned. Any special features for the HRSG necessary to permit both constant and variable pressure operation for the turbine steam temperature matching shall be incorporated. The capacity in terms of interval at maximum continuous steaming rate between normal water level, low water level, low water level alarm, low water level trip and minimum level at which the HRSG will not sustain damage shall be not less than ten seconds.

(2) Design and Operating Conditions

HRSG shall be suitable for the normal and abnormal operating conditions to suit the proven combined cycle plant design and as per the Heat Balance Diagrams.

The gas side of the HRSG passages shall be designed for the maximum temperature, pressure and mass flow that can be anticipated under all operating conditions (including trip situation). The maximum values will not necessarily be concurrent.

The HRSG shall be able to meet the requirements of sustained base load as well as two shift operation.

The HRSG shall be capable of automatic variable pressure operation both for sustained base load as well as two cycling regimes, to minimize the turbine thermal stress levels and obtain the desired flexibility and efficiency. The manufacturer shall define the variable pressure characteristics of the HRSG including the minimum load at which variable pressure operation can be sustained.

Under conditions of total load rejection, the operation of the HRSG shall be rapidly transferred to the steam turbine bypass operation mode by means of the high pressure, intermediate pressure and low pressure steam bypass system as well as the exhaust gas bypass modulating control dampers and the thermal load of the HRSG shall be reduced in accordance with the gas turbine shut down characteristics. In the case of the steam turbine generator trip, the gas turbine and HRSG shall be able to continue operation in the steam turbine bypass operation mode to supply steam for the neighboring industries and the hot water supply system instead of the steam turbine for at least a few days until the back up from the existing power plants becomes available.

The starting and loading to full load of the gas turbine shall not be restricted in combined cycle operation. It is intended that the diverter damper shall be capable of being operated in a number of pre-fixed intermediate positions to cater for hot, warm and cold starts of the HRSG with the gas turbine operating at full load as well as during HP/LP bypass operation.

The HRSG is to be designed such that it can be started-up in following two operating modes:-

- Start-up together with GT
- Start-up of HRSG when the GT is already operating at full load. Flue gas regulation shall be achieved by regulating the diverter damper.

The HRSG design shall be optimized for continuous efficient operation over the entire operating range of the gas turbine. The efficiency between 70% and 100% MCR shall be maximized.

The feed water quality shall meet the requirement of the HRSG and steam turbine as per applicable code.

(3) Design Standards and Codes of Practice
All materials, designs, manufacture, construction, and inspection and testing shall conform to criteria and recommendations of the relevant codes and standards.

All pressure parts, mountings, fittings and sub-assemblies shall be designed, constructed, and tested to conform to the requirements of the approved Inspection Authority.

(4) Design and Construction of HRSG
1) HRSG Gas Path
The gas turbine exhaust gas path through the HRSG shall be horizontal or vertical with water and steam tubing located horizontally/vertically across the gas stream to suit the plant layout and as per the manufacture’s standard design.

The heating surfaces of various modules in the gas stream shall reduce the gas temperature to the lowest value practicable, with each of the fuels available to the gas turbine, without risk of damage from corrosive sulfur products at the economizer outlet or within the stack. Control of the feed water temperature to ensure that metal temperatures in any part of the economizer remain above the dew point shall be achieved via the deaerator.

The tubes and headers in each plenum shall be completely drainable and provision shall be provided to gain access to the tubing for inspection and maintenance.

2) Tubes

The tubes shall be of solid drawn or electrical resistant welding (EWR) steel as per the manufacturer’s experiences. The design, manufacture and testing of the tubes shall be in accordance with the relevant standard specification.

Adequate circulation ratio shall be provided to minimize circulation upsets that may occur during rapid start-up or load change.

Fins added to the heat exchanger tubing to improve the heat transfer characteristics must be continuously welded to the outside surface of the tubes.

All welds and tube connections to headers shall be outside the gas passage and readily accessible for inspection and maintenance.

3) Superheaters and Reheaters

The H.P superheater tubing shall be designed and located in the HRSG unit such that the steam temperature at delivery to the steam turbine will not exceed the H.P steam chest and rotor stated limits, with the gas turbine at base continuous output with highest anticipated ambient temperature, without recourse to desuperheating the steam. The design will be compatible with the requirements of constant and variable pressure operation and the variable characteristics of the gas turbine exhaust gas flow.

The design of the H.P., I.P and L.P superheater within the HRSG units shall ensure even distribution of steam through the tubes at all loads.
Superheaters and reheaters shall be in the form of fully drainable elements.
Superheater and reheater tubes are to be designed for with no steam flow in tubes during start-up. Material selection shall conform to the same.
Austenitic stainless steel shall not be used anywhere in the superheater.

4) Evaporators

The HP., IP and LP evaporator plenums will be designed to achieve a steam generation rate such that the gas leaving the zones is not more than 17.5ºC above the steam saturation temperature in that zone. (i.e. temperature difference at the pinch point: maximum 17.5ºC).

The evaporator shall be designed to operate over the full load range of the HRSG without drumming or vibration and the design will ensure an even distribution of water through the tubes. The evaporator elements shall be drainable completely.

5) Economizers

The HP, IP and LP economizers shall be designed to ensure stable non-steaming operation/single phase flow throughout the full operating range of the HRSG. Connections shall be arranged between the steam drum and the economizer inlet to enable circulation of water to be maintained through the economizer during start-up. Should recirculation of water through the economizer be necessary during start-up or low load conditions, the connections shall be arranged complete with a pump to allow this. The economizer elements shall be drainable completely.

6) Condensate Preheater (if applicable)

A condensate preheater for HRSG as the last heat recovery module shall be provided, if necessary for maximum heat recovery. The condensate preheater shall be designed for the condensate extraction pump shut off head. Material selection for the preheater shall be suitable for undeaerated condensate water.

7) Steam Temperature Control

The steam temperature at the outlet of the superheaters and reheaters shall be controlled using direct spray type desuperheaters.

The capacity of each desuperheater shall be selected taking all operating conditions especially operations with the duct firing system into consideration.

Spray water control station shall have a motorized isolation valve in the common line, interlocked to close automatically when the steam temperature reaches below a set point and to prevent water induction into steam turbine.

8) Safety Valves

Safety valves of approved number, design, and capacity shall be mounted in approved locations in accordance with the requirements laid down by the relevant regulations.

The safety valves at the superheater outlet shall be sized to have a discharge capacity equal to at least 20% of the maximum steam quantity generated by the HRSG. The safety valves at the steam drum shall have total discharge capacity equal to at least the remaining of the maximum steam quantity required for the protection of the HRSG.

Safety valves on the reheater must be sized to pass the maximum reheater flow without a rise in reheater inlet pressure of more than 10% of the highest set pressure.

9) HRSG Insulation and Cladding

The whole of HRSG shall be insulated internally and/or externally and all external insulation shall be cladded in accordance with the Specification to provide an entirely weatherproof unit suitable for indoor operation.
The insulation shall be of proven material and suitable for continuous service at the maximum operating temperature.

10) Access and Inspection Doors

Adequate access and inspection doors of an approved type and size shall be provided to allow free entry for maintenance and cleaning of the HRSG gas-path, and pressure parts.

11) Blowdowns and Drains

The steam drum shall be provided with a continuous drum water blowdown connection, located to ensure preferential discharge of concentrated drum water, complete with parallel slide isolating and regulating valves in accessible positions adjacent to the drum connection, capable of controlling the rate from 0.05% minimum to 4% maximum of the HRSG steam rating.

Intermittent blowdown and drain piping shall be included where necessary from all drainable sections of the HRSG down to the intermittent blow down tanks.

HRSG shall be provided with a continuous and intermittent blowdown tanks.

An adequate number of electrically operated blowdown valves and superheater and reheater drain valves shall be provided for automatic operations during start up, load operation, and shut down of the HRSG.

12) Economizer/Condensate Preheater Recirculation System (if applicable)
Economizer/condensate preheater recirculation pumps shall be provided if the overall plant design demands such an arrangement for the safe and efficient operation with the desired flexibility and reliability of the plant as specified in the Design Consideration under start-up and low load operation.

(5) HRSG Control & Instrumentation Requirements

1) General
The control and protection requirements for the HRSG are principally bounded by the following:

- On the gas side by the gas turbine exhaust and HRSG diverter damper position
- On the feed/steam side by the HP/IP and LP feed pumps discharge and the HRSG HP/IP and LP steam stop valves.

The control system for the HRSG shall be implemented in the Distributed Control System (DCS). All necessary control functions and interlocks required for safe and efficient operation of the HRSG shall be incorporated within the DCS. Separate DCS Field Control Stations/Remote I/O Stations shall be provided for interlock and protection related parameters and signals meant for control and monitoring purpose.

The control functions of HRSG shall comprise of the following as minimum:

- HP, IP and LP feed water control
- Start-up/load rate control
- Superheated steam temperature control
- Reheated steam temperature control etc.

The main protection/interlock associated with HRSG shall be implemented by utilizing the signals associated with the following as minimum:

- Gas Turbine Trip
- High-High and Low-Low Drum Level
- Steam Turbine Trip
- Steam Turbine steam bypass failure
- Local and Remote Emergency Trip, etc.

The start up, operation within the normal load range and shut down of the HRSG shall be fully automated up to the functional group level. However, the initial HRSG filling operation and the establishment of initial HRSG drum level shall be manually controlled and supervised from the Central Control Room and only local control may be provided for minor drain and vent valves, where these are not automatic and which are not required during normal steam rating.

The HRSG shall be capable of constant pressure operation up to 60% load and thereafter on variable pressure operation.

In the incidence of a steam turbine trip (at any load), excessive rate of increase of the HP/IP superheater temperature within the HRSG or a HRSG trip due to say a loss of feed water supply shall initiate the appropriate interlocks to move the diverter flap to the blast stack position and not trip the gas turbine unless the diverter flap fail to move to the correct position within a preset time.

HRSG permissive signals shall be required for moving the diverter flap from the bypass stack position to the HRSG position.

The following as a minimum shall move the diverter flap to the bypass stack position:

- Gas Turbine Trip
- Low-Low Drum Level
- Steam Turbine steam bypass failure
- Local and Remote Emergency Trip
- In the case of a steam turbine trip, the <<diverter flap>> shall be moved to a predetermined intermediate position to maintain the HRSG in a ready condition for reloading.

In the case of a steam turbine trip, the steam turbine bypass system shall be functioned to maintain the HRSG in a ready condition

MTBF (Mean Time Between Failure) of HRSG control & protection system, except for the transmitter, detecting elements and regulating devices, shall be more than 100 thousand hours of design.

The manufacturer shall supply the following instrumentation, control and protection system with all necessary components and accessories, but not be limited to:

- HRSG modulating control system
- HRSG system sequence control
- HRSG autonomous control system
- HRSG instrumentation etc.

2) Turbine Exhaust Gas Control Requirements

All control and instrumentation systems required for the regulation and supervision of the heat input to the HRSG shall include the controls for the turbine exhaust gas (TEG) diverter flap position for the direct regulation of TEG flow through the HRSG as well as all temperature and pressure measurement both on the gas and feed/steam sides.

The control system shall regulate the TEG flow into the HRSG to achieve the maximum rate of initial steam raising, steam load and delivery temperature variation compatible with the design thermal stress limitations associated with the critical HRSG and steam turbine components. Automatic HRSG start up shall be possible under the full spectrum of operating conditions which shall include the following:

- The parallel run up and loading of the two gas turbine generators and HRSG's
-

- The start up of the HRSG from any initial temperature condition (i.e. cold to full load temperature) with the associated gas turbine generator operating under part or full load conditions.

To control the temperature and pressure rise of the HRSG and steam piping during start-up, the diverter flap shall be set to predetermined positions based on the gas turbine load as well as the condition of the HRSG at start-up. This function may not be necessary if the HRSG can accommodate the full exhaust gas flow for all conditions of start-up and during transient operating conditions without the need to set the diverter flap to intermediate positions.

In addition to the start up requirements, the control system shall meet the following disturbance conditions:

- It shall maintain maximum steam generation compatible with the turbine bypass capacity in the event of the steam turbine tripping to permit the reloading of the latter with the minimum of delay.

- It shall minimize the effect of a partial or total block load rejection and maintain the HRSG in a state, which shall minimize the delay in the subsequent re-connection and loading of the steam turbine.

The control and supervisory functions of the following plant items shall be considered:

- The TEG diverter flap
- The gas passage between the inlet diverter flap and the HRSG exhaust.
- The HRSG LP economizer, drum, evaporator and superheat sections
- The HRSG HP/IP economizer, drum, evaporator and superheater sections

The principal sequence and protection control functions shall include the following as minimum:

- The start-up and HRSG Loading Control

The requirement for these control functions, is sequential in nature. In addition to the TEG diverter flap, the sequence controls of HRSG stop valves and associated bypass valves including all necessary state monitoring shall be controlled by these control functions.

A check to ensure that the diverter flap is fully closed in the bypass stack position shall form a pre-check in the HRSG start-up sequence. Only local controls are considered necessary for the operation of the diverter flap, to be restricted by a Permit-to-Work system.

- Shut-down

This function shall be capable of being initiated both manually and automatically from the central control system. The shut down function shall initiate co-ordinated closing of the TEG inlet and closing of HRSG stop valves after an appropriate delay. The stopping of HRSG feed pumps and circulation pumps may be regarded as manual action.

This sequence function shall initiate the tripping of the gas turbine if the diverter flap fails to move to the bypass stack position within a preset time after the HRSG is tripped and the operation of the diverter flap initiated.

The HRSG supervision shall not exercise any direct control functions but shall comprise of all measurement hardware required for the monitoring of the operational state of the HRSG.

3) Feed Control Requirement

The control and instrumentation system required to regulate feed water supply to HRSG shall include feed water regulation valves, instrumentation associated with drum, main steam and feed water together with feed water pumps.

Feed control system shall comprise of single element drum level control operating on low load feed water control valve and three element control operating on the full load feed water control valve nominally rated for 0% to 100% MCR feed water flow. Differential pressure across the feed water control station shall be maintained at constant value by varying the scoop position of the feed water pumps.

The system shall be designed to maintain the drum level within acceptable limits under all anticipated HRSG load changes and disturbances such as transfer from the duty feed water pump to the standby feed water pump etc.

The principal modulating control functions to be associated are:

(a) Start up feed water control
(b) Normal load feed water control

4) Drum Level/Feed Water Control

The control system shall comprise of single element drum level control operating on low load feed water control valve and a three element control operating on full load control valve (in case of HP & IP on one of the full load control valve). Low load feed water control valve is envisaged for controlling the drum level during plant start-up and low load operation upto 30% MCR. For normal load upto 100% MCR, full load control valve is envisaged to maintain the drum level. A stand-by full load feed water control valve (in HP & IP feed water control stations) shall be provided for improving the availability during on-line maintenance of the main valve. Facility shall be provided for both manual and automatic changeover from single element to three element control and vice versa.

The three element function shall consist of the steam flow, feed water flow and drum level. Steam flow measurements shall be pressure and temperature compensated and the drum level measurements shall be pressure compensated.

The feed water control shall develop the flow control signal for matching between feed water flow and steam flow using drum level deviations from the drum level set-point.

5) Main Steam Temperature Control

The steam temperature shall be designed to maintain the main steam temperature at the turbine inlet by means of the spray control valves. One or more stages spray control based on HRSG design shall be used for the control of superheater temperature.

The spray desuperheater shall be provided with shut-off valves. The feed forward circuit shall be used for the sufficient control response.

6) HRSG Autonomous Control System

The HRSG autonomous control system shall interface with the data highway of the Distributed Control System (DCS) through process I/O interface devices. The process I/O system shall have duplicated system architecture

The interface type shall be of either the conventional hardwired I/O interface (I/O) or the remote I/O interface (R-I/O)

The following ACS of the HRSG auxiliaries shall be interfaced to the data highway through I/O interface devices but not be limited to:

- HRSG metal temperature measurement system
- Environmental measurement system
- Water/steam sampling system
- Instrument air compressor system
- Service air compressor system

7) Instrumentation

The manufacturer shall provide all necessary instruments for HRSG and auxiliaries to allow centralized control and monitoring facilities from the operators' consoles in Central Control Room, through microprocessor based Distributed Control System (DCS).

The following field control and instrument devices shall be provided:

- Gauges, Transmitters, etc.
- Detecting elements such as flow element, thermocouple, pressure switches and temperature switches, etc.
- Regulating devices such as control valves, vanes, dampers, and drives, etc.
- Local instrument panels (if necessary)
- All piping, tubing and wiring necessary for satisfactory operation shall be provided.

This shall include instruments for measuring the following minimum process parameters:
(a) Feed water
(b) Drum
(c) Steam

HRSG metal temperature, drum level viewing system including indicator (optical fiber system) and all other necessary pertinents.

The manufacturer shall provide all local instruments.
- Pressure gauges
- Thermometers
- Flow indicator
- Level gauges
- Limit switches, etc.

6.4.4 Heat Supply System

6.4.4.1 Steam Supply System and Hot Water Supply System

(1) Introduction

Supply of processing steam for neighboring industries (industrial steam supply) and supply of hot water for district heating (hot water supply) shall be carried out, using two adjustable steam extractions from the steam turbine of CCCGP No. 2.

In accordance with Preliminary Feasibility Study of the project, the capacities of the industrial steam supply and the hot water supply are 230 Gcal/h and 120 Gcal/h respectively. However, the Study Team would like to recommend that the capacities should be 100 Gcal/h and 100 Gcal/h. The reasons are as following:

i) The capacity of 350 Gcal/h (230Gcal/h + 120 Gcal/h) seems to be too large for a single unit to shoulder. Since the heat supply capacity is more than two (2) times larger than the maximum unit capacity of the existing facilities (maximum 150 Gcal/h), and the heat capacity can cover the whole heat demand in Navoi TPP, in case that the unit should trip due to some trouble, it is difficult for the existing units to start up soon and back up the deficiency. The existing units and the new plant should share the heat demand to prevent such a fault.

ii) The heat supply capacity shall be specified at 200 Gcal/hr (100 Gcal/h+100 Gcal/h), which would be optimum to realize the reliable operation of heat supply system.
The Study Team also proposed to supply the required heat in accordance with operation mode as per shown in Table 6.4.4-2 “Heat demands and combination of operating plants”.

The existing plants were all constructed 30 to 50 years ago and their life spans have almost expired. However, in order to manage the heat supply systems in Navoi city, the existing plant must continue their operation with CCCGP No. 2 until the day when another new back up plant should be constructed. Therefore, it seems indispensable that the renovation plan of these plants should be planned and carried out urgently.

Table 6.4.4-1 Current Situation of Heat Supply Capacity

Name of Plant	Industrial Steam (Gcal/hr)	Hot Water (Gcal/hr)	Total (Gcal/hr)
Existing plants			
Unit No.4		33	33
Unit No.5	150		150
Unit No.7	113		113
Unit No.9		33	33
CCCGP			
Unit No.1		43	43
Unit No.2	100	100	200
Total Capacity	363	209	572

Table 6.4.4-2 Heat demands and combination of operating plants

	Steam (Gcal/hr)	Hot Water (Gcal/hr)	Total (Gcal/hr)
Heat Demand (*1) -High (Nov. ~ March) -Low (April ~ Oct.)	 231~**250** 139~**192**	 131~**194** 16~**47**	 362~444 163~224
Typical combination of operating units to satisfy the heat demands	High season: -No. 5+CCCGP2: 250 -No. 5+No. 7: 263 Low season: -No. 7+CCCGP2: 213 -No. 5: 150	High season: -No.4, 9+CCCGP1, 2: 209 -No. 9 + CCCGP1, 2: 176 Low season: -CCCGP2: 100 -No.4, 9: 66 -CCCGP1: 43	

Remarks: *1: Steam and hot water demands are based on the data collected at the 3rd site survey. Please refer to Fig 4.2.1-5 “Record of Monthly Heat Supply in 2011” for detail.

(2) Description of industrial steam and hot water supply system

Schematic thermal diagram of the unit for steam and hot water supply system from equipment of power unit of CCCGP No. 2 is given in Fig 6.4.4-1 ~ Fig. 6.4.4-3.

