JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

NATSIONALNA ELEKTRICHESKA KOMPANIA(NEK)
REPUBLIC OF BULGARIA

# THE FEASIBILITY STUDY ON MARITSA EAST NO.1 REPLACING THERMAL POWER PLANT FOR IMPROVEMENT OF THE PERFORMANCE OF THE UNITS AND THE ENVIRONMENTAL PROTECTION

## FINAL REPORT



SEPTEMBER 1996

ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO ELECTRIC POWER SERVICES CO., LTD.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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# THE FEASIBILITY STUDY
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PREFACE

In response to a request from the Government of the Republic of Bulgaria, the Government of Japan decided to conduct the Feasibility Study on Maritsa East No. 1 Replacing Thermal Power Plant for Improvement of the Performance of the Units and the Environmental Protection in the Republic of Bulgaria and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a study team, led by Mr. Juro Inoue of Electric Power Development Co., Ltd. (EPDC) and organized by EPDC and Tokyo Electric Power Services Co., Ltd. (TEPSCO) to the Republic of Bulgaria five times from June 1995 to July 1996.

The team held discussion with the officials concerned of the Government of the Republic of Bulgaria, and conducted related field surveys. After returning to Japan, the team conducted further studies and compiled the final results in this report.

I hope this report will contribute to the promotion of the plan and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Bulgaria for their close cooperation throughout the study.

September 1996

Kimio FUJITA
President
Japan International Cooperation Agency

September, 1996

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita,

Letter of Transmittal

We are pleased to submit to you the feasibility report on Maritsa East No. 1 Replacing Thermal Power Plant for Improvement of the Performance of the Units and the Environmental Protection in the Republic of Bulgaria. This report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency as well as the formulation of the above mentioned project. Also included are comments made by related personnel of the Government of Bulgaria and Natsionalna Elektricheska Kompania during technical discussion on the draft final report which were held in Bulgaria.

This Report presents an optimum replacing project to install a coal-fired thermal power plant at the former site of two 150MW units which are currently being removed due to aging. In this Project, it is planned to use lignite coal from the Maritsa East coal mine, Bulgaria's sole domestic energy resource. The Project conforms with the environmental standards of Bulgaria. The application of existing facilities is also considered in this Project.

Upon realization of this Project, the Maritsa East No. 1 Replacing Thermal Power Plant will be able to respond to the peak demand which is expected to reach 8,470MW in 2001. It will also enable the shutdown of the initial two units (440MW each) of the Kozloduy Nuclear Power Plant. In effect, it will enable the efficient supply of adequate and stable domestic energy.