Thermal energy supply in steam is carried out to general station header from processing extraction of the steam turbine with 8-13 kg/cm2 abs. pressure. Steam conduit from steam discharge unit of processing extraction passes through the hot water supply system house.

In accordance with letter of “Navoi TPP” OJSC No. 9/875-GRP dated 03.10.2012, return of condensate from the process steam consumers is 27% of the quantity of supplied steam.

Hot water heaters in hot water supply system are intended for heating return water from the hot water return mains as well as hot water make-up water with the extraction steam of steam turbine. The heating steam is supplied to distributing header and then to main heaters of hot water (hereinafter as HHSW). Selection of the quantity and schemes of the heaters had been carried out based on requirements of the paragraph 11.7 of Departmental standards of process engineering 81 “Process engineering standards of thermal power plants”. Total number of HHSW is four (4). In the state of moderate realization of thermal energy three (3) HHSW are used as operating units and one (1) HHSW is used as standby unit. In the state of maximal realization of thermal energy all four (4) HHSW may be used in operation. Taking into account of availability of peak-load hot water heaters in Navoi TPP as well as for avoidance of wasteful operation mode of power unit of CCCGP No. 2, peak-load heaters of hot water supply system water are not provided.

Condensate of heating steam after integrated condensate cooler and level controller in HHSW is supplied to suction header of condensate pumps (hereinafter as CP). In accordance with the paragraph 11.8 of Departmental standards of process engineering 81, number of CP is to be taken as two (2) units without standby. After CP condensate of heating steam is received to discharge header and further returned to circuit of turbine condensate (TC) of power unit of CCCGP No. 2.

In start-up conditions condensate of heating steam from HHSW through additional cut-ins is received to general header by gravity flow and then through hydraulic loop is branched to tank of low points (TLP) of power unit of CCCGP No. 2.

Return water is supplied to general inlet header before HHSW of φ630 x t8 after hot water supply system pumps. Return water for input of each of four (4) HHSW is received by separate pipelines ofφ325 x t8. After heating in HHSW up to 110°C hot water is branched from each HHSW to general header of direct hot water supply system water. For enabling water temperature control special control unit is provided in direct line of hot water supply system with adequate fitting. The main flow of hot water from the header is supplied to consumers (including heating of working area of CCCGP No. 2 and utility module).

Part of the water from header of direct hot water supply system water is supplied through pipeline as heating medium to a column of vacuum deaerator. The remaining part of the water is supplied through pipeline to plate heater of chemically treated water before vacuum deaerator.
For removing of corrosive gases (oxygen and free carbon dioxide) from chemically treated makeup water, vacuum deaerator (hereinafter as VD) is provided.

Capability and number of hot water supply system pumps are accepted in accordance with paragraphs 5.21, 523 of KMK 2.04.07-99 “Heating systems” as well as according to the paragraph 11.8 of Departmental standards of process engineering 81:

- One (1) x 100% capacity winter hot water supply pump is installed for operation and one (1) backup winter hot water supply pump with the same capacity is provided in warehouse;
- One (1) x 100% capacity summer hot water supply pump is installed and one (1) backup summer hot water supply pump with the same capacity is provided in warehouse.

In winter conditions two (2) winter hot water supply pumps are operating simultaneously. In winter conditions the following are received to suction header of hot water supply pumps:

- Return hot water from consumers;
- Water after makeup pumps plus heating water after DV-300;
- Hot water make-up water chemically treated and heated by plate heaters

Water from discharge header of hot water supply system pumps is received to general inlet header before HHSW. Capability and number of makeup pumps are accepted in accordance with paragraphs 5.22, 5.23 of KMK 2.04-07-99 “Heating systems” as well as according to the paragraph 11.8 of Departmental standards of process engineering 81 “Process engineering standards of thermal power plants”:

- Two (2) winter make-up pumps where one is operating and another is standby;
- One (1) summer make-up pump.

In winter conditions or in summer period of peak load one winter makeup pump is in operation. The second pump is in standby condition. Summer makeup pump is intended for operation within off-peak periods of hot water supply. Water from deaerator tank (deaerated chemically treated water plus heating water after DV-300) at 70°C is received to suction header of makeup pumps. Water at 70°C is received to suction header of hot water supply pumps from discharge header of makeup pumps. Two water-jet ejectors (hereinafter as WJE) are used as gas-suction unit for VD, one as operating and one as standby. Widespread closed circuit of water-jet ejectors is used. Power water is supplied to ejectors by special pumps of power water NRV-1, NRV-2 with constant pressure head.

In normal conditions, one ejector and one pump of power water are in operation. In this case the second ejector and second pump are standby. After suction and condensation of gas-vapor mixture, power water is returned to power water tank. For avoidance of power water overheating, its cooling is provided in plate-type heat exchanger which functions as cooler of power water. Raw water serves as cooling medium in cooler which is supplied to water treatment plant from raw water pumps.
Additional cooling of power water is carried out by raw water makeup of power water tank for making up of its losses. Part of the water from header of direct hot water supply system water at 110°C is supplied to inlet of plate-type heater as heating medium for heating of raw water before water treatment plant (heater of raw water – HRW).
For providing of hot water circulation, two recirculation pumps are provided for its heating in summer conditions, one as operating, and one as standby.
In summer conditions one (1) recirculation pump is in operation.
In summer conditions the followings are received to suction header of recirculation pumps:

- Hot water chemically treated and heated to 60°C by plate-type heater;
- Raw water heated to 60°C by plate-type heater;
- Water after makeup or hot water supply system pumps (depending on required pressure head in hot water supply system of consumer);
- Make-up water deaerated and heated to 70°C by DV-300.

Water from discharge header of recirculation pumps is received to general inlet header before HHSW according to special collected summer scheme. In summer conditions one (1) of four (4) HHSW is in operation.
After heating in HHSW up to 110°C, hot water is branched to Hot water supply general header from operating HHSW.
Part of the water at 110°C from the supply header is supplied through pipeline to column of vacuum deaerator as heating medium. Another part of the water at 110°C is supplied through pipeline to plate-type heater of chemically treated water before vacuum deaerator and to plate-type heater of raw water.
Water for hot water supply (HWS) of consumer is supplied after makeup or hot water supply system pumps (depending on required pressure head in hot water supply system of consumer) at design temperature of 70°C. Water to HWS may be supplied both through direct and through return pipeline of main hot water supply system.

Description of the main processing equipment layout
Boiler house with deaerator of hot water supply system and other auxiliary equipment is directly adjoined to turbine hall of steam turbine.

All pumping equipment is located at the mark of 0.000 of boiler house.

- Hot water supply system pumps for winter conditions (position 2) are longitudinally placed – 2 pumps;
- Hot water supply system pump (position 1) for summer conditions is longitudinally placed;
- Makeup pumps (position 4) for makeup in winter conditions and summer conditions of extensive flow for HWS are longitudinally placed – 2 pumps;
- Makeup pump (position 3) for makeup in summer conditions within off-peak period of HWS is longitudinally placed – 1 pump;
- Recirculation pumps (position 12) for summer conditions are transversally placed – 2 pumps;

- Condensate pumps (position 13) for pumping out of condensate of heating steam from HHSW are longitudinally placed – 2 pumps;
- Power water pumps (position 5) are longitudinally placed – 2 pumps;

The following processing equipment is located at the mark of 0.000:
- Water-to-water plate-type heat exchanger (position 11) for power water cooling of ejectors and simultaneous preheating (first stage) of raw water further to be supplied to HRW;
- Water-to-water plate-type heat exchanger (position 15) for heating of raw water – HRW for its subsequent supply to water treatment plant;
- Power water tank (position 6) for power water pumps of ejectors.

Four (4) vertical heaters of hot water (position 10) are installed at the mark of 9.000 of hot water heater house. The following processing equipment is installed at the mark of 18.00 of hot water heater house:

- Column vacuum deaerator (position 7) with deaerator tank (position 8);
- Water-jet ejectors (position 9) – 2 ejectors;
- Water-to-water plate-type heat exchanger (position 14) – heater of chemically treated water before vacuum deaerator.

Installation of hoisting device is provided for carrying out of repair and maintenance work – supporting bridge crane with lifting capacity of 12.5 tonnes based on weight of detachable part of HHSW.

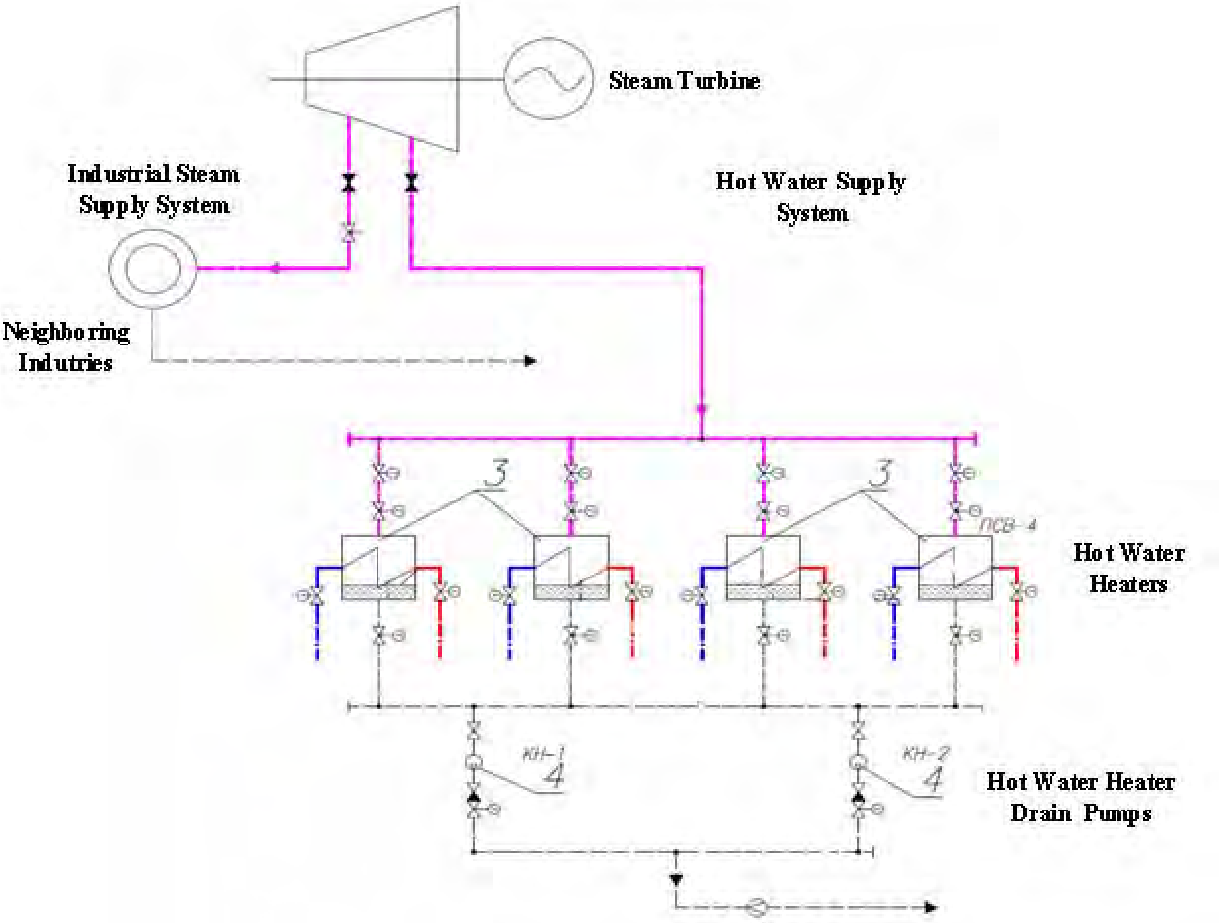


Figure 6.4.4-1 Flow Diagram of Steam and Condensate for Heat Supply System

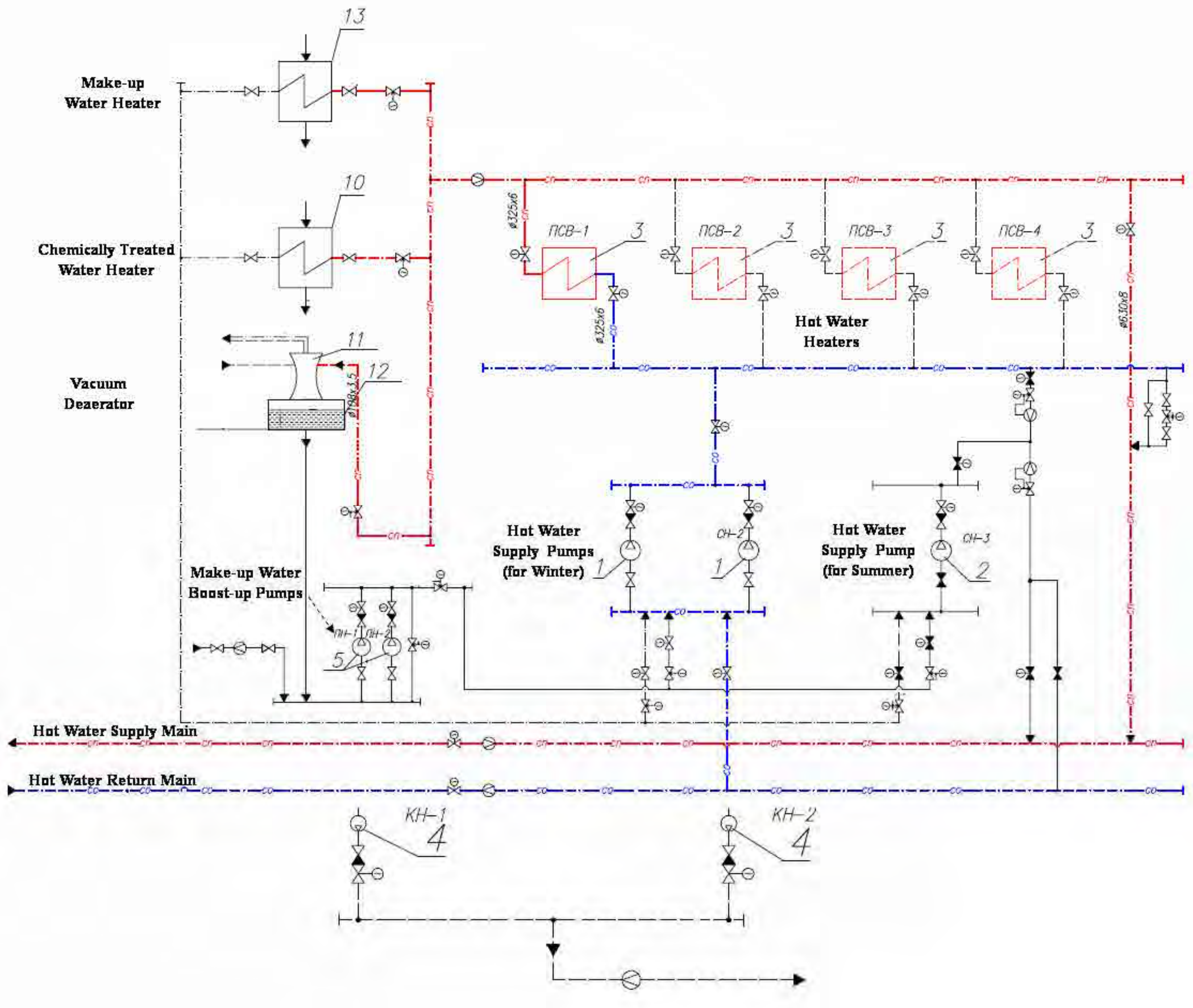


Figure 6.4.4-2 Flow Diagram of Heaters and Water Pipes for Hot Water Supply System

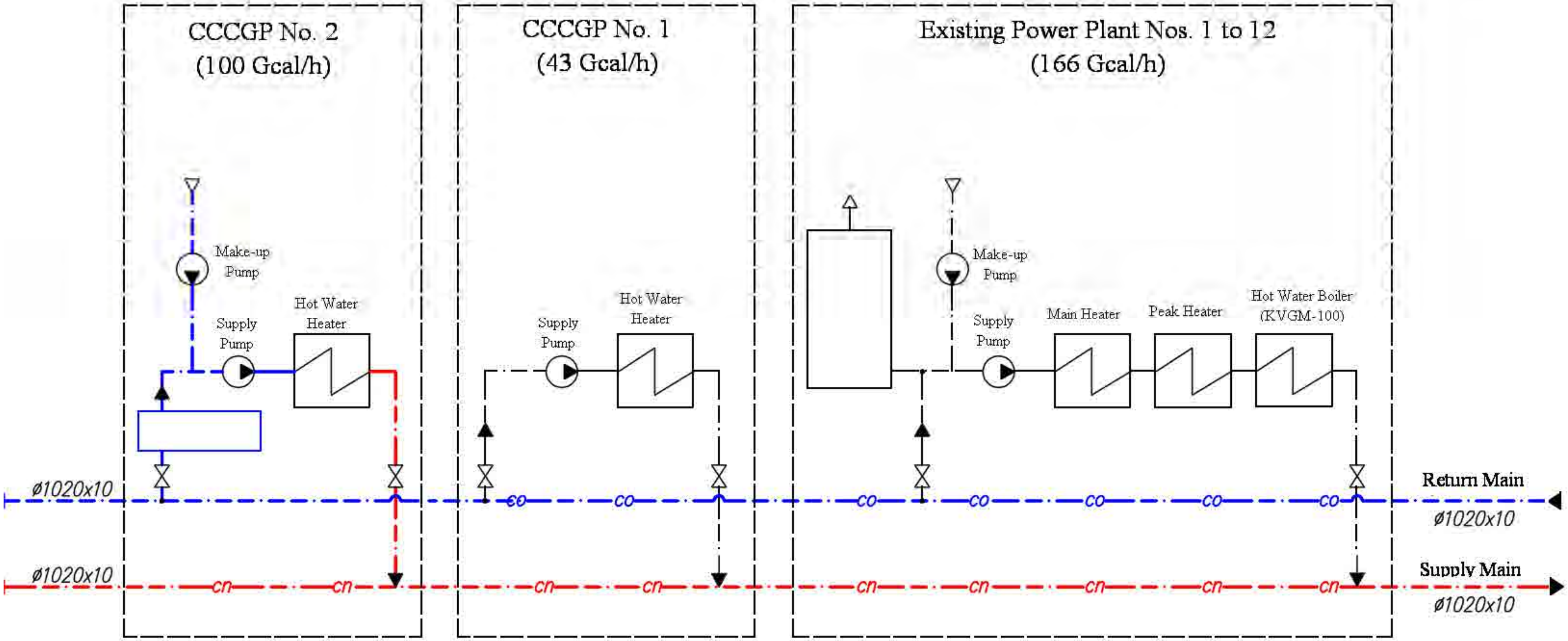


Figure 6.4.4-3 Block Diagram of Connections for Hot Water Heaters for CCCGP No. 2 and Existing Hot Water Mains

6.4.4.2 Water Treatment System for Hot Water Make-up

(1) General

A complete water treatment system shall be provided, comprising one set of water pre-heater, two trains of uniflow H-Na-cation exchangers, decarburizer, and auxiliary equipment and water storage tanks to supply the make-up water required for the hot water supply system of CCCGP No. 2.

Regarding the industrial steam make-up water, it is provided as make-up water for the steam turbine and HRSG cycle through the demineralized water plant described in Section 6.4.5 “Water Treatment System”.

Raw water for water treatment system shall be drawn from the main piping of town water supply system. A typical analysis of raw water (town water) is as shown in Table 6.4.4-3.

Table 6.4.4-3 Chemical Analysis of Raw Water (town water)

Description of parameter	Molecular weight or in conversion per 1 mole (kg/kmol)	Minimal value		Maximal value	
		mg/l	mg-eq./l	mg/l	mg-eq./l
Alkalinity	-	-	3.2	-	4.4
Dissolved solids	-	1300	-	2000	
Total hardness		-	11.9	-	18
Bicarbonates	61.02	195.2	3.2	268	4.4
Chlorides	35.48	77.9	2.2	110.0	3.1
Sulfates	48.03	500	10.41	680	14.16
Nitrates	62.01	6.0	0.1	10.4	0.17
Calcium	20.04	107	5.34	200	9.98
Magnesium	12.16	83.9	6.9	96	7.9
Sodium	23.0		3.59		
Iron total	56.0	5.0			
SiO_2^-		8.3		13.0	
pH		8.3		8.3	

The hot water shall conform to requirement of Russian National Standards GOST 2874-82 “Drinking water. Hygienic requirements and quality control” as well as the requirements of RD 34-37-10-504 for water of hot water supply system as shown in Table 6.4.4-4.

Table 6.4.4-4 Requirements of Hot Water

Description of parameter	Required Value	Codes and Standards
Alkalinity	0.7 to 1.5 mg-eq./l	GOST 2874-82
Hardness	< 7 mg-eq./l	“
Heated up temperature	Up to 110°C in hot water heaters	RD 34-37-10-504
Carbonate index	3 mg-eq./l	“

(2) System Description of Water Treatment Plant

The version of operating scheme of water-treatment plant shall be parallel H-Na-cation-exchange of raw water followed by decarburization of general flow. In selection of treatment method the required amount of H-cationic water and Na-cationic water shall be taken into account for their mutual neutralization based on alkalinity index of the raw water followed by decarburization of overall flow treated by cationic water.

The plant is intended for water treatment of hot water supply system makeup with open water pumping. The chemical composition of raw water is given in Table 6.4.4-1. Plant capacity based on auxiliaries is 223.0m^3/h.

Water treatment is carried out according to the scheme: uniflow H-Na-cation exchange, and decarburization. This scheme provides scale-free operation of hot water heaters by margin of calcium sulfate solubility and carbonate index.

In the period of high heat loads, design water temperature in hot water heaters based on heat development and near-wall boiling will be 150°C (110° + 20° + 20° = 150°). For preventing calcium sulfate deposit 16.9% of water is exposed to H-cation exchange and 83.1% of water to Na-cation exchange followed by decarburization of overall water mix. In this case product solubility of calcium sulfate will be PSCaSO4 = 1.05 x 10-6 (mg-eq./l) and equals to tolerable PSCaSO4 for 140°C temperature.

Structurally the plant consists of six (6) Na-cation-exchange filters: (four (4) in operation, one (1) in standby, one (1) under repair), three (3) H-cation-exchange filters (one (1) in operation, one (1) in standby and one (1) under repair).

Water treatment plant is located in the main building and consists of the following premises:

- Filtering room with filters of water treatment plant for hot water makeup;
- Two pumping lines where all pumping outfit is installed.
  Heater of raw water is installed in the main hot water heater house.
- Gauge tanks are mounted on stacks, level is 5.0 m.
- External tank facilities

(3) Layout of Water Treatment Plant for Hot Water Makeup

Raw water from consolidated power system of Navoi Mining and Metallurgical Complex flows to tank of raw water (position 1) with 400 m^3 capacity and then supplies to suction pumps of raw water (position 2). Pump thrust is 62 m of water column with 300 m^3/h capacity. Line of recirculation pumps is planned for flow control of raw water to be supplied to raw water tank.

Line from raw water pumps is provided for filling of washing water tanks of Na-cation-exchange filters (position 21).

Then water supplies to heat exchanger (position3) which is located in boiler house for heating up to 35°C. Heated water in the control unit is separated into two flows: 16.9% of water supplies to H-filters and 83.1% of water to Na-filters.

Both flows of softened water are combined in pipeline and supplied to decarbonator (position 9). Further the water is collected in decarbonated water tank with 250 m3 capacity (position10) where pumps for decarbonated water (position 11) are pumped to vacuum deaerator at the mark of 18. Line of decarbonated water has adjustable branch pipe to salt warehouse for preparation of regenerant solution as well as recirculation line of decarbonated water pumps to decarbonated water tank (position 10).

Dosing unit of regenerant saline solution consists of two gage tanks with 10 m^3 capacities each (position 4) and two pumps for salt (position 5) (pump capacity – 50 m^3/h, head – 32 m of water column).

Gage tanks have: control unit for supplying of 6% saline solution from the warehouse of salt depending on their operation; discharge and pouring pipe directed to drainage pit with 18 m3 capacity (position 20).

Salt feeding pumps are equipped with recirculation line (self adjustable) directed to gage tanks.

Recovery of Na-cation exchange filters is uniflow, regenerant solution – 6% saline solution.

Recovering waters and 25% of washing waters of Na-cation exchange filters are received to drainage pit (position 20) and simultaneously pumped out to equipment set for processing of industrial drain by pumps of drain water of Na-cation exchange filters (position 19) (pump capacity – 50 m^3/h, head – 32 m of water column), and the remaining 75% of washing waters are sent to washing water tank of Na-filters (tank volume 160 m3) (position 21). Scheme of washing water tanks of Na-filters is provided for capability of washing water reuse for loosening of Na-filters by loosening pumps of Na-filters (position 22) (pump capacity – 160 m^3/h, head – 30 m of water column) followed by water accumulations after loosening and pumping them out by above mentioned pumps to feeding line to clarifier or to equipment set for processing of industrial drain.
Pumps of backwash water (position 22) have self adjustable recirculation line to washing water tanks of Na-filters (position 21).

Recovering of H-cation exchange filters:
Recovering unit of H-cation exchange filters consists of: gage tank of concentrated sulfuric acid (92%) with 1 m^3 capacity (position 6), two dosing pumps (position 7) (pump capacity – 400 l/h, head – 16 kg-force/cm). Gage tank of sulfuric acid (92%) has a pouring and discharging line directed to drainage pit of H-filters (position 16) with 18 m^3 capacity. Filling of gage tank by sulfuric acid is carried out by pumping-over of sulfuric acid from ibc-container once per day. Dosing pumps of sulfuric acid have recirculation line which is directed to gage tank of (92%) sulfuric acid. Dosing of the acid is carried out for general recovering header to which the decarbonated water is simultaneously supplied by pressure pumps (position 8) (pump capacity – 100 m^3/h, head – 32 m of water column) from decarbonated water tank with 250 m^3 capacity (position 10).
Recovering of H-cation filters is uniflow. Recovering acid solution is fed by portions with 0.3%, 0.6%, 1%, 3% and 6% concentrations. The first two portions of the acid with 0.3% and 0.6% concentrations after regenerant filter are received to drainage pit with 18 m3 capacity (position 16) and simultaneously pumped out by drainage pumps of H-filters (pump capacity – 50 m^3/h, head – 32 m of water column) (position 15) to equipment set for processing of industrial drain. The remaining three portions of the acid with 1%, 3% and 6% concentrations after regenerant filter and part of the washing water are collected in tank for loosening of H-filters with 100 m^3 capacity (position 17) for reusing, i.e., for loosening of H-filters by loosening pumps of H-filters (pump capacity – 200 m^3/h, head – 32 m of water column) (position 14). The major part of the washing water is collected to washing water tank of H-filters with 250 m^3 capacity (position 18) to which the waters after loosening of H-filters are also collected where the scheme is provided for pumping out of these waters by group of pumps stated above to equipment set for processing of industrial drain or to feeding line of water to clarifier. Loosening pumps of H-filters (position 14) have self adjustable recirculation lines to a loosening tank of H-filters (position 17) and a washing water tank of H-filters (position 18).

6.4.5 Water Treatment Plant

(1) General

A complete water treatment system comprising water settling ponds, water pre-treatment plant and demineralized (DM) water plant to supply the make-up water required for the steam turbine and HRSG cycle of CCCGP No. 2 shall be provided.

Since the industrial steam is extracted from the steam turbine and consumed in the neighboring chemical companies, its make-up water needs to be provided through the demineralized water plant.

On the other hand, the make-up water of hot water, of which water quality is different from that of the demineralized water, shall be provided through the other water treatment facilities in the hot water supply system as described in Section 6.4.4 "Heat supply system".

Raw water for water treatment system shall be drawn from Zarafshan River. The result of water quality survey of the river water is shown in Section 8.1.2 "Table 8.1.2-1 Comparison of water quality in Zarafshan River with the environmental standard".

(2) Scope of Work

The scope of work shall include design, manufacturing, supply, delivery to site, installation at site, commissioning and testing of complete water treatment system comprising the following:

1) Settling ponds comprising two (2) sets x 100% capacity ponds, two (2) sets x 100% capacity raw water pumps and two (2) sets x 100% capacity sediment removing equipment.
2) Water Pre-treatment (Filtration) Plant comprising two (2) sets x 100% capacity raw water pumps, two (2) streams x 50% capacity multi-media filters (2 x 530t/h), two (2) sets x 100% capacity backwash pumps, two (2) sets x 100% capacity blowers for filter air scouring, and one filtered water storage tank to store filtered water required for backwash.
3) Demineralization Plant comprising two (2) set x 50% capacity activated carbon filters (ACF) with 10 micron cartridge filter, and two (2) streams x 50% capacity demineralizers (2 x 480t/h) including resins, and two (2) DM water storage tanks (2 x 34,000m^3), and two (2) x100% capacity DM water transfer pumps
4) Chemical regeneration system including storage tanks, regeneration pumps backwash tower and measuring equipment.
5) Pipe work and valves, supports, fittings and interconnections.
6) Electrical equipment.
7) Instrumentation and control system.
8) Instrument air supply system.
9) Spare parts required for two year operation and specified in the specification
10) Special tools and standard tools set

(3) Applicable Standards and Codes

The water treatment plant shall be designed and constructed in accordance with the requirements of international standards and codes.

(4) Design and Performance Requirements

1) Capacity of water treatment plant

The consumptions of demineralized water and pre-treated water are estimated as 19,050m^3/day and 20,990m^3/h respectively. The consumption of the Zarafshan River water is 20,990t/day for this treatment plant. On the other hand, the consumption of the city water (tap water) is 6,000t/day for the hot water make-up water of CCCGP No. 2. The break downs are as shown as following:

i) Demineralized water consumption

Industrial steam supply capacity shall be 100 Gcal/h (13 ata, 300 ºC, 140.4t/h). Cycle loss shall be taken account as much as 4% of main steam flow.

The make up water for the mechanical draft wet type cooling tower 560t/h shall be provided from the demineralized water, since the river water contains dissolved solid exceeding the allowable limit and the pretreated water is not applicable for the make-up water.

Table 6.4.5-1 Demineralized water consumption

Item	Unit	Consumption	Remark
Industrial steam	t/day	3,370	13ata x300ºC, 100Gcal/h 140t/h
Steam cycle loss	t/day	450	Max 4 % of main steam
Closed cooling water	t/day	30	1.0t/h
Cooling tower	t/day	13,440	560t/h
Miscellaneous	t/day	20	
Demineralizer washing	t/day	1,740	10 % of the above total
Total	**t/day**	**19,050**	**794t/h**

ii) Service water consumption
Make up water for the mechanical draft wet type cooling tower is estimated as 440t/h.

Table 6.4.5-2 Service water consumption

Item		Consumption	Remark
Demineralized water	t/day	19,050	From item i) above.
Miscellaneous	t/day	30	
Pre-treatment washing	t/day	1,910	10 % of the above total
Total	**t/day**	**20,990**	**875t/h**

iii) Hot water consumption (for reference)
The total consumption of hot water in Navoi city is estimated as 26,400t/day, among which 6,000t/day shall be provided from CCCGP No. 2 and the remainder will be provided from the existing Navoi Thermal Power Plant. Since the tap water will be treated and supplied to the hot water system, the make-up water shall be provided from the other water treatment plant using the Navoi city water as a raw water. He details of the system are as described in Section 6.4.4 “Heat supply system”.

Table 6.4.5-3 Hot water consumption

Item	Max	Winter	Summer	Remark
Supply water	6,500 t/h	5,800 t/h	850t/h	
Return water	5,400 t/h	4,700 t/h	0t/h	
Consumption	1,100 t/h 26,400t/day	1,100 t/h 26,400t/day	800~900t/h	
Make-up water by CCCGP No. 2	250t/h 6,000t/day			Max. 100Gcal/h

iv) Capacity of water treatment plant
The capacity of each water treatment plant shall be determined based on the operating time of twenty (20) hours a day excluding regenerating or cleaning time of four (4) hours a day.

Table 6.4.5-4 Capacity of water treatment plant

Item	Pretreatment	Demineralizer	Remark
Consumption	20,990t/day	19,050t/day	
Operating hour	20h/day	20h/day	
Required capacity	1,050t/h	953t/h	
No. of Train x Capacity	2 x 50%	2 x 50%	
Selected capacity	**2 x 530m^3/h**	**2 x 480 m^3/h**	

v) Capacity of Treated Water Tank
The capacity of each water storage tank shall be determined taking account of three days storage and effectiveness factor of 0.85.

Table 6.4.5-5 Capacity of water storage tank

Item	Unit	Service water	Demi water	Potable water	Fire Tank
Water Flow Rate	t/day	20,990	19,050	45	-
Storage day	day	3	3	3	-
Effective storage capacity	m^3	62,970	57,150	135	1000
No. of tanks	**tank**	**2**	**2**	**1**	**1**
Capacity per tank	**%**	**50**	**50**	**100**	**100**
Effective capacity	m^3/tank	31,485	28,575	135	1,000
Effectiveness factor	-	0.85	0.85	0.85	0.85
Required storage capacity	m^3/tank	37,041	33,618	159	1,176
Selected storage capacity	m^3/tank	**38,000**	**34,000**	**160**	**1,200**

Water balance of CCCGP No.2 is as shown in Figure-6.4.5-1 attached hereinafter.

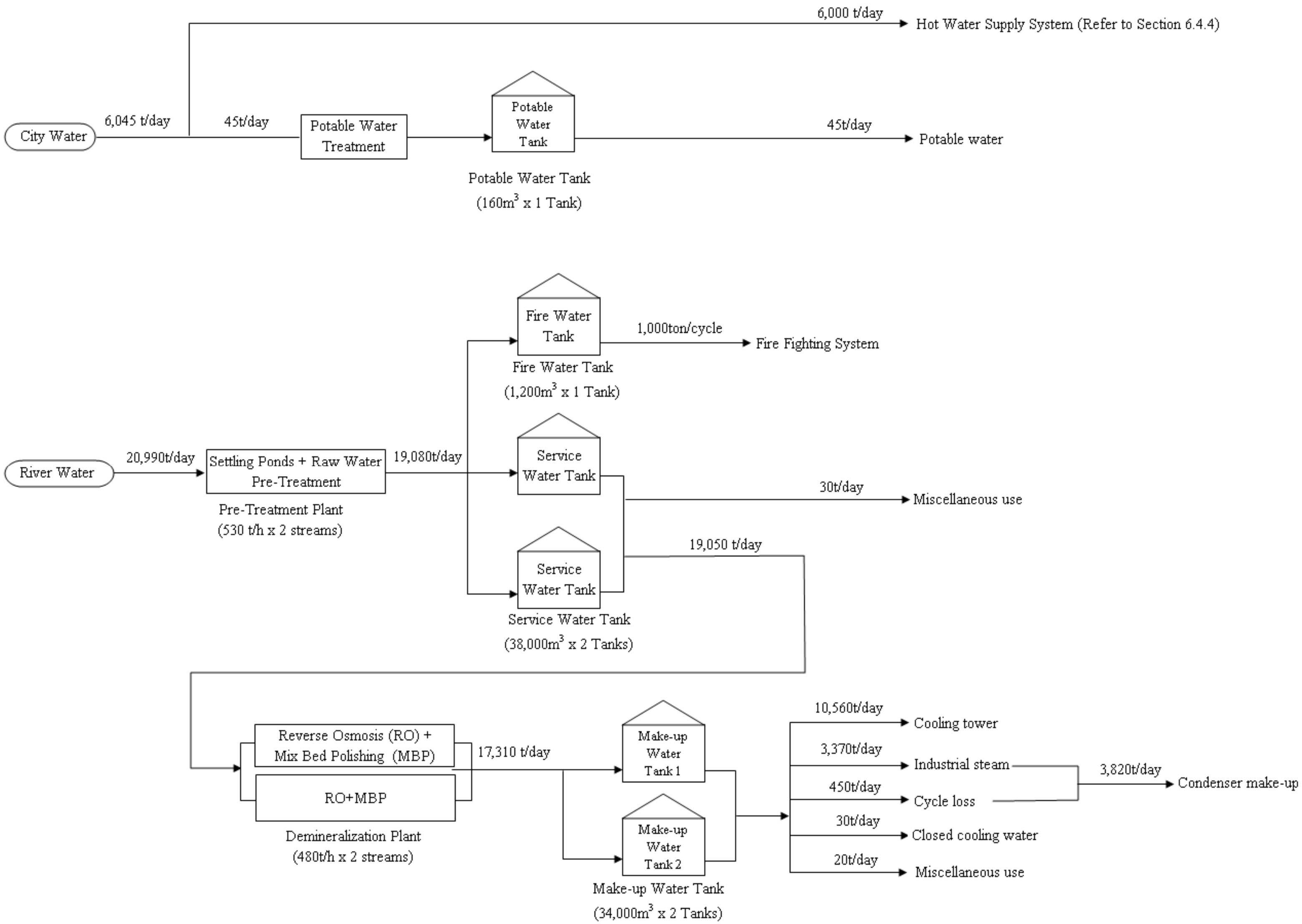


Figure 6.4.5-1 Water Balance of CCCGP No. 2

2) Water Pre-treatment (Filtration) Plant

The water filtration system consists of a rapid filtering device, various pumps, blowers, pipes and valves. This system shall be capable of removing non-reactive (colloidal) silica effectively from the raw water.

Due to the presence of free chlorine in the raw water, the chlorine scavenging chemical dosing equipment shall be provide, which is capable of treating raw-water with a maximum chlorine level less than 0.1 mg/l.

The water pre-treatment plant components shall include provision for the following:

- The clarity of water treated by the filtered water plant shall be below 1 mg/l.
- Two (2) sets of 100% duty each raw water pumps shall be installed. The capacity of each pump shall have a margin to keep the service water production capacity of two (2) streams x 370t/h.
- The type of the filter shall be cylindrical, vertical, mild steel (designed per ASME standard), rubber coating inside, gravity or pressure dual media sand-anthracite filters.
- Two (2) sets of filter air blowers (each 100% duty) shall be equipped for filter air scouring.
- Puddle pipes and fittings for filtered water sump shall be constructed in reinforced concrete.
- Two (2) sets of 100% duty each filter backwash pumps shall be installed.
- Filter water tank with appropriate capacity shall be installed for backwashing of filters.

3) Demineralized Water Plant

The demineralized water stream will consist of reverse osmosis system (RO) and mixed bed polishing system (MBP) (or cation tower, anion tower, mixed bed polisher, vacuum degasifier, regeneration system), pumps, tanks, and pipes.

The demineralized water plant shall have two (2) streams with each production capacity of 480m^3/hr.

The period between regenerations shall not be less than twenty (20) hours, and the regeneration period shall be less than four (4) hours.

The raw water quality shall be taken account of in the design of the Demineralizer plant.

Under all operating conditions the plant shall produce water equal to or better than the specified quality for the boiler feedwater, which shall be as follows:

Table 6.4.5-6 Quality of demineralized water

Item	Unit	Demineralized Water
Conductivity	µs/cm @ 25ºC	Max. 0.2
Total Silica	mg/l	Max 0.02
pH	-	-
Suspended Solids	mg/l	-
Turbidity	Degree	-

Item	Unit	Demineralized Water
Total Fe	mg/l	Max 0.01
Total Cu	mg/l	Max 0.005
CO_2	mg/l	Max 2
Cl^-	mg $CaCO_3$/l	-
SO_4^{-2}	-	-
TDS	mg/l	-
Residual C1	mg/l	-
Sodium and Potassium	mg/l	Max 0.01

The equipment to be supplied for Demineralizer shall have the design features as the following in the case of ion exchange system:

i) Activated carbon filter with 10 micron cartridge filter
   Quantity: Two (2) nos.
ii) Cation Tower (Vessel)
   Quantity: Two (2) towers
   Tank: Fabricated mild steel, rubber lined
   Capacity: 50% duty
   Type: Cation exchanger, cylindrical, vertical, counter flow
   Resin: Strongly acidic cross-lined styrene-divinyl-benzene or macroporous structural type
iii) Anion Tower (Vessel)
   Quantity: Two (2) towers
   Tank: Fabricated mild steel, rubber lined
   Capacity: 50% duty
   Type: Anion exchanger, cylindrical, vertical, counter flow
   Resin: Strong base acrylic based Type 1
iv) Polisher
   Quantity: Two (2) towers
   Tank: Mild steel, rubber lined (design to be the same as for cation and anion vessels)
   Type: Ion exchanger cylindrical, vertical
   Resin: Macroporous structured/strongly basic type 1 cross-linked styrene-divinyl-benzene type

The cation and anion towers (vessels) shall be fabricated from carbon steel and shall be of welded construction designed in accordance with ASME code for unfired pressure vessels. The design pressure shall be 50% in excess of the shut-off head of the demineralizer transfer pump.