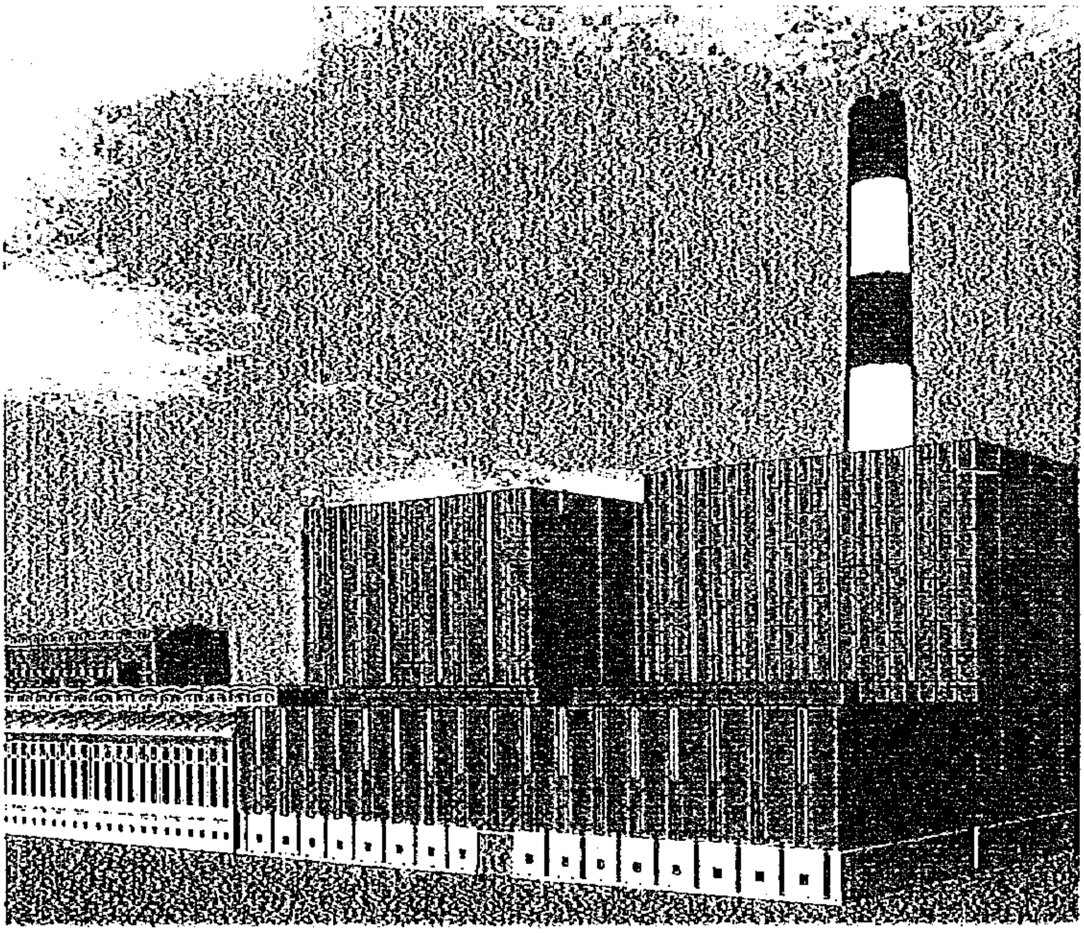
In view of the importance of Power Development and of the need for socio-economic development of the Republic of Bulgaria, we recommend that the Bulgarian Government implements this Project as a top priority.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs and the Ministry of International Trade and Industry. We also wish to express our deep gratitude to the Natsionalna Elektricheska Komapnia, and other authorities concerned of the Government of Bulgaria, Embassy of Japan in Bulgaria and JICA Vienna office for the close cooperation and assistance extended to us during our investigation and study.