The vessel shall be lined internally with a suitable rubber to a minimum thickness of 3 mm to cover all surfaces, nozzles and flange faces.

The vessel shall be complete with all nozzles and fittings necessary for the process and shall include:

i) One (1) manhole located at top of vessel
ii) One (1) manhole located at bottom of vessel
iii) One (1) sight glass located at top of resin level (150mm diameter minimum)
iv) One (1) drain connection

v) One (1) vent connection
vi) Two (2) blind nozzles for resin removal

Sight glasses shall be located such that easy access is available to allow clear visibility of the resin.

The vessel shall be equipped with the distribution and collection systems. The under drain collection system shall be designed to prevent resin from entering the treated effluent.

i) Degasifier
Quantity: Two (2)
Capacity: 100% each
Type: Cylindrical and vertical, fabricated from mild steel, rubber lined

The system shall use a blower with motor driven to degasify carbon dioxide. The exhaust gas shall be led outside of the demineralizer house.

ii) Degassed Water Pit
Quantity: One (1) pit each
Capacity: As required

iii) DM Water Transfer Pump
Quantity: Two (2) pumps
Capacity: 100% duty each
Type: Horizontal, motor driven

iv) Demineralized Water Storage Tank
Quantity: Two (2) tanks
Capacity: 7,000 m^3 (minimum)
Type: Cylindrical, vertical epoxy lined carbon steel

The capacity of the storage tank shall be computed based on the three (3) days supply requirement. However the storage capacity of the tank shall be at least 7,000 m^3.

v) Low Pressure Air System
Quantity: Three (3) sets including low pressure air blowers, separator and controls for resin mixing and compaction.

vi) Instrument Air
Instrument air receiver with necessary distribution of instrument air (tapped off from station instrument air header for valve control). Dedicated compressed air system should be considered alternatively for the DM plant.

vii) Backwash Tower
In case the resins of the cation/anion filters need to be cleaned (backwashed) the same cleaning shall be carried out in the backwash tower using the regeneration pumps. The backwash filter and interconnecting piping shall be included in his scope of work.

4) Chemical Regeneration Plant

A complete chemical regeneration plant shall be provided to regenerate the demineralized water plant. The regeneration waste water shall be stored in the regeneration neutralization pit and discharged to the high salt side of the effluent storage tank by the demineralizer neutralization pumps. The equipment to be supplied shall include the following:

i) HCl/H_2SO_4 (98%) Storage Tank
Quantity: Two (2) tanks
Capacity: For 3 days each
Type: Cylindrical, horizontal, carbon steel

ii) HCl/H_2SO_4 Measuring and Dilution Tank (Demineralizer)
Quantity: Two (2) tanks each
Type: Cylindrical, vertical carbon steel for measuring tank and rubber lined carbon steel for dilution tank

iii) HCl/H_2SO_4 Measuring and Dilution Tanks (Mixed Bed)
Quantity: Two (2) tanks each
Type: Cylindrical, vertical, carbon steel for measuring tank and rubber lined carbon steel for dilution tank.

iv) NaOH (47%) Storage Tank
Quantity: Two (2) tanks
Capacity: For 3 days each
Type: Cylindrical, horizontal, carbon steel

v) NaOH Measuring Tank (Demineralizer)
Quantity: One (1) tank
Type: Cylindrical, vertical, carbon steel

vi) NaOH Measuring Tank (Mixed Bed)
Quantity: One (1) tank
Type: Cylindrical, vertical, carbon steel

vii) Regeneration Pumps (H_2SO_4/HCL)
Quantity: Two (2) pumps each
Capacity: 100% duty each
Type: Horizontal, motor driven

viii) Regeneration Pumps (NaOH)
Quantity: Two (2) pumps
Capacity: 100% duty each
Type: Horizontal, motor driven

ix) Heating Device for NaOH Solution
Quantity: Two (2) for anion tower
Two (2) for polisher

Extreme care shall be taken to ensure the design and layout of the equipment is so arranged that in the event of failure of any fitting or other item of equipment, there is no danger to the operating personnel.

The chemical storage, measuring and dilution tanks shall be installed within bunds. Each bund shall have valved drain lines to the neutralization pit. The drain lines in the foundations and the necessary valves shall be supplied. Since the chemical storage tanks shall be installed outside of the demineralizer house, a sunroof shall be provided.

Each chemical tank shall be supplied with the following fittings:

- i) Access ladders and platforms for storage tanks
- ii) Access manhole
- iii) Filling connection with suitable valves clearly marked
- iv) Drain valve and emergency plug discharge vent
- v) Vent with air dryer and by-pass
- vi) Thermostatically controlled heaters (if required)

(5) Instrumentation and Control

1) Operation Philosophy

Complete water treatment system equipment and auxiliaries shall be primarily operated and monitored from central control room (CCR). Plant shall also be locally operated and supervised from the local control room located in water treatment plant building.

Man-machine interfacing (MMI) of the plant from CCR shall be through CRT/keyboards of the two (2) nos. operator workstations identified for all BOP systems. MMI equipment in local control room shall be CRT/keyboard based operator console.

Operation from CCR and local control room shall cover start-up, shutdown and normal operation of the complete water treatment plant.

2) Control System

Industry standard Programmable Logic Controller (PLC) shall be provided for accomplishing water treatment plant, control system. PLC shall be provided with processor level redundancy PLC shall be interfaced with redundant BOP terminal bus through redundant bi-directional communication link and also to local control room located operator console. BOP terminal bus shall be interfaced to CCR located BOP operator workstations by redundant link through redundant station wide LAN.

Redundant non-interruptible power supply shall be provided for all control system equipment. PLC shall be provided with processor level redundancy. PLC shall have spare processing capacity.

Engineer’s workstation for system modification of PLC shall be provided. Engineer’s workstation shall have the capability to make changes to the system configuration while the plant is on-line. Engineer’s workstation will be common for all BOP control system PLCs.

PLC, Engineer’s workstation, etc. shall be located in the water treatment plant local control room along with operator console and the room shall be air-conditioned.

3) Specific Control System Requirement

The water treatment system shall be fitted with the following control devices.

i) Level control system of each tank

Level control system of each tank is consisting of a level detecting element, level indicator, and their accessories. This system performs operation and control for transfer of material from each tank. The level detecting element must be easy to maintain, stable of action, and free from malfunction due to adhering impurities. It also must be highly anticorrosive.

ii) Demineralizer control system

The plant shall be capable of full automatic operation on manual initiation. Provision for semi automatic control and manual operation of individual motors or valves should be included. Each section of the ion exchange plant shall be capable of automatic sequence control initiated by remote operator command. This control shall include regeneration, filter backwashing and the preparation of regenerants.

The control shall have interlocks such that no mode of operation can be initiated unless the existing mode completes its cycle or is stopped by operator manual override.

The level in the demineralized water storage tank shall determine the control of the plant. In particular, high water level of the demineralized tank and low water level in raw water reservoir shall be annunciated and shall shut down the plant.

The automatic sequence operation during plant start-up shall provide for water recycling to achieve the specified quality of treated water before discharging into the demineralized water storage tanks. In the event that the water quality has not reached the specified quality within a specified time the plant shall not discharge any water and initiate an alarm.

Regeneration of the exhausted resins shall be carried out by automatic sequence operation. Regeneration of each steam will be initiated automatically by the passage of a predetermined volume of water or when the conductivity analyzer show demineralized, water is outside the acceptable quality range. The regeneration of the cation and anion units is simultaneous, in order that the effluents produced are nominally self-neutralizing.

The conductivity analyzer will be located above the bottom of the anion beds. Once the bed starts to become exhausted, the conductivity analyzer indicates a higher conductivity level and will start the regeneration process. The resin volume below the conductivity probe is not exhausted and ensures the water at the outlet is within the required quality range.

Control system shall allow the option to regenerate the ion exchangers individually or in-groups to match system loading. The regeneration rinse/recycle system will be optimized to reduce wastewater production. All necessary initiating devices, instrumentation and control equipment for automatic operation of regeneration cycle shall be provided under this Contract.

The sequence controllers shall permit the length of any filter air scour/backwash and ion exchange regeneration sequence to be varied without the need to reprogram the remainder of the process. Facilities shall be provided for manual overriding of the automatic sequence at any stage.

The cation and anion regeneration sequence controller shall include provision for giving the ion exchange resins a full backwash as part off the regeneration process after a number of normal exhaustion regeneration cycles. Facilities shall be provided to automatically include the full backwash sequence after a variable number of exhaustion and regeneration cycle and also for the operator to manually initiate a backwash at their discretion.

The sequence controllers shall also permit the inclusion of a double and triple regeneration to be given to the resin. This latter facility will be manually initiated at the operator's discretion.

Interlocks shall be provided to prevent any flow of concentrated regenerant solution unless there is a suitable flow of water.

Interlocks shall be provided to prevent initiation of the regeneration cycle unless the effluent sump is at low level.
The control system shall be capable of speed-up 'off-line' test. It shall be possible to manually step through each step in the sequence with the state of the output, appropriate to each step, being indicated whilst isolated from the plant and without reference to the plant input states.

4) Specific Instrumentation Requirement

i) Water analyzing apparatus

Treated water shall undergo a final check by this apparatus. The water analyzing apparatus shall be made up of the sampling system, silica, sodium and conductivity measuring apparatus, flow element, and other hand sampling/analyzing devices. When the stream is off, distilled water shall be supplied to these water analyzers.

ii) Pressure gauge

A pressure gauge shall be fixed at the outlet of each pump. The pressure gauge shall be water-proof as well as aseismatic, so that it is suited for outdoor use. The diaphragm and chamber shall be made of anticorrosive material. A method of installation shall be employed which will render it capable of absorbing vibration.

iii) The raw water discharging flow meter shall be provided.

iv) The minimum required instrumentation is shown in the Table blow.

Table 6.4.5-7 Instrumentation for Pre-treatment DM water plant

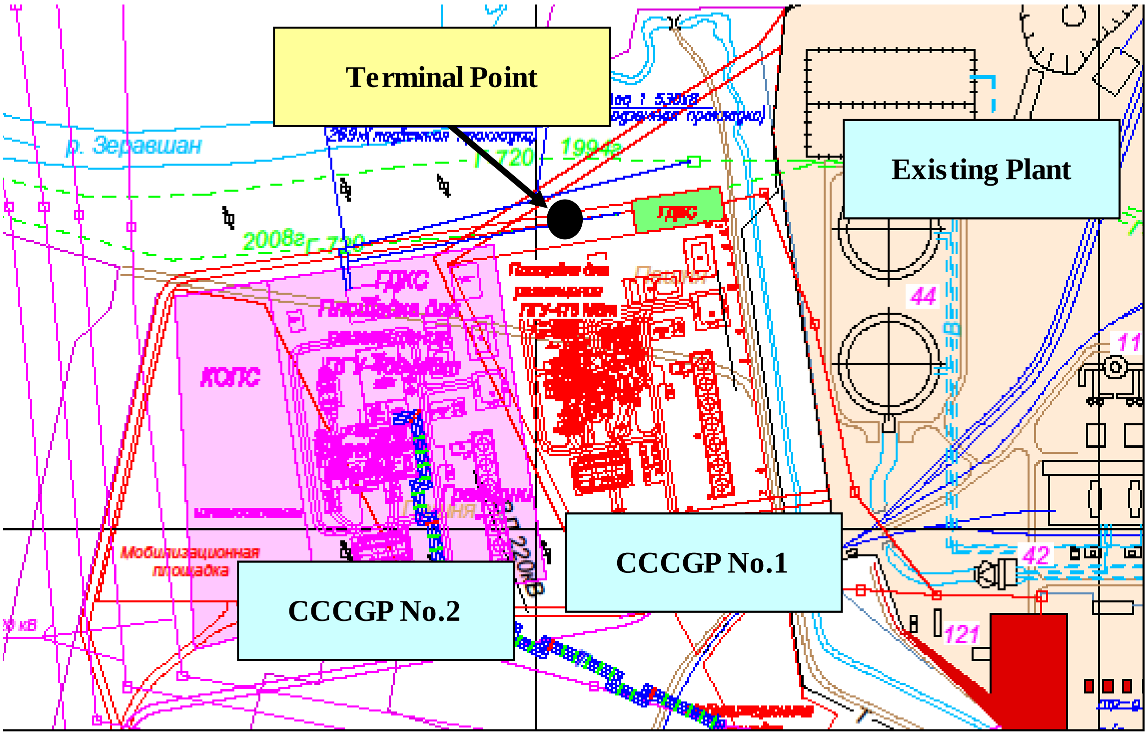
Measuring point	Parameter	Local monitoring	Remote	
			CCR/local control room	Functional usage
Raw water reservoir	Level	X	X	Indication, alarm
Inlet to each filtration vessel	Flow		X	Indication, alarm,

Measuring point	Parameter	Local monitoring	Remote	
			CCR/local control room	Functional usage
				control
Inlet to each filtration vessel	Pressure	X		Indication
Outlet from each filtration vessel	Pressure	X	X	Indication
Outlet from each filtration vessel	Differential pressure		X	Indication, alarm, control
Outlet from each filtration vessel	Clarity	X	X	Indication, alarm
Filtered water storage tank	Level	X	X	Indication, alarm, control
Backwash water	Flow	X	X	Indication
Backwash water	Pressure	X	X	Indication, alarm
Air to filter	Pressure	X	X	Indication, alarm
Inlet to each cation vessel	Pressure	X	X	Indication
Inlet to each cation vessel	Flow	X	X	Indication, alarm, control
Outlet from each cation vessel	Pressure	X	X	Indication
Outlet from each cation vessel	Differential pressure	X	X	Indication, alarm
Outlet from each cation vessel	Sodium		X	Indication, alarm, control
Outlet from each cation vessel	PH		X	Indication, alarm
Inlet to each anion vessel	Pressure	X	X	Indication
Inlet to each anion vessel	Flow	X	X	Indication, alarm, control
Outlet from each anion vessel	Pressure	X	X	Indication
Outlet from each anion vessel	Differential pressure	X	X	Indication, alarm
Outlet from each anion vessel	Conductivity		X	Indication, alarm, control
Outlet from each anion vessel	Silica		X	Indication, alarm, control
Outlet from each anion vessel	Ph		X	Indication, alarm
Inlet to each mixed bed vessel	Pressure	X	X	Indication
Inlet to each mixed bed vessel	Flow	X	X	Indication, alarm, control
Outlet from each mixed bed vessel	Pressure	X	X	Indication
Outlet from each mixed bed vessel	Flow	X	X	Indication, alarm, control
Outlet from each mixed bed vessel	Differential pressure	X	X	Alarm
Outlet from each mixed bed vessel	Silica		X	Indication, alarm, control
Outlet from each mixed bed vessel	Conductivity		X	Indication, alarm, control
Outlet from each mixed bed	Ph		X	Indication, alarm

Measuring point	Parameter	Local monitoring	Remote	
			CCR/local control room	Functional usage
vessel				
Resin traps	Differential pressure		X	Alarm
Dm water storage tank	Level	X	X	Indication, alarm, control
Rinse water to each vessel	Flow	X	X	Indication
Rinse water to each vessel	Pressure	X	X	Alarm
HCl/H_2SO_4 storage tank	Level	X	X	Indication, alarm
NaOH storage tank	Level	X	X	Indication, alarm
HCl/H_2SO_4 dilution & measuring tank	Level	X	X	Alarm
NaOH measuring tank	Level	X	X	Alarm
DM water transfer pump outlet (each)	Pressure	X	X	Indication
Ejector motive water	Pressure		X	Indication, alarm
Ejector motive water	Level		X	alarm

6.4.6 Fuel Gas Supply System

Natural gas is used as the fuel for CCCGP No.2 as well as CCCGP No.1. The natural gas is supplied to the Navoi Thermal Power Plant from the Navoi Gas Distribution Station (hereinafter referred to as "Navoi GDS") through two pipeline systems having a diameter of 720 mm.
The following describes the natural gas terminal point and terminal point supply conditions.



Source: Navoi TPP

Figure 6.4.6-1 Location of the terminal point

Table 6.4.6-1 Supply condition at the terminal point

Item	Unit	Value
Temperature	°C	-5 ~ 22
Pressure	MPa	1.0 ~ 1.2

Source: Navoi TPP

The natural gas is separated at the above-mentioned terminal point and is supplied to CCCGP No.2. After that, the natural gas is led to the pre-treatment system having a filtering function to remove foreign substances.
After the foreign substances have been removed, the natural gas is led to the fuel gas compressor so that the pressure is increased up to the level required at the inlet of the gas turbine. This required pressure level is approximately 3 through 5MPa although this value differs according to each gas turbine manufacturer. Since the operation of the gas turbine depends on the fuel gas compressor, it is recommended to install a total of two fuel gas compressors including one standby, similar to the case of CCCGP No.1.

6.4.7 Electrical Equipment

(1) Electrical System

1) Evacuation of Generating Power

Figure 6.4.7-1 shows the of generator main circuit.

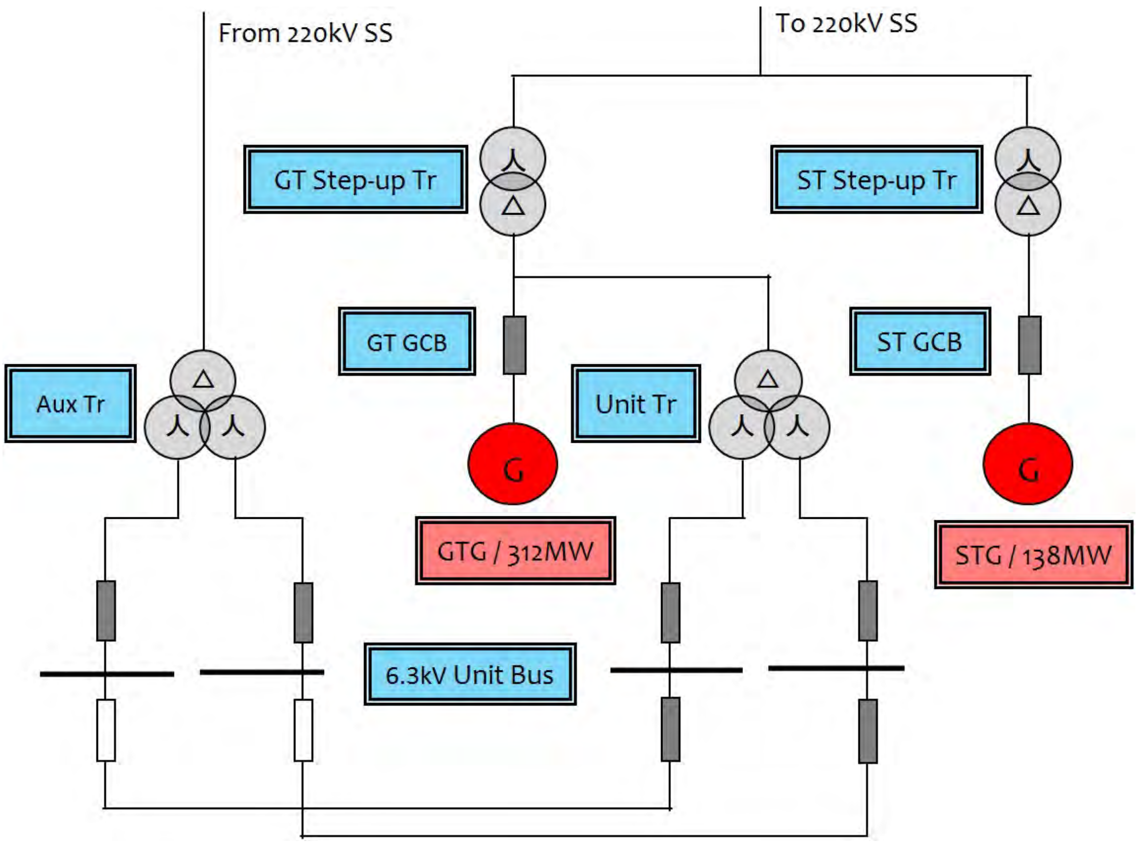


Figure 6.4.7-1 Scheme of generator main circuit

The electrical system will be designed on the basis of the multi shaft configuration having two (2) generators, Gas Turbine Generator (hereinafter called as “GTG”) and Steam Turbine Generator (hereinafter called as “STG”) and two (2) transformers, Gas Turbine step-up Transformer (hereinafter called as “GT transformer”) and Steam Turbine step-up Transformer (hereinafter called as “ST transformer”). The voltage of the power output from the GTG and STG will be stepped up to 220kV via GT transformer and ST transformer. The output from these two transformers is merged and transmitted to the 220kV substation. The bus switching arrangement utilizes double bus and one circuit breaker with transfer bus scheme.

During the unit operations, the power source to the unit auxiliary loads under 6.3kV unit bus will be fed from the GTG via unit transformer and 220kV substation via auxiliary transformer. During the unit shut down and the unit start-up, the power source to the unit auxiliary loads will be fed from 220kV substation via unit transformer and auxiliary transformer. The unit transformers shall be connected to 6.3kV unit bus BA and BB via the circuit breakers. On the other hand, auxiliary transformer shall be connected to the 6.3kV unit bus CA and CB via the circuit breakers. The power will be distributed to the auxiliary loads from the 6.3kV unit buses.

The auxiliary system and associated equipment shall be designed with flexibility and adequate redundancy to provide a reliable source of power for all auxiliaries that will be required for the new plant.

GTG shall be synchronized by GTG circuit breaker when GTG is attained at rated speed and voltage. Next STG shall be synchronized by STG circuit breaker when STG is attained at rated speed and voltage. Also GTG and STG can be synchronized at 220kV power system breaker in the alternative.

(2) Generators

1) GT Generator and ST Generator

The overview specifications of the Generators are shown below.

Table 6.4.7-1 Overview Specifications of the Generators

Generator	GTG	STG
Type	Three Phase Synchronous	Three Phase Synchronous
Number of Poles	2	2
Number of Phases	3	3
Net Power	312MW	138MW
Rated Capacity	368MVA	163MVA
Frequency	50Hz	50Hz
Rated Speed	3,000rpm	3,000rpm
Terminal Voltage	24.0kV	17.5kV
Power Factor	0.85（Lagging）	0.85（Lagging）
Rotor Cooling Method	Hydrogen or Water Cooled	Hydrogen or Water or Air Cooled
Stator Cooling Method	Hydrogen or Water Cooled	Hydrogen or Water or Air Cooled

2) Type of Generator Cooling System

The generators cooling system shall be adopted of hydrogen gas, water or air cooled type.

As a result of recent technological advance of cooling performance and windage loss reduction, an air-cooled system is adopted in generators of 300MVA class. It is not possible to select air cooled type for GTG because of the capacity shortage (GTG rated capacity: 368MVA > Maximum air cooled generator capacity: 300MVA). Hydrogen supply system for generator cooling is necessary and shall be included in Scope of

Works by the Contractor.
However it is possible to select air cooled type for STG (STG rated capacity: 163MVA < Maximum air cooled generator capacity: 300MVA).Air-cooled system has some advance from hydrogen gas-cooled system such as; simpler system, easy operation and maintenance, allowing for cost savings.

(3) Excitation Method

1) Excitation System

Each generator will be provided with thyristor static excitation system which makes it possible to provide full ceiling voltage, either positive or negative, almost instantaneously under conditions of system disturbances. The system shall include transformer, automatic voltage regulator system (hereinafter called as “AVR”) cubicle, thyristor, convertor cubicle and field circuit breaker. Current transformer for control, regulation, protection and metering of the generator would be either provided in the generator stator terminal bushing both on the lines as well as neutral sides, or would be housed in IPB.

2) Automatic Voltage Regulator System

The generator manufacturer shall have AVR. AVR detects generator voltage and control the reactive power to control the generator voltage.

(4) GT Start-up Method

GT start-up method shall be selected thyristor or motor driven torque converter start-up method.

(5) Transformers

1) GT Transformer

GT Transformer shall step up from GTG voltage (24.0kV) to transmission line voltage (220kV).
GT Transformer shall have tap changing mechanism, oil insulation three (3) phase transformers or four (4) single phase transformer (One for spare). Cooling type shall be Oil Natural Air Forced (hereinafter called as “ONAF”) type. Phase connection shall be Delta-Star (hereinafter called as “Δ-Y”) type.

2) ST Transformer

ST Transformer shall step up from STG voltage (17.5kV) to transmission line voltage (220kV).
ST Transformer shall have tap changing mechanism, oil insulation three (3) phase transformers or four (4) single phase transformer (One for spare). Cooling type shall be ONAF type. Phase connection shall be Δ-Y type.

3) Unit Transformer

Unit Transformer shall step down from GTG voltage (24.0kV) to Unit Bus BA and BB (6.3kV).
Unit Transformer shall have tap changing mechanism, oil insulation three (3) phase transformers or four (4) single phase transformer (One for spare). Cooling type shall be Oil Natural Air Natural (hereinafter called as “ONAN”) type. Phase connection shall be Star-Delta-Delta with Stabilizing Winding (hereinafter called as “Δ-Y-Y”) type.

4) Auxiliary Transformer

Auxiliary transformer shall step down from transmission line voltage (220kV) to Unit

Bus CA and CB (6.3kV).

Auxiliary transformer shall be oil insulation three (3) phase transformers or four (4) single phase transformer (One for spare). Cooling type shall be ONAN. Phase connection shall be Δ-Y-Y type.

The overview specifications of the Transformers are shown below.

Table6.4.7- 2 Specifications for Transformers

Transformer		GT Transformer	ST Transformer	Unit Transformer	Auxiliary Transformer
Rated Voltage	1st	24.0kV	17.5kV	24.0kV	220.0kV
	2nd	220.0kV	220.0kV	6.3kV	6.3kV
Rated Capacity	1st	400MVA	200MVA	25MVA	40MVA
	2nd	400MVA	200MVA	12.5/12.5MVA	20/20MVA
Phase Connection		Δ-Y	Δ-Y	Δ-Y-Y	Δ-Y-Y
Cooling Type		ONAF	ONAF	ONAN	ONAN

(6) Single Phase Transformer and Three Phase Transformer

Comparison of Three Phase Transformer and Single Phase Transformer is shown in the following Table.

Single Phase Transformer has advantage in case of transportation or replacement of one phase transformer by accident. On the other hand, Single Phase Transformer is more expensive because of necessity of the spare transformer, control equipment for each transformer and each basement. Three phase transformer and single phase transformer are equal in performance aspect.

Therefore transformer method shall be three phase transformer or single phase transformer method.

Table 6.4.7-3 Three Phase Transformer and Single Phase Transformer

Type	Three Phase Transformer	Single Phase Transformer
Unit	One (1)	Four (4) : Three (3) + Spare One (1)
Transportation	Base	Easier
Cost	Base	Higher
Space	Base	Larger
Construction	Base	Longer
Management	Base	Same
Reliability	Base	Same

(7) Generator Circuit Breaker and Disconnecting Switch

GT/ST circuit breaker and GT/ST disconnecting switch are set at primary side of GT and ST transformer for synchronization.

GTG is synchronized at 220kV power system via GT circuit breaker when GTG is attained at rated speed and voltage. Next STG is synchronized at 220kV power system via ST circuit breaker when STG is attained at rated speed and voltage. GTG and STG can be synchronized at 220kV power system breaker which is formed by double bus and one circuit breaker with transfer bus scheme.

(8) Isolated Phase Bus

The isolated phase bus (hereinafter referred to as “IPB”) duct shall be forced-air cooled and shall deliver the generator output to the GT/ST step-up transformer with GT/ST circuit breaker, potential transformers, generator surge protection equipment, unit transformer, auxiliary transformer and excitation transformer.

(9) Seal Oil Equipment

Seal oil equipment is necessary when hydrogen cooling method is adopted. The generator seal oil system shall be designed to minimize leakage. The system shall be designed single sided or double sided depending on the manufacture's standard. It shall consist of AC motor driven seal oil pumps with a 100% capacity emergency backup DC motor driven seal oil pump.

(10) Hydrogen Generation System

Hydrogen generation system is necessary when hydrogen cooling method is adopted. Hydrogen generation system currently provides an economical hydrogen supply solution for generator cooling system.

(11) Unit Electric Supply

The unit electric supply shall be configured from unit transformer and auxiliary transformer.

The equipment used for power plant operation shall be powered from the unit transformer. The equipment used for common equipment (water handling, waste water handling, etc) shall be powered from the auxiliary transformer system.

Moreover, as electric power source for emergencies, 1 set of 3 phase diesel fueled generator is installed for power plant and this enables obtaining safety electricity upon total cessation of the operation of the power plant.

Table 6.4.7-4 shows house load apportion.

Table 6.4.7-4 House Load Apportion

Type	Power supply voltage [V]	Power supply board classification	Usage classification
Three (3) phase AC	6,300	6.3kV Medium Voltage switchgear	Load>200kW
	400	400V Low Voltage switchgear	90kW<Load<200kW
		Motor Control Center	3kW<Load<90kW
	200	Motor Control Center	Load <3kW
	100	Motor Control Center	Valve<1kW
One (1) phase AC	100	AC distribution board	
DC	220	DC Motor Control Center DC distribution board	DC load

1) 6.3kV Unit Bus

6.3kV Unit Bus shall supply necessary auxiliary power for plant operation.

The design of 6.3kV unit bus shall be based on the four (4) configurations of BA, BB, CA and CB.

Unit Transformer shall step down from GTG voltage (24.0kV) to unit bus BA and BB.

Auxiliary transformer shall step down from transmission line voltage (220kV) to unit bus CA and CB.

Unit bus BA/BB and CA/CB shall be connected via bus-tie circuit breaker and disconnecting switch. Basically the bus-tie circuit breaker shall be opened. The bus-tie circuit breaker and disconnecting switch shall be closed in case of unit or auxiliary transformer accident. Unit bus CA/CB evacuates Unit bus BA/BB the electric power in that case. Also Unit Bus CA/CB evacuates Unit Bus BA/BB the electric power when plant accidentally tripped.

6.3kV unit bus shall supply necessary auxiliary power and 400kV Unit Bus.

2) 400kV Unit Bus
400kV unit bus shall supply medium motors and auxiliary power for switching.

3) 220V DC Supply System
220V DC supply system shall have battery equipment and DC load shall be supplied by the power from DC distribution board. Plant can stop safely by DC power from battery under blackout condition.

4) Uninterruptible Power System
Uninterruptible power system (UPS) shall be to supply continuous AC power to the essential AC bus. Uninterruptible power system shall be supplied with AC supply source and 220V DC supply system.

5) Emergency Diesel Generator Equipment
Plant shall have one (1) emergency diesel generator equipment at least.
It shall be capable to supply emergency power from emergency diesel generator equipment. Emergency AC power shall be supplied from emergency diesel generator to 400V emergency unit bus.

6) Site grounding
IEEE-80 recommendations shall be used to determine grounding system requirements for this plant. The entire ground grid system shall exclusively utilize copper conductors with exothermic connections for in-ground connections.

(12) Generator Main Circuit Protection
The typical protections for GTG, STG, GT transformer and ST transformer are shown in the following table.

Table 6.4.7-5 Generator Main Circuit Protection

Name	Factor
GT Generator differential	$87G_{GT}$
GT Transformer differential	$87T_{GT}$
ST Generator differential	$87G_{ST}$
ST Transformer differential	$87T_{ST}$
Current unbalance	46
Loss of excitation	40
Reverse power	67
Stator ground detection	51GN
Generator overexcitation	24
Generator overvoltage	59
Generator undervoltage	27G
Generator over/under frequency	81

Generators and transformers shall be protected by 87G and 87T. As a back-up protection for generator, restricted earth fault relay as well as voltage type ground fault relay is also proposed.

6.4.8 I&C Equipment

(1) Control Philosophy

The control system shall control and monitor the status of equipment and process variables associated with the CCCGP to ensure safe and efficient operation with the applicable specifications and performance requirements.

All control and monitoring functions necessary for startup, normal operation and shutdown of the CCCGP shall be provided in Central Control Room (CCR) The CCR will normally be manned.

(2) System Configuration of the Control and Monitoring System

Figure 6.4.8-1 shows Configuration for CCCGP Control.

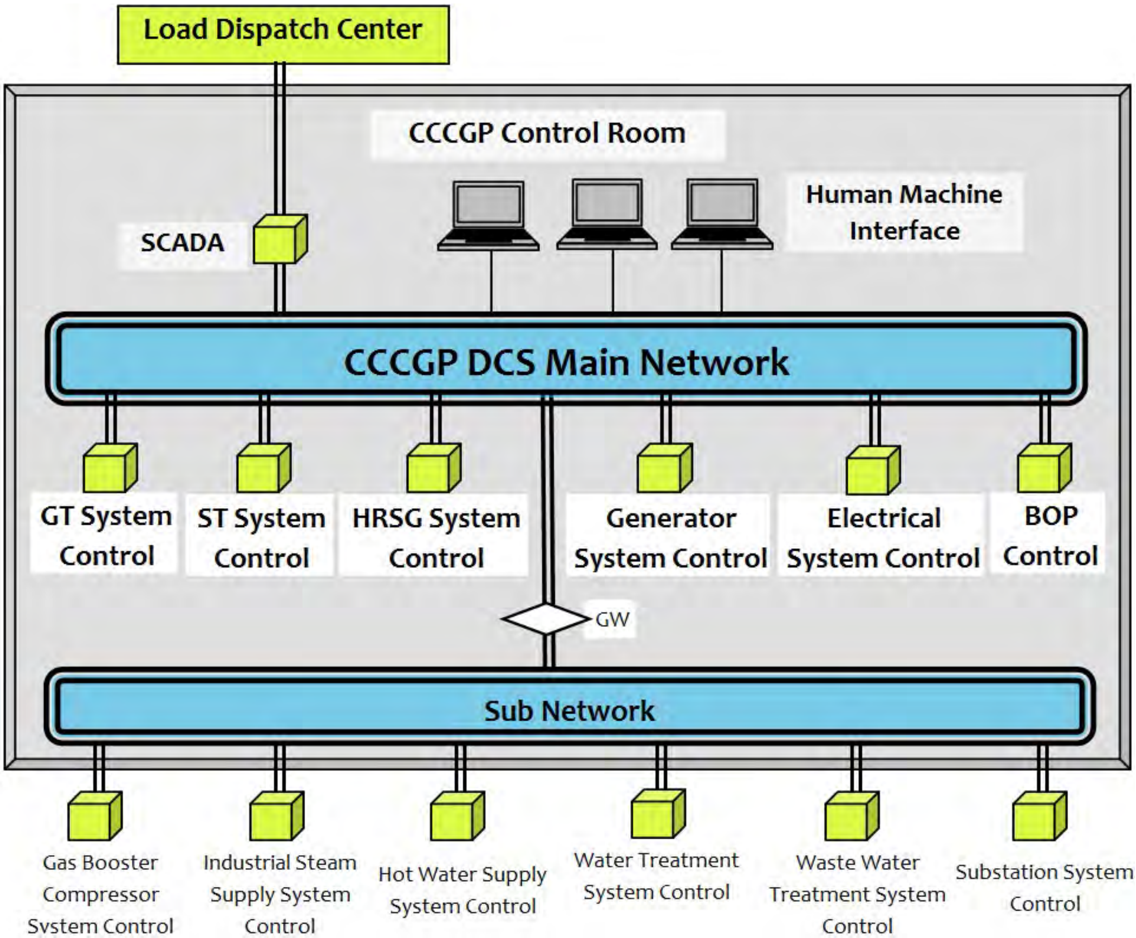


Figure 6.4.8-1 Configuration for CCCGP Control

The design of all instrumentation and control systems shall provide the maximum security for plant personnel and equipment while safely and efficiently operating the new plant under all conditions with the highest possible availability.

Operator Workstation with Human Machine Interface (HMI) and a microprocessor based Distributed Control System (DCS) including redundant controllers using a plant-wide redundant communication highway shall be provided to allow the operators to control CCCGP and to receive monitoring and alarm information.

- The computing and electric power section shall be duplex and the input and output of the DCS will be single.

- Power supply shall be duplex with both AC and DC (butted method)
- Operation during normal times will be through the use of a mouse while confirming the CRT screen.

The operating and monitoring system of the power station are configured by DCS, information management system, maintenance and repair system, network system and related equipment.
The DCS is comprised of the CRT operation system, turbine control system, data assembly system, sequence control system, process I/O system and peripheral equipment. Each independent system is interfaced with DCS.

(3) Control Functions
The design of the control system for the new plant shall utilize the state-of-the-art DCS (Distributed Control System) with data logging system in combination with proprietary controls furnished with the gas turbine / generator, steam turbine / generator, HRSG and BOP (Balance of Plant), gas compressor system and so on.
The operator console of the plant installed in the CCR (Central Control Room) shall be used for the primary operator interface and shall contain LCD (Liquid Crystal Display) with keyboards and mouse. CCR shall equip with shift operator’s room, locker room, WC & shower room etc. in order to create better environment condition for operators.
The gas turbine control system, steam turbine control system, HRSG and BOP control system shall be tied into the DCS with redundant communications networks and hardwired signals for critical control signals.
Those remaining control and monitoring signals for gas compressor control system, heat sources supply control system and so on shall be brought directly or via Remote I/O into the DCS I/O cabinets.
The LCD graphics shall provide the operator with control, monitoring, recording/trending, status, and alarming of equipment and process conditions.
The detector/instrument for protection/control of gas turbine, steam turbine and HRSG shall be redundancy/triple configuration to enhance the reliability of the new plant.
The control system shall be designed to operate and control the new plant with fully automatic, and shall give information of conditions of the new plant and guidance of operation/trouble shootings during start-up, steady state operation and shutdown to the operators.
The configuration of control logic and graphic display of the control system shall be designed for maintenance engineers to be able to easily and correctly modify and change them at site.
DCS shall have the following functions.

1) Turbine automatic operation control system

- Gas turbine operation, control and protection including gas turbine supervisory instruments.
- Steam turbine control and protection including turbine supervisory instruments
- HRSG control and protection
- Generator protection, excitation, voltage regulation and synchronization systems
- Electrical equipment control and protection including supervisory instruments
- Balance of plant control

2) Data collection equipment

- Scan and alert

- Process computation (including performance computation)
- Data log function and data display

3) Common equipment in DCS function
- Gas Booster Compressor System
- Industrial Steam Supply System
- Hot Water Supply System
- Water treatment system
- Waste water treatment system
- Substation System, etc.

4) Maintenance function
Maintenance tools (Engineering Work Station) for the maintenance of DCS are installed and these tools shall have the following functions.
- Control system setting/modification function
- System diagram setting/modification function

These systems have independent monitoring and control. In the event of a defect in the devices, the impact on the power station will be large. For this reason, calculation system, power supply system etc. are multiplexed in order to contribute to the reliable operation of system.
Operator can select each mode to correspond to the plant condition. The typical control modes are shown in the following table.

Table 6.4.8-1 Control Mode by DCS

Control Mode	Event
Full-Automatic	In the “Full-Automatic” mode, the startup or shutdown shall be done by one-push button. Main master sequence is related with each master sequence and operation status on unit side. For example, boiler start preparation to absorber system startup, absorber system startup completed to limestone system startup. As a result, startup is automatically executed from boiler preparation to full load under normal operation via CCCGP startup process.
Semi-Automatic	In the “Semi-Automatic” mode, the startup or shutdown shall be done by step by step. Operator can proceed to step the CCCGP startup and shutdown process to recognize the each breakpoint accomplishment by master sequence.
Manual	In the “Individual” mode, the startup or shutdown shall be manually done.