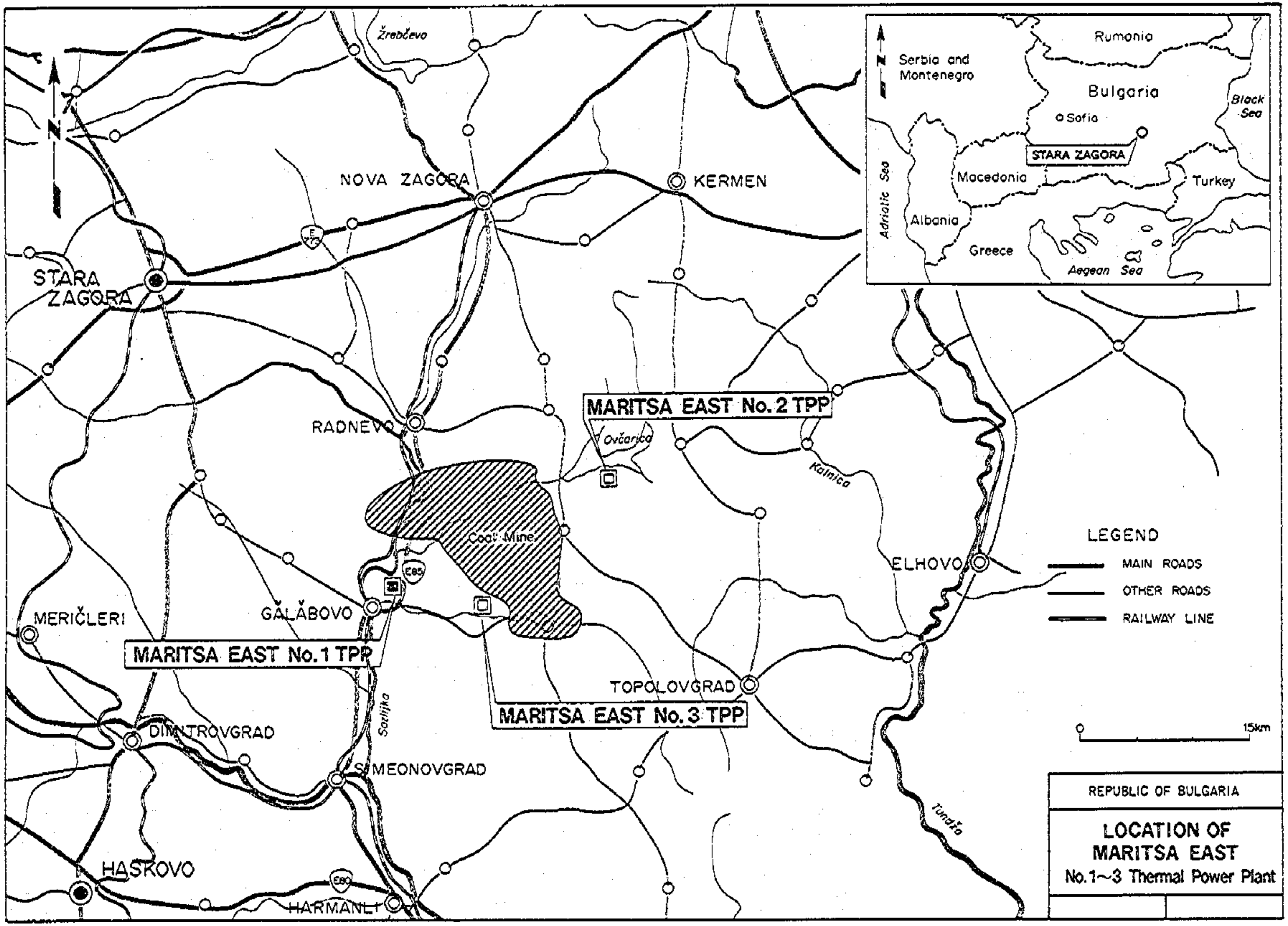
Very truly yours,

J. Inoue

Juro Inoue
Team Leader
Maritsa East No. 1 Replacing Thermal Power Plant
for Improvement of the Performance of the Units and
the Environmental Protection