(4) Field Instrumentation
Field instrumentation for CCCGP such as pressure / level / flow / temperature – transmitters / switches / instruments, flue gas analyzers, vibration detector, etc., will be provided for monitoring the status of equipment and the process variables associated with the CCCGP to ensure safe, efficient operation and performance requirements.
All units are established according to the International System of Units (SI).
Main field instrumentations are as follows:
- Pressure/Differential pressure measurements;
- Level indicating measurements;
- Flow measurements;
- Temperature measurements;
- Density measurements;

- Chemical measurements (pH, conductivity, etc);
- Vibration measurements;
- Position indicators of dampers/valves;
- Continuous Emission Monitoring System (CEMS)

All outdoor mounted instruments shall be designed to withstand the outdoor ambient temperatures. Adequate freeze protection system installations shall be set up in case of the instrument line freezing.

(5) I&C Equipment Power Supply

I&C equipment power supply will be from following switchboards:

- 3x400 / 200 V, 50Hz network supply,
- 200 V, 50Hz Safe AC
- 220 V Battery DC

DC supply system for CCCGP shall not rely on existing Unit and shall be independent.

Other I&C equipment power shall be supplied, as follows:

- 24 VDC redundant
- 48 VDC redundant (if necessary).

(6) Telecommunication System

Telecommunication shall be included in the following system

- CCTV System by IP cameras, Video server and IP Network
- IP telephone system
- Master Clock System
- Uninterruptible power supply (UPS) system

6.4.9 Civil engineering and architectural facilities

The following lists up the planned CCCGP No.2 structures and buildings:

Table 6.4.9-1 List of planned CCCGP No.2 structures and buildings

No.	Names of buildings and structures	Dimensions of building (structure), (width×length×height in meters)	Note
10a	Main building consisting of:		
10a-1	- gas-turbine unit room	45 × 48	
	- steam turbine room	36 × 45	
10a-2	- insertion for GCP (general control panel) and electrical devices	24 × 15	
10a-3	- stack of electrical devices (under CACI (complex air-cleaning installation))	6 × 24	

No.	Names of buildings and structures	Dimensions of building (structure), (width×length×height in meters)	Note
10a-4	- area for steam boiler-utilizer - chimney - tank farm of CWT (chemical water treatment)	1 piece 1 piece	 H=90 m
10a-5	- Gas unit	1 piece	
10a-6	- building of Chemical water treatment (CWT) and Integrated industrial effluent treatment (IIET) - area for tank farm Set of washing equipment - tank farm:	36 × 36 1000 m^3 - 4 pieces 160 m^3 - 1 piece	
10a-7	- deaerator room with feedwater pump and chemicals dosing system	18 × 24	
10a-8a	- boiler room with heating system deaerator	18 × 24	
10a-9a	- engineering and residential building	12 × 36	3 stores
13a	Open installation of transformers with rerolling ways		
	- oil collector (underground based) for collecting accident-related oil from the transformers	180 m^3	
	- capacity of accidental discharge of turbine oil	25 m^3	
	- network of accidental oil runoffs		
19a	ODU-220 kV	1 cell	
19b	Bus-bar assembly	65×60	

No.	Names of buildings and structures	Dimensions of building (structure), (width×length×height in meters)	Note
19d	HV-220 kV AC - 3×300, with length of 0.7 km from bus-bar assembly CCGT-450 with installation for gas switch in cell #10A of existing ODU-220 kV.		At existing ODU-220 the bus-bar bridge L=420 m
25a	Cable tunnels and channels		
26a	Electrical container with backup diesel		
28a	Technological trestles		
	- heating networks		
	- heating network feeding pipelines	2.5 km	Ø325x5
	- hot water (forward and backward) pipelines with armature	0.8 km	Ø630×8
	- steam pipelines with armature	1.5 km	Ø720×9
	- condensate return pipelines with armature	1.5 km	Ø159×5
	- pipeline to GSPU (gas separator pump unit)	59 lm	2 pieces Ø426×6
39a	Gas separator pump unit (GSPU) with armature	30 × 42	
39b	Gas processing facility (GPF)	6 × 18	
39c	System of purge and dump gas pipelines of CCGT and GSPU		
73a	Compressor room for compressed air with receivers	6 × 9	
81a	Electrolysis room with receivers, including nitrogen generating room on sludge disposal site of oily water at flow rate 8-10 m/h, pressure of 20-22 m	12 × 18	
Technical water supply at the site			

No.	Names of buildings and structures	Dimensions of building (structure), (width×length×height in meters)	Note
41a	Circulation pump station - above-ground part - underground part	21×12×13.5 21×12×8.2	
41b	Circulation water lines - 2Ø1420×10 - 2Ø1620×10	 200 lm 200 lm	
43b	Water lines of supplementary at the production site 2Ø377×8 L=300 lm	600 lm	2 lines
44a	Ventilator cooling stacks 18 × 18m	1620 m^2	5 pieces
44b	Pumping installation for cooling stack scavenging	22×9.4×9.4	
46a	Pumping installation for drainage of main building - above-ground part - underground part	9.5×6.5×4.5 6×6×10	
46b	Circular drainage of main building	500 lm	
46c	Pressure water passage of drainage of main building - Ø219 × 6	300 lm	
99a	Piezometric network at the CCGT production site		
	- in site roads	7000 m	
	- access road	600 lm	
	- transfer of HV-220 kV	1500×4 pieces	
	- excavation works	15000 m	
	- soil embankment	35000 m	
	- transformer rerolling ways	100 lm	
	- Security fencing of the territory with the check-point	900 lm	

No.	Names of buildings and structures	Dimensions of building (structure), (width×length×height in meters)	Note
	- towers	2 pieces	
	- trenches	2 pieces	
	- security lighting	900 lm	
	- security alarm	900 lm	
	- concrete fence around the site boundary		
	- storage of transformer and turbine oil with regenerative equipment		
	- fixed gas system wiring for gas welding		
	- showers with dressing room		
	- canteen		

6.5 Construction program

6.5.1 Material/equipment procurement program

Equipment required for the construction of the Uzbekistan site is mostly imported from overseas countries. Materials such as cement, aggregate, sand, rebar etc. can be procured in Uzbekistan.

6.5.2 Material/equipment transport program

Since Uzbekistan is an inland country without a coast line, difficulties are found in the transport of large-sized heavy products.
In the 450MW-class CCCGP No.2, the maximum weight of a product will exceed 300 tons even when the heavy product is divided in several parts for transportation.
Several months will be required for transportation when consideration is given to the canal transportation route by the Volga canal from the Black Sea (the Black Sea through the Caspian Sea) and the inland transportation route (through the Republic of Turkmenistan).
Again, when a construction program is to be worked out, a sufficient transportation period must be taken into account with consideration given to the frozen period of the Volga and the distance of transportation.

Chapter 7 System Analysis and Grid Connection Plan

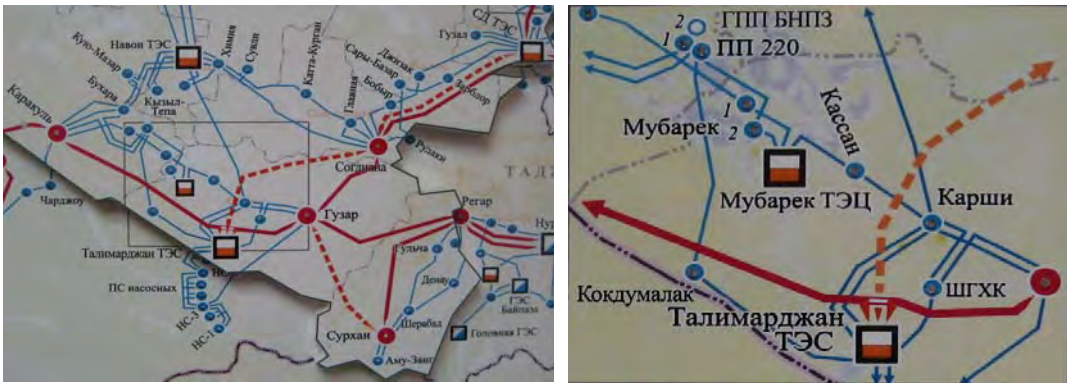
7.1 System analysis

7.1.1 Objective

A 450 MW combined cycle co-generation plant No.2 (hereafter referred to CCCGP No.2), which is scheduled to begin its operation in 2015, is to be added to the Navoi Thermal Power Plant. The objective of the power system analysis is to evaluate the impact of installing this facility under normal condition and emergency condition against the nation's power grid, specifically to the 220-kV network surrounding the power plant. The task of this system analysis is mainly composed of three sub-tasks, namely power flow analysis, fault current analysis, and stability analysis.

7.1.2 Premise

(1) Examined Case
The analysis covers the 220-kV network surrounding Navoi Thermal Power Plant, bordered by three 500 kV substations, namely, Syrdaria Substation, Guzar Substation, and Karakul Substation. Figure 7.1.2-1 shows the area to be analyzed in this study (220-kV power system network around Navoi Power Plant as of year 2010). The analysis simulates the winter peak of year 2015, as the commission of the generation facility is scheduled in the year. The system analysis is carried out using PSS/E software, while SJSC Uzbekenergo uses another software, "Mustang," which had been developed in former Soviet Union.



Source: SJSC Uzbekenergo

Figure 7.1.2-1 Analyzed network area (Left: Analyzed area, Right: part of the analyzed area)

(2) Input Data/ Data Source
The JICA Study Team cited its key input data such as generated power and load from the preliminary study conducted by SJSC Uzbekenergo, SAESP [*1]. For the line constants and parameters related to generators, the team referred to the figures provided by SJSC Uzbekenergo's National Dispatch Center (NDC). Data which are not available in the above two sources are supplemented from the other sources such as SJSC Uzbekenergo's answer sheet to the team's questionnaire [*2] and the past JICA Study [*3]. Table 7.1.2-1 summarizes the data source.

Table 7.1.2-1 Data reference

Item	Reference
Actual Parameters related to existing transmission facilities	Data provided by National Dispatch Center (NDC)
Typical line constants	Excerpt from Design philosophy provided by SAESP
Generation output (P)	Network diagram provided by SAESP [*1]
Load (P and Q)	Network diagram provided by SAESP [*1]

*1: 3618-10-t1-9.dwg, “Determination of the optimal site location PGU-450MW in the system. Scheme of power: Power flow and voltage levels in networks of 220-500kV area of influence, I Option (Recommended), Navoi thermal power plant in the winter maximum 2015.”
(Originally, “Определение оптимальной площадки размещения ПГУ-450МВт в энергосистеме. Схема выдачи мощности. -- I Вариант (рекомендуемый) -- Потоки мощности и уровни напряжения в сетях 220-500кВ района влияния Навоийской ТЭС в зимний максимум 2015г.”
*2: Answer sheet to the team’s questionnaire [26.09.2012 No. IB-01.21/3371].
*3: “The detailed design study for modernization of Tashkent Thermal Power Plant in the Republic of Uzbekistan final report: main report,” Jan. 2004, Japan International Cooperation Agency (JICA)

7.1.3 Power Flow Analysis

Table 7.1.3-1 shows the average values of the line constants for the existing/ planned transmission facilities.

Table 7.1.3-1 Line Constants (average values)

Voltage [kV]	Rated capacity [MVA]	Positive-phase-sequence Impedance (pu/km)[*]		
		R	X	B
500	1,732 (partly 1,297)	0.0001	0.0011	0.0009
220	262 - 360	0.0015	0.0088	0.0001

* 1,000MVA Base

Source: Developed by JICA Study Team based on the collected data

Table 7.1.3-2 shows the list of major power plants in the analyzed network

Table 7.1.3-2 The list of Power Plants (Year 2015)

Name	Rated capacity [MVA]	Voltage of grid to be connected [kV]
Navoi Thermal Power Plant	25 x 2 units (*1) 150 x 1 unit (*1) 150 x 1 unit 50 x 2 unit 60 x 1 unit (*1) 160 x 1unit (*1) 210 x 2 units 313 (GT) + 163 (ST) 310 (GT) + 140 (ST)	110 110 110 220 220 220 220 220 220
Talimarjan Thermal Power Plant	800 x 1 unit 450 (310 (GT) + 140 (ST)) x 2 unit	500 220
Syrdaria Thermal Power Plant	700 x 1 unit 830 x 1 unit (*2)	500 220
Mubarek Heat Power Plant	60 x 1 unit	220
Buhara Heat Power Plant	70 x 1 unit	220
Kondon Heat Power Plant	30 x 1 unit	220

*1: Normally out of service. Operated under specific condition like inspection of the other units (According to the interview of the staff of Navoi Power Plant, the plant’s Unit 1, 2, 3, 6, and 8 will remain after the commission of the CCCGP No.2).
*2: The unit is set as slack in the system analysis. Because the analysis set the boundary of the analyzed area at

Syrdaria power plant, the unit size of the plant shown in the table does not necessarily represent the actual capacity per unit.

(1) Criteria

For power flow analysis, transmission sections whose loading rate is over 100% of the rated thermal capacity is considered “overloading.” The system is also assumed to satisfy the N-1 standard. For verification of the simulation model, the JICA Study Team referred to the aforementioned result diagram of power flow study targeting the year 2015, which has been provided by SAESP.

The normal operation range of the grid voltage is between -10 % to +5 % of base voltage (500 kV and 220 kV). Table 7.1.3-3 summarizes the criteria.

Table 7.1.3-3 Power Flow Criteria

Item	Criteria
Loading	Rate < 100 %
Voltage	-10% < V < +5%

Source: SJSC Uzbekenergo

(2) Calculation Results

a. Loading

Figure 7.1.3-1 shows the results of the power flow analysis with and without the new CCCGP No.2 to the Navoi Thermal Power Plant. For all the transmission lines, the calculated flow was within the allowable current capacity. For N-1 criteria, the sections shown in Table 7.1.3-4 were evaluated. These cases showed that the analyzed network also satisfies the N-1 standard (Figure 7.1.3-2).

Table 7.1.3-4 Power Flow Analysis Result (N-1 analysis. During Winter Peak)

Section	Calculated power flow amount [MW] and Rated capacity [MVA]		
	Normal case [MW per circuit]	N-1 case [MW per circuit]	Rated capacity [MVA per circuit]
From K-Mozof SS to Navoi TPP	155.2	256.0	360 (planned future)
From Himiya SS to Navoi TPP	158.5	211.4	360

According to SJSC Uzbekenergo’s design standard, the actual rated capacity would be more than 360 MVA for the designated sections, as temperature factor would be considered, up to almost 420 MVA. The standard rated capacity assumes the temperature of 25 degree in Celsius.

b. Voltage

For the purposes of maintaining the proper voltage, the static capacitors with required capacity will be necessary to be inserted into the several substations, because several buses at substations show the voltage below their operation range (-10 % of base voltage). For this purpose, the conducted power flow analysis has put static capacitors at the location shown in Table 7.1.3-5. It is, however, not sure that this attributes to the actual facility configuration or lack of simulation data.

Table 7.1.3-5 Locations where static capacitors are placed in the analysis

Location	Capacity
Koson 220kV Substation	118.50 Mvar
Djizak 220kV Substation	160.80 Mvar
K. Kurgn 220kV Substation	148.40 Mvar
Buhara 220kV Substation	116.30 Mvar

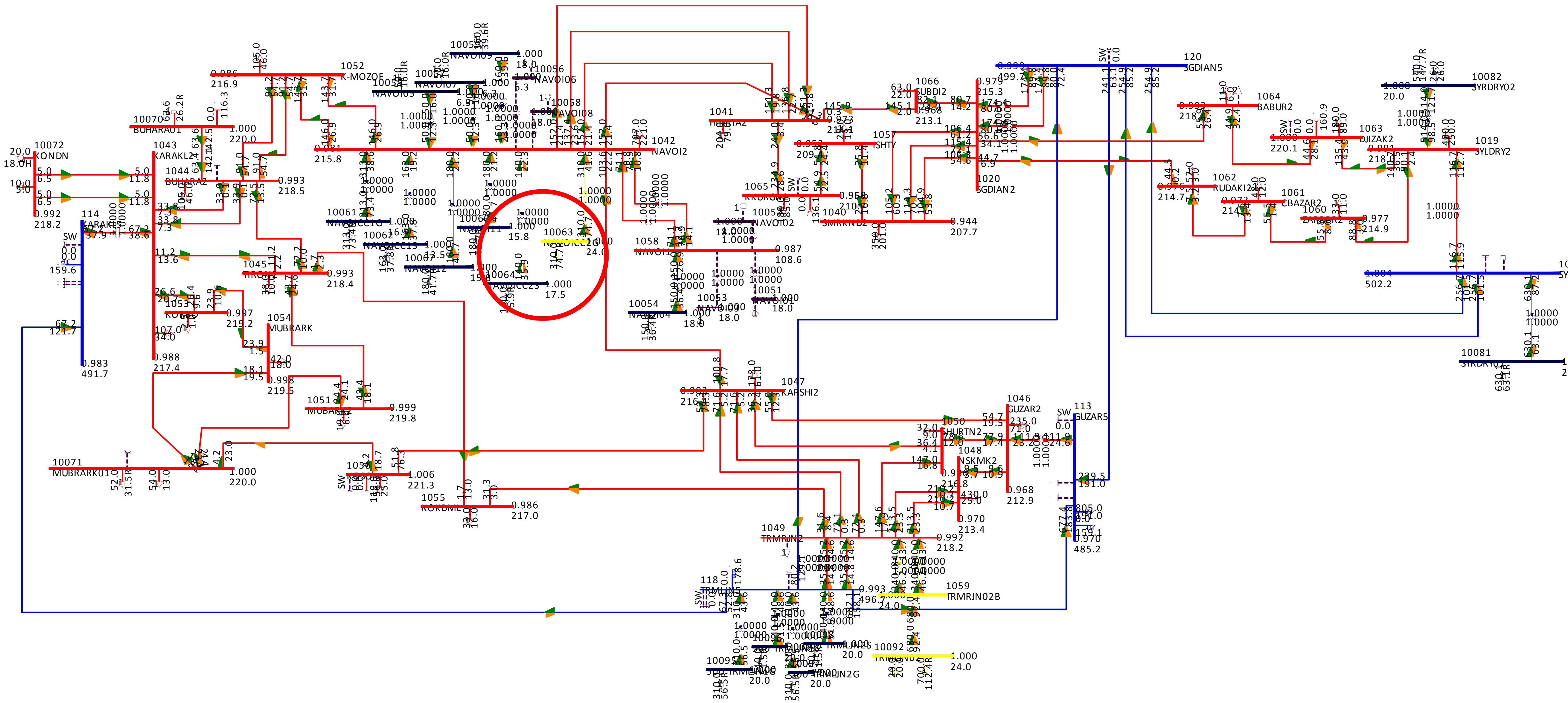


Figure 7.1.3-1a Power Flow Analysis Result (Normal Time. With CCCGP No.2)

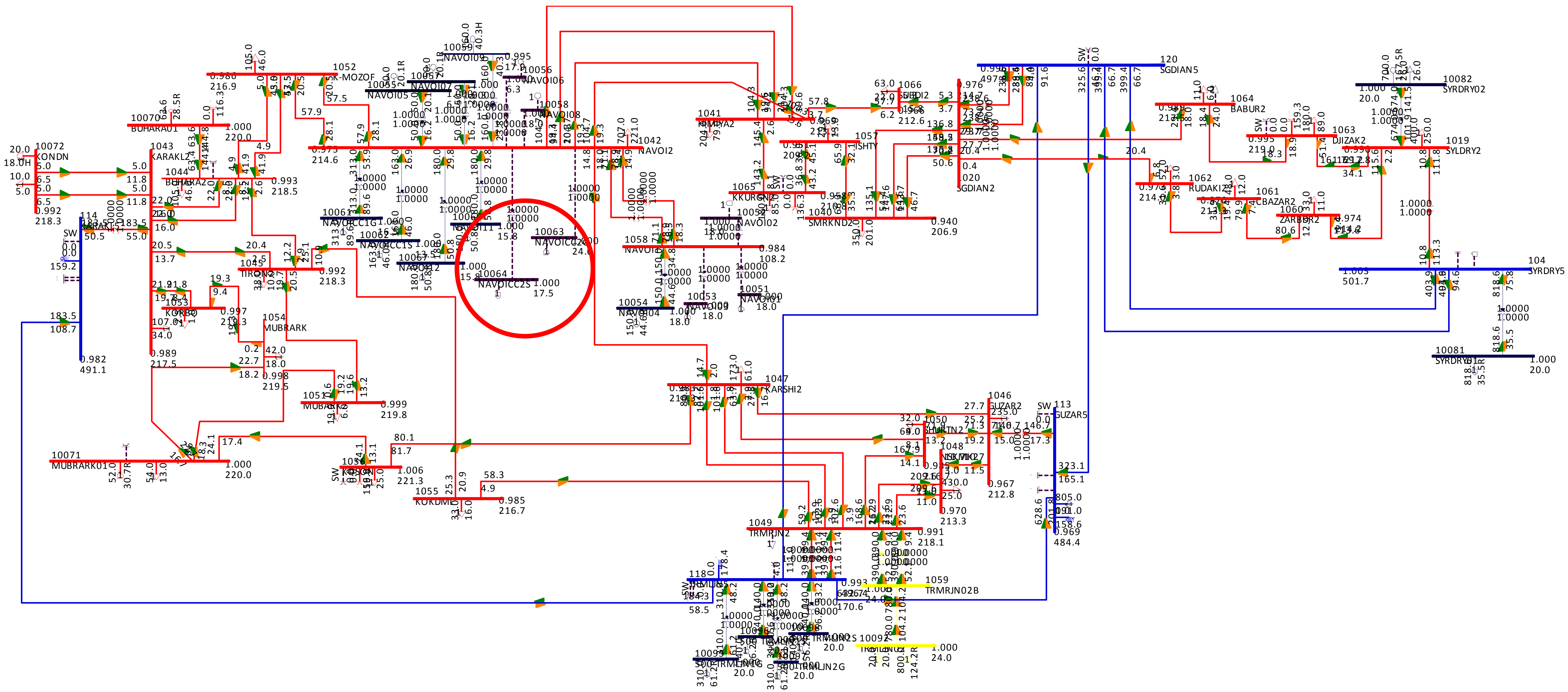


Figure 7.1.3-1b Power Flow Analysis Result (Normal Time. Without CCCGP No.2)

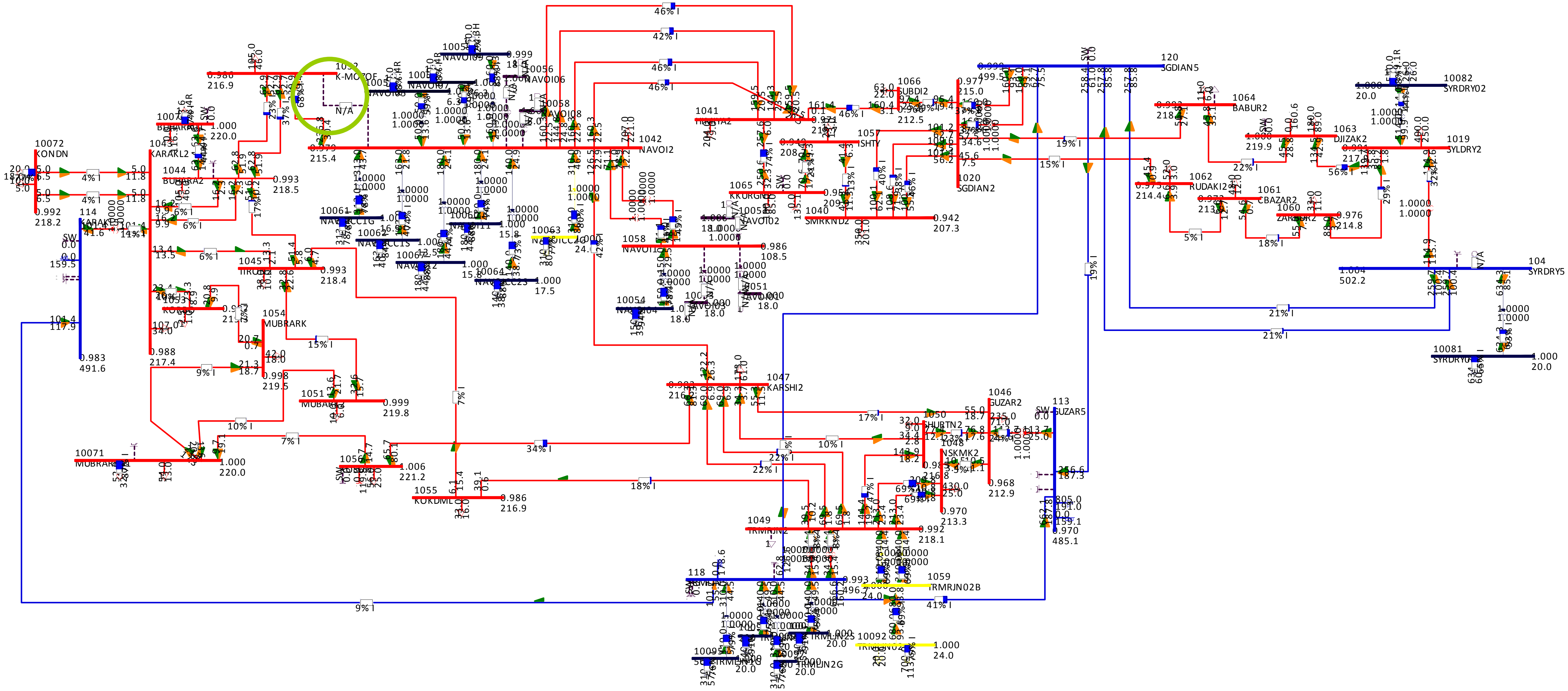


Figure 7.1.3-2 Power Flow Analysis Result (N-1 case at the section between Navoi TPP and K-Mozof SS)

7.1.4 Fault Current Analysis

Because the total installed capacity of Navoi TPP will be increased from 1,250 MW as of now to around 1,800 MW in year 2015, it is anticipated that the fault current around the power plant would be largely increased. This analysis evaluates the impact of adding the new CCCGP No.2.

(1) Approach and Methodology
The 3-phase short-circuit current case is evaluated. Table 7.1.4-1 shows the criteria.

Table 7.1.4-1 Maximum Allowable Fault Currents (representative case)

Nominal Voltage	Total Clearance time (Primary protection)	Maximum Allowable Fault Current
500kV	Max 120 ms	41.8kA
220kV	Max 160 ms (200 ms)	31 kA

Source: SJSC Uzbekenergo

For the actual facilities, the maximum allowable fault current is set individually, e.g., 50 kA for a circuit breaker at Guzar 500 kV Substation. The analysis evaluates the impact of adding new CCCGP No.2 by comparing the value of short-circuit current between the cases with and without the CCCGP No.2.

(2) Result
The 3-phase short-circuit current values for the 500 kV and 220 kV buses for major substations were shown in Table 7.1.4-2 (with and without 450-MW CCCGP No.2). The influence of introduction of 450 MW combined cycle power plant on the network system was +0.5 kA for a 500kV bus and +0.4 kA for a 220kV bus of Navoi Thermal power Plant. In summary, the current was within the rated current/ planned capacity, and therefore, the impact of adding CCCGP No.2 is confirmed to be small.

Table 7.1.4-2 Result of Fault Current Analysis at major buses

Name of facility		Maximum Allowable Fault Current	Without CCCGP No.2	With CCCGP No. 2
Navoi TPP	220 kV Bus 110 kV Bus	60 kA (planned[*])	5.9 kA 8.2 kA	6.4 kA 8.6 kA
Guzar SS	500 kV Bus	31.5 kA	3.0 kA	3.0 kA
Talimarjan TPP	500 kV Bus	40 kA or 56 kA	3.2 kA	3.3 kA
Karakul SS	500 kV circuits	31.5 kA	2.6 kA	2.7 kA
	220 kV circuits	25 kA	5. 8 kA	6.0 kA

*: According to NDC (National Dispatch Center) calculations, the present 3-phase short-circuit current value of Navoi Thermal Power Plant 220kV bus is so large that they plan to upgrade the size of the circuit breakers up to 60kA before the plant's commission in 2015.

7.1.5 Dynamic Stability Analysis

(1) Approach and Methodology

When all of the synchronous generators in the system are able to maintain synchronized operations even in the event of an equipment fault occurring, which constitutes the system, the system can be considered stable. The calculations were executed under the criteria that "when the oscillations of the phase angles among the rotors of synchronous generators which constitute the system tends to converge even in the case of the severest single contingency, the system is stable."

Fault sections were selected taking into consideration typical heavy-loaded sections near Navoi TPP (Table 7.1.5-1).

Table 7.1.5-1 Stability Analysis Cases

Case	Fault Section (1cct)
Case 1	220 kV Navoi TPP – K-Mozof SS Transmission line
Case 2	220 kV Navoi TPP – Himiya SS Transmission line
Case 3	500kV Talimarjan TPP – Guzar SS

Table 7.1.5-2 Fault Sequence

Time	Event
0 ms	Single Circuit Three-phase Short Circuit Fault at the selected section
160 ms	Fault Clearance (1cct Open)
10 s	End of Calculation

(2) Analysis Conditions

The stability analysis was conducted under the following conditions:

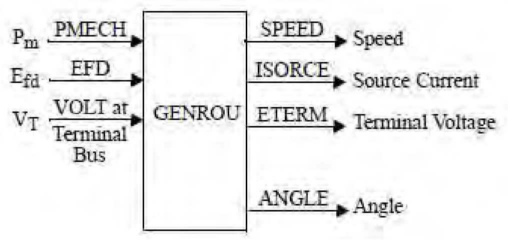
- Generator models were developed based on the data provided by SJSC Uzbekenergo as shown in Table 7.1.5-3. For items without data provided, typical figures were set. Because all the generators are for thermal power plant, the round rotor generator model was assumed for all the generators.

Table 7.1.5-3 Generator Model: GENROU (Round Rotor Generator Model)

	T'do	T''do	T'qo	T''qo	H	D	Xd	Xq	X'd	X'q	X''d=X''q	Xl	S(1.0)	S(1.2)
CCCGP No.1 and No. 2														
Gas Turbine	8.9	0.044	0.99	0.07	2.0	0	2.48	2.3	0.232	0.53	0.22	0.187	0.12	0.37
Steam Turbine	9.0	0.046	1.25	0.08	3.2	0.11	2.02	1.95	0.285	0.39	0.148	0.123	0.12	0.37
Other generators														
Navoi #12	6.45	0.03	0.5	0.03	3.2	0	1.38	1.2	0.23	0.5	0.16	0.15	0.12	0.37
Talimarjan 500 kV	9.0	0.03	1.5	0.02	3.22	0	2.22	2.1	0.29	0.49	0.22	0.17	0.12	0.37

Source: SJSC Uzbekenergo

Note: The study cited the parameters for CCCGP No.2 from those for the existing CCCGP No.1, as the technical specification of CCCGP No.2 is expected to be similar to that of the CCCGP No.1



Source: PSS/E manual

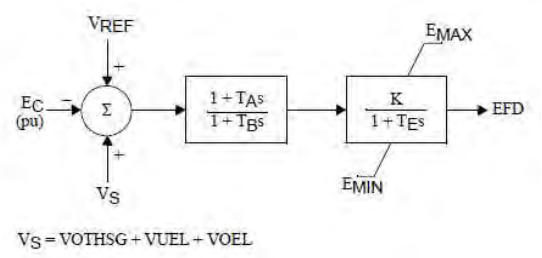
Figure 7.1.5-1 Block Diagram of GENROU

- The simple exciter model (SEXS), shown in Table 7.1.5-4, was applied as the exciter models for all the generators due to the limited data availability. This assumption also applied to the designated CCCGP No.2.

Table 7.1.5-4 Exciter Model for the other generators: SEXS (Simplified Excitation System)

TA/TB	TB	K	TE	EMIN	EMAX
0.1	10	100	0.05	0	5

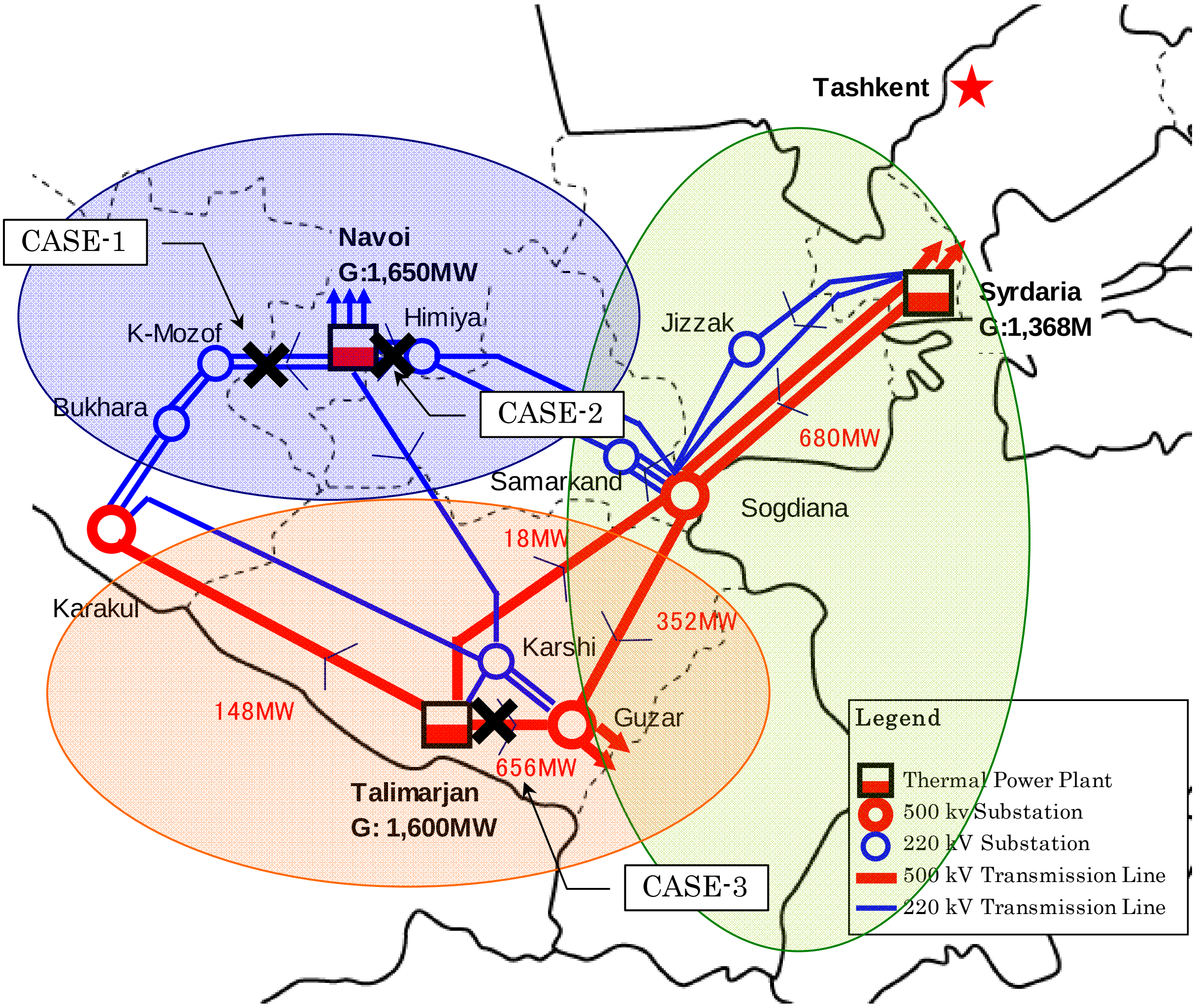
Source: SJSC Uzbekenergo



Source: PSS/E manual

Figure 7.1.5-2 Block Diagram of SEXS

- To set the severest calculation condition, the power plants with relatively-smaller capacity, namely Mubarak, Buhara, and Kondon Heat Power Plants, are set as out of service for the stability analysis. Instead, the other larger-size power plants' output are set as almost maximum.



Source: Developed by JICA Study Team
Note: The demand area covered by green circle is mainly supplied by Syrdaria TPP. Likewise, the area covered by red circle is supplied by Talimarjan TPP, while the area covered by blue circle is supplied by Navoi TPP.

Figure 7.1.5-3 Power Flow Diagram for the Stability Analysis (During Winter Peak in 2015).

(3) Result

Table 7.1.5-5 shows the stability analysis results for each case in Table 7.1.5-1. Behaviors of phase angle oscillation for the cases were shown in Figure 7.1.5-4 to -6.

Table 7.1.5-5 Stability Analysis Results

Case	Fault Section (1cct)	Result
Case 1	220 kV Navoi TPP – K-Mozof SS Transmission line	Stable
Case 2	220 kV Navoi TPP – Himiya SS Transmission line	Stable
Case 3	500kV Talimarjan TPP – Guzar SS	Stable

For the planned system in the year 2015, the oscillation waveforms of phase angle differences were found converged in the case of a single circuit fault of the primary heavy-loaded sections near Navoi TPP. Therefore, it was confirmed that the planned system was stably operated under such severe conditions.

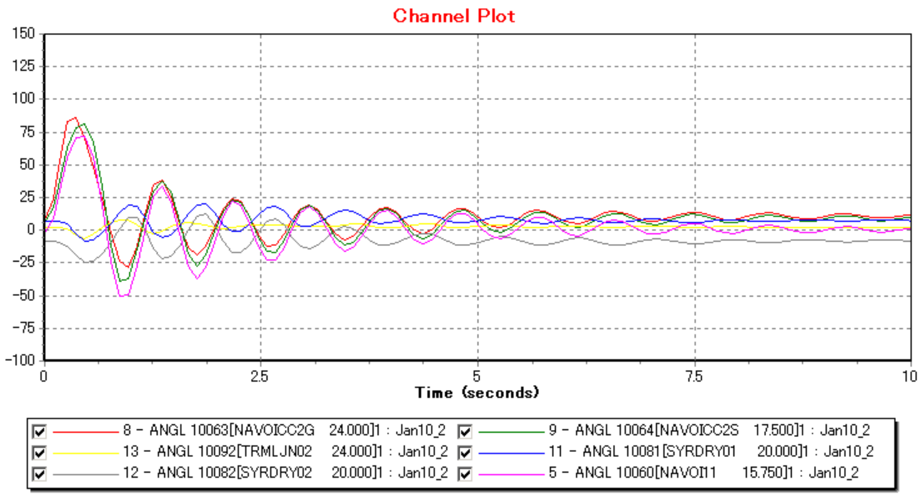


Figure 7.1.5-4 Case-1 Line Fault: 220 kV Navoi TPP – K-Mozof SS Transmission Line

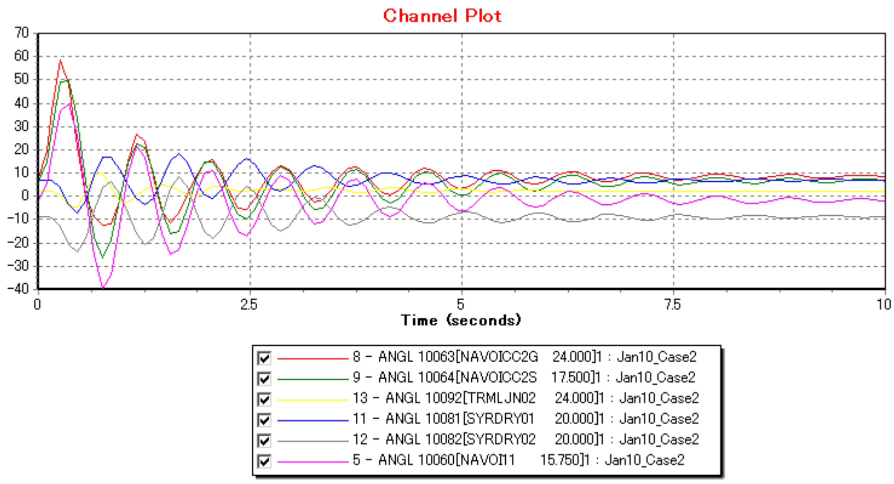


Figure 7.1.5-5 Case-2 Line Fault: 220 kV Navoi TPP – Himiya SS Transmission Line

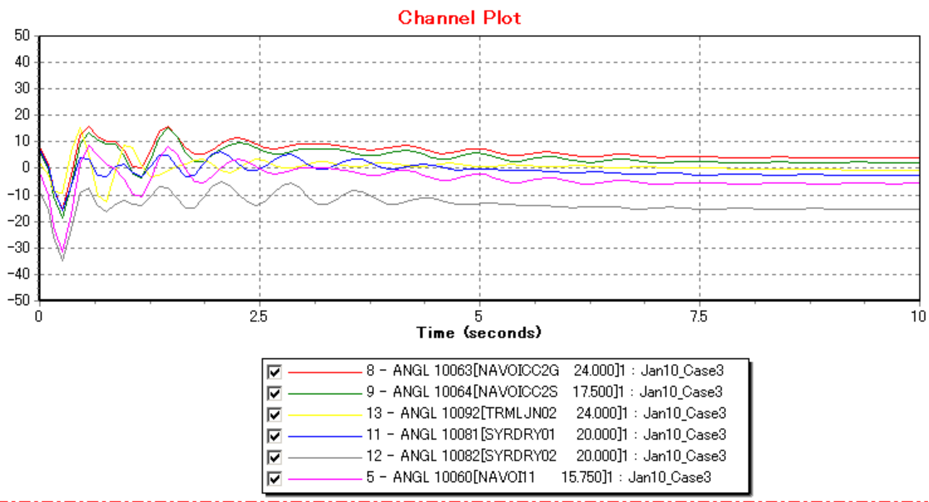


Figure 7.1.5-6 Case-3 Line Fault: 500 kV Talimarjan TPP – Guzar SS Transmission Line

7.1.6 Conclusion

The analysis revealed that there will be no significant problem of power flow, voltage, short-circuit current, and dynamic stability caused by connecting the new 450 MW CCCGP No.2 of the Navoi Thermal Power Plant to the currently-planned power system of year 2015. Therefore it is confirmed that the installation of CCCGP No.2 would not require to modify or strengthen the currently-planned power system.

7.2 Grid Connection Plan

For the transmission line and substation design of this project, the materials and information provided by the counterpart and JICA Report “Republic of Uzbekistan Supplemental Study to enhance the collaboration with NEDO on Tashkent Heat Supply Power Plant Modernization Project” were referred to.

7.2.1 Layout of Transmission Line

Concept of transmission line route selection

- The locations of towers are set to be a good distance from west settlement and close to new thermal power stations as far as possible.
- The clearance of transmission lines is set to be secured as 40m in light of the length of tower arms, Right of Way (ROW: 25m)
- Some boundary towers between new towers and existing towers are considered for reconstruction. It is possible that reconstruction and reinforcement of other towers or tower members will be required, arising from unclear present conditions and the design conditions of existing towers.

7.2.2 Basic design conditions of Transmission lines

For the design of the branch span of this project, both the Regulations on Electrical Devices (PUE) and Uzbek-Standard (GOST) were referred to.

(1) Voltage
220kV
(2) Ambient Temperature
Ambient Temperature is shown in Table 7.2.2-1.

Table 7.2.2-1 Ambient Temperature

Item	Temperature[^{o}C]
Maximum air temperature	45 ^{o}C
Minimum temperature	-30 ^{o}C
Annual mean air temperature	15 ^{o}C
Temperature in case of glazed frost	-5 ^{o}C

Source: JICA Report" Republic of Uzbekistan Supplemental Study to enhance the collaboration with NEDO on Tashkent Heat Supply Power Plant Modernization Project"

(3) Wind Velocity
Maximum normative wind velocity: 28m/s
Conductor installation condition: 10m/s

(4) Wind Pressure
Maximum normative wind velocity pressure: 490Pa
Conductor installation condition: 60Pa

(5) Grazed frost condition
Thickness: 10mm
Density: 0.9g/cm^3

(6) Load Condition
8 conditions which consist of normal operation, conductor installation, and maximum temperature conditions were considered.
1) Maximum air temperature, no wind, no glazed frost
2) Minimum air temperature, no wind, no glazed frost
3) Annual mean temperature, no wind, no glazed frost
4) Conductors are covered with grazed frost (thickness: 10mm, density: 0.9g/cm^3), temperature -5℃, no wind
5) Maximum normative wind velocity pressure q_{max}, temperature –5 ^{o}C, no glazed frost
6) Conductors are covered with glazed frost (thickness: 10mm, density: 0.9g/cm^3), temperature –5oC, wind velocity pressure 0.25 q_{max}
7) During conductor installation (temperature -15 ^{o}C, wind pressure 6.25kgf/m2, no glazed frost
8) Maximum conductor temperature (assumed 100 ^{o}C), no wind, no glazed frost)

7.2.3 Allowable Tension

(1) Allowable Tension of Conductor and Ground wire
In PUE "Allowable tension of conductors and cables for overhead line (more than 1kV)", the allowable tensions in the case of conductor installation were provided as shown in Table 7.2.3-1. Therefore, the tension in the severest condition was assumed 45% of the ultimate

tensile strength of the conductor and ground wire.

Table 7.2.3-1 Allowable Tension

Temperature	Allowable Tension in case of installation (% of Ultimate Tensile Strength)
Maximum load at the minimum air temperature (-30 °C)	45
Maximum load at the annual mean temperature (15 °C)	30.

Source: JICA Report" Republic of Uzbekistan Supplemental Study to enhance the collaboration with NEDO on Tashkent Heat Supply Power Plant Modernization Project"

(2) Allowable Tension of insulator
Based on Table7.2.3-1, the allowable tension in the severest condition was assumed 45% of Rated Ultimate Strength (RUS) of insulator.

7.2.4 Design of Conductor and Ground wire

(1) Conductor and Ground wire
The Conductor and Ground wire which were assumed in this consideration were shown in Table7.2.4-1.

Table 7.2.4-1 Properties of Conductor and Ground wire

Type	Conductor	Ground wire	
	ACSR300mm^2	AC70mm^2	OPGW70 mm^2
Component of stranded wires	Al:24/4.0mm St:7/2.65mm	AC: 7/3.5	AC:8/3.2mm OP unit 1/5.0
Total area of aluminum wires	300mm^2	67.35mm^2	77.89mm2
Overall diameter	23.95mm	10.5mm	11.4mm
Weight	1,138kg/km	426.5kg/m	470.1kg/km
Ultimate tensile strength	90.6kN	77.3kN	80.2kN
Modulus of elasticity	78,300N/mm^2	149,000N/mm^2	142,000N/mm^2
Coefficient of linear expansion	19.5*10^{-6}/ °C	12.9*10^{-6}/ °C	13.8*10^{-6}/ °C
DC resistance at 20 °C	0.0958 Ω /km	1.12 Ω /km	0.834 Ω /km

Source: Study Team

(2) Maximum working tension of conductor
As a maximum span length is measured to be approximately 440m at point between Ntc3 and Tc5, the maximum design span length is assumed to be 450m in consideration of elevation difference. Therefore, the maximum tension of conductor and ground wire for this project will be occur in 450m span. The values of maximum working tensions of conductor and ground wires satisfy the determined allowance tension as shown in Table7.2.4-2. The applied stringent condition was "Conductors are covered with grazed frost (thickness: 10mm, density: 0.9g/cm^3), temperature -5 oC, no wind" in clause 2. (6).

Table 7.2.4-2 Working Tension and Allowable Tension of Conductor

Type	UTS	Tension		Allowable Tension
ACSR300mm^2	90.6kN	Maximum Tension	40kN	0.45>0.42

Source: Study Team

(3) Maximum working tension of ground wire
The working tension of ground wire is determined so that it's sag becomes less than 80% of

the conductors' sag under the condition which is "Annual mean temperature, no wind, no glazed frost", (usually called EDS: Every Day Stress) at the standard span length (450m) for avoiding reverse flashover from ground wire to the conductors and direct lightning strokes to conductors.

Table 7.2.4-3 Working tension and Allowable Tension of Ground wire

Type	UTS	Tension		Allowable Tension
AC70mm^2	77.3kN	Maximum Tension	21kN	0.45>0.27
OPGW70 mm^2	80.2kN	Maximum Tension	23kN	0.45>0.28

Source: Study Team

(4) Standard Span Length
450m

7.2.5 Insulator Design

(1) Insulator Type and Size

1) Type
The standard disc type porcelain insulator with socket complying with the IEC 60305 is applied to the transmission lines for this project.

2) Size
The selected insulator size and its strength, respectively are shown in Table 7.2.5-1.

Table 7.2.5-1 Insulator Size

Size	Height	Diameter	RUS
250mm disc	146mm	255mm	120kN

RUS: Rated Ultimate Strength
Source: IEC 60305

(2) Number of Insulator Unit

1) Pollution level
Pollution level assumed "Light" classified in the IEC 60071-2 (Table I). The required creepage distance /phase to earth voltage for "Light" level is 16mm/kV.

2) Standard lightning impulse withstand voltage
Standard lightning impulse withstand voltage for 220kV equipment is 1,050kV and minimum clearance at 1,050kV is 2,100mm as classified in IEC60071-2.

3) Number of insulator units per string: 15units
From the necessary creepage distance of insulator, the number of insulator units per string of the standard string is 12 units. While from the standard lightning impulse withstand voltage, the number of insulator units per string was determined as 15 units Standard insulator sets applied to the existing have 16 units per string.

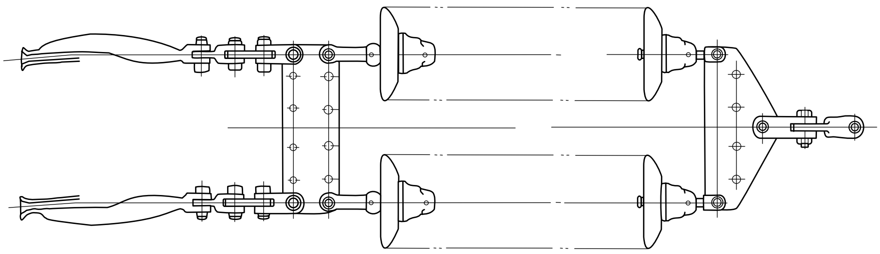
(3) Tension insulator assembly
Working tension of insulator assemblies and allowance strength were shown in Table 7.2.5-2. Example of insulator assemblies (Tension type) is shown in Figure 7.2.5-1.

Table 7.2.5-2 Working Tension of Insulator Assemblies

Conductor	Maximum Tension (Span length :450m)	Suspension and Tension insulator assembles	Allowance Strength*
ACSR300mm^2	80 (40kN×2 bundles) kN	Double strings of 240kN (120kN×2)	0.45>0.33

*Allowance Strength is applied as 45% of RUS which is as same as the value of conductor

Source: Design by JICA study team



Source: Study Team

Figure 7.2.5-1 Example of insulator assembly (Tension type)

7.2.6 Ground Clearance

The most severe state for the ground clearance of conductors will occur when the assumed conductor's temperature rises to 100°C under still air conditions. As for this project, the minimum height of conductor above ground provide by counterpart is shown in Table 7.2.6-1. As the area for this project is purchased by counterpart, so it is assumed the public do not enter this area. Therefore, Ground Clearance Value of plain as the minimum ground clearance was applied to this project.

Table 7.2.6-1 Minimum Height of Conductor above Ground

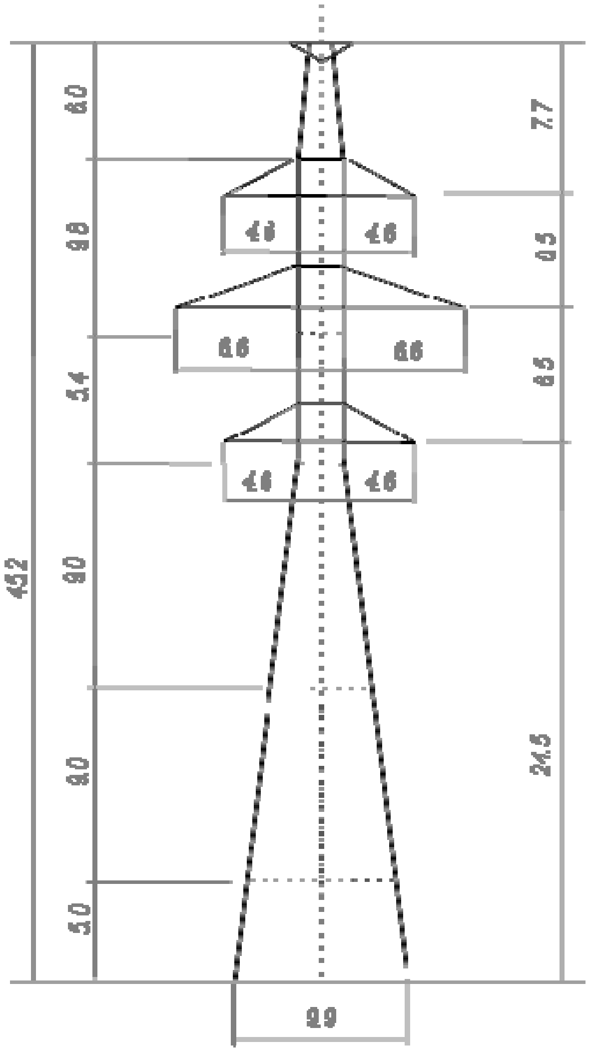
Classification	Height
Plain	8m
Crossing point of roads	15m
Crossing point of railway	16.5m

Source: SAESP

7.2.7 Tower Design

Based on the consideration of minimum ground clearance and the materials provide by counterpart, Tower type "y220-2T+14" was applied to this project as shown in Figure 7.2.7-1.

Final tower type at each tower including such as heavy angle tower, tower near the river and boundary tower between new construction tower and existing tower shall be examined by the results of detail design.

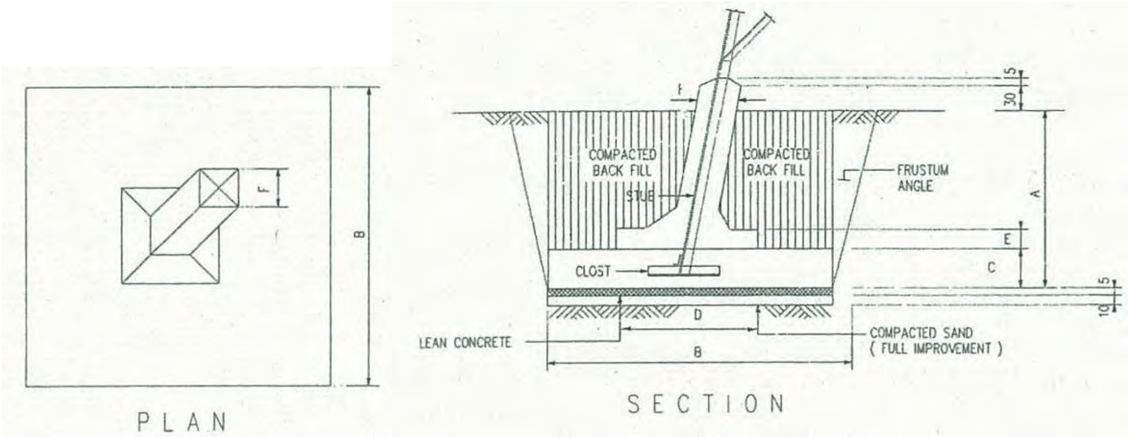


Source: SAESP

Figure 7.2.7-1 Tower Skelton Type”y220-2T+14”

7.2.8 Foundation Design

As it is considered that the nature of soil in the area is good, it can therefore be assumed that normal pad and chimney type foundation are applicable to all towers in this project as shown in Figure 7.2.8-1. Final Foundation type at each tower including such as heavy angle tower, tower near the river and boundary tower between new construction tower and existing tower shall be examined by the results of detail design.



Source: Study Team

Figure 7.2.8-1 Foundation Type and Chimney

7.2.9 Designs on a bay and bus bar into an existing substation

(1) Standard of Bay design

Counterpart personnel has not submitted any standards, design criteria and actual construction costs in relation to a 220kV bay connected into an existing substation and a 220kV bus bar in the substation.

Then, the study team has made assumptions in the basic design of such facilities based on our experiences of overseas design works.

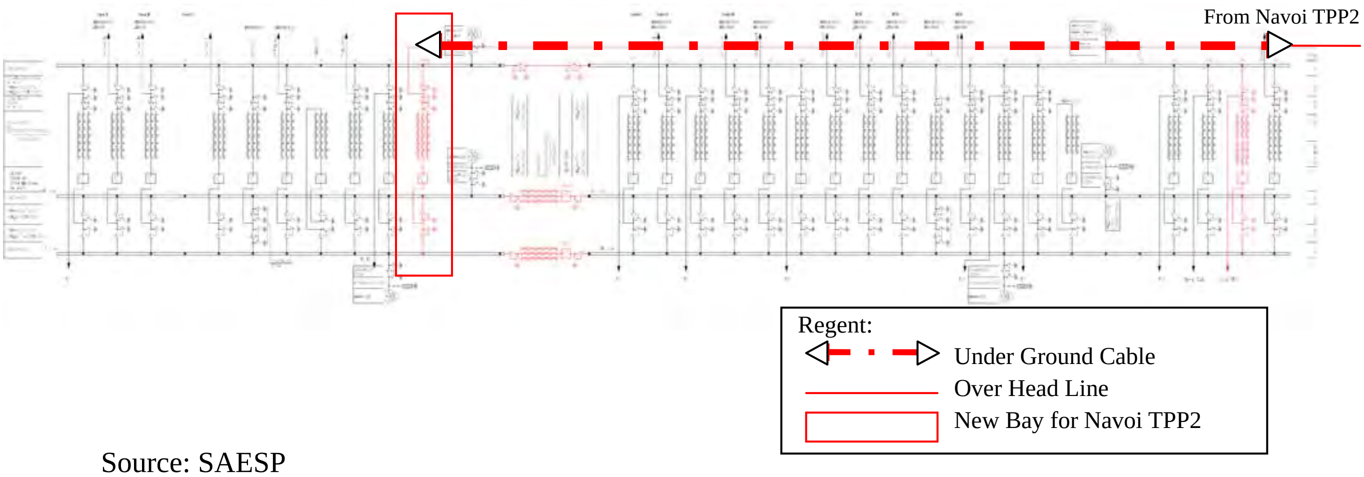
The 220kV equipment of switchgear is subject to a following standard.

- IEC 60056 High Voltage equipment
- IEC 60076-1 Power transformers, General.
- IEC 60076-2 Power transformers, Temperature rise.
- IEC 60076-3 Power transformers, Insulation levels, dielectric tests and external clearances in air.
- IEC 60076-5 Power transformers, Ability to withstand short circuit.
- IEC 60076-10 Power transformers, Determination of sound levels.
- IEC 60137 Insulating bushing for alternating voltages above 1kV
- IEC 60156 Transformer Insulating liquids-determination of the breakdown voltage at power frequency – test methods
- IEC 60214 On-load tap-changers.
- IEC 60255 Protection relays
- IEC 60296 Specification for unused minerals insulating oils for transformers and switch-gear
- IEC 60354 Loading guide for oil-immersed transformers
- IEC 60420 High voltage alternating current switch-fuse combinations.
- IEC 60427 High Voltage Switchgear
- IEC 60439 Low voltage switchgear
- IEC 60551 Determination of transformer and reactor sound levels
- IEC 60616 Terminal and tapping markings for Power Transformers
- IEC 60694 Common specifications for high-voltage switchgear and controlgear standards.
- IEC 60722 Guide to the lightning impulse and switching impulse testing of power transformers and reactors.
- IEC 60815 Guide for the selection of transformer insulators in respect of polluted conditions

- IEC 61330 high voltage/low voltage prefabricated substations

(2) Design of Bus & bay in the existing substation

220kV cable system has been applied to utilize a bus extension in this study due to safety and maintenance reasons. The route of bus bar extension is planned to be located under eight (8) existing transmission lines. The study team recommends that the underground cable system should be utilized in the bus bar extension from bay of the CCCGP No.2 due to secure availability to prevent interruptions by maintenance and turbulence from other transmission lines. Shown in Figure 7.2.9-1 the design of the bus and bay from CCCGP No.2.



Source: SAESP

Figure 7.2.9-1 Single Line Diagram of 220kV Navoi SS on the Bus & Bay from CCCGP No.2