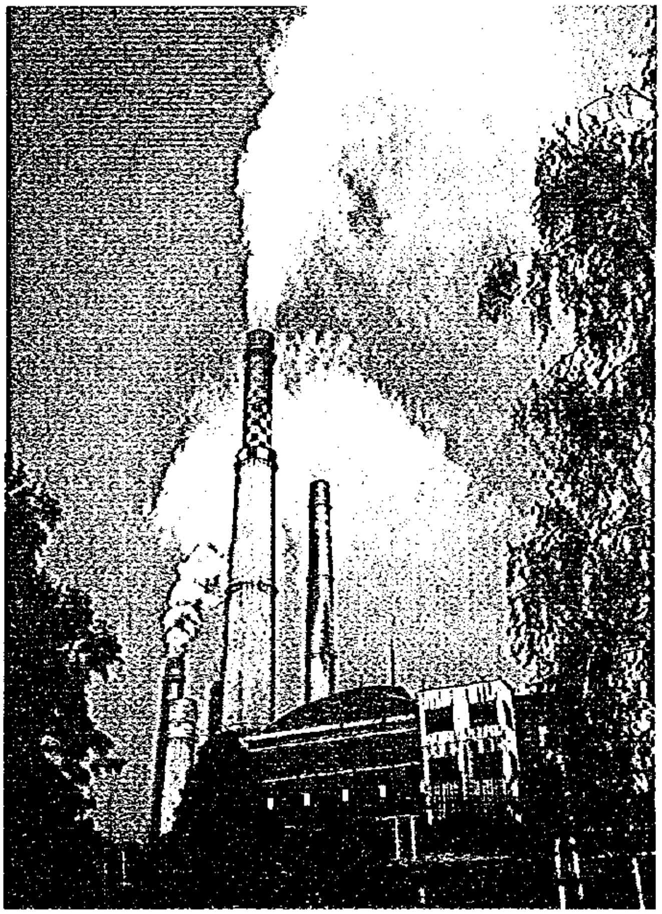


Maritsa East No.1 Replacing Thermal Power Plant

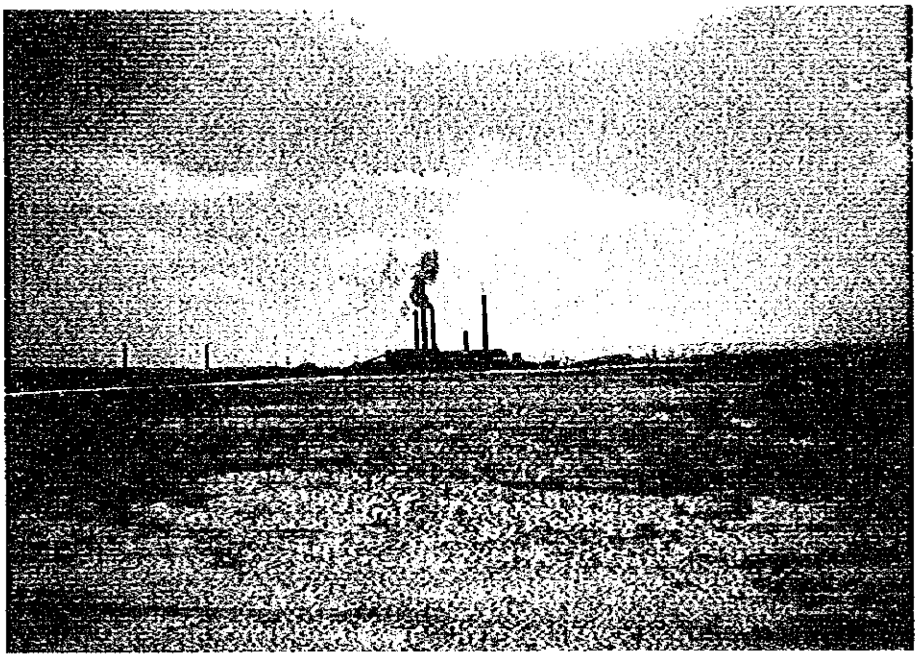


Rumonia
Serbia and Montenegro
Bulgaria
Sofia
Black Sea
STARA ZAGORA
Macedonia
Turkey
Adriatic Sea
Albania
Greece
Aegean Sea
Žrebčevo
NOVA ZAGORA
KERMEN
STARA ZAGORA
RADNEVO
MARITSA EAST No. 2 TPP
Ovčarica
Kalnica
Coal Mine
ELHOVO
LEGEND
MAIN ROADS
OTHER ROADS
RAILWAY LINE
MERIČLERI
GĂLĂBOVO
MARITSA EAST No. 1 TPP
TOPOLOVGRAD
MARITSA EAST No. 3 TPP
Sazlijka
DIMITROVGRAD
SIMEONOVGRAD
0
15km
Tundža
HASKOVO
HARMANLI
E85
E80
REPUBLIC OF BULGARIA
LOCATION OF MARITSA EAST
No.1~3 Thermal Power Plant

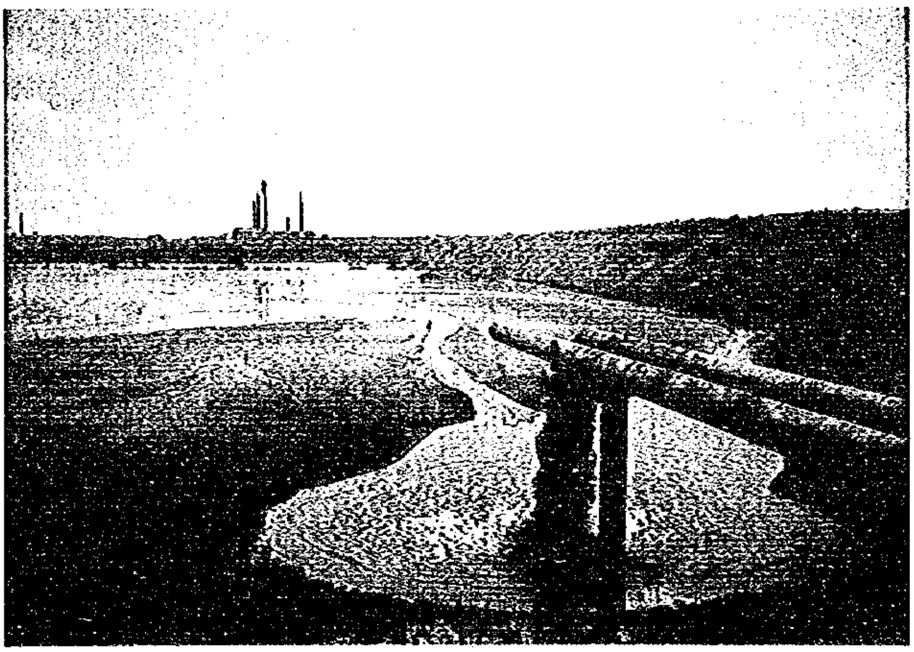
Maritsa East No.1 Thermal Power Plant and Rozovkladenets Lake
(Artificial Lake for Cooling Water)



Flue Gas from Stack for Boilers Nos.1～6 (FRONT)
and Stack for Coal Drying Facilities (LEFT)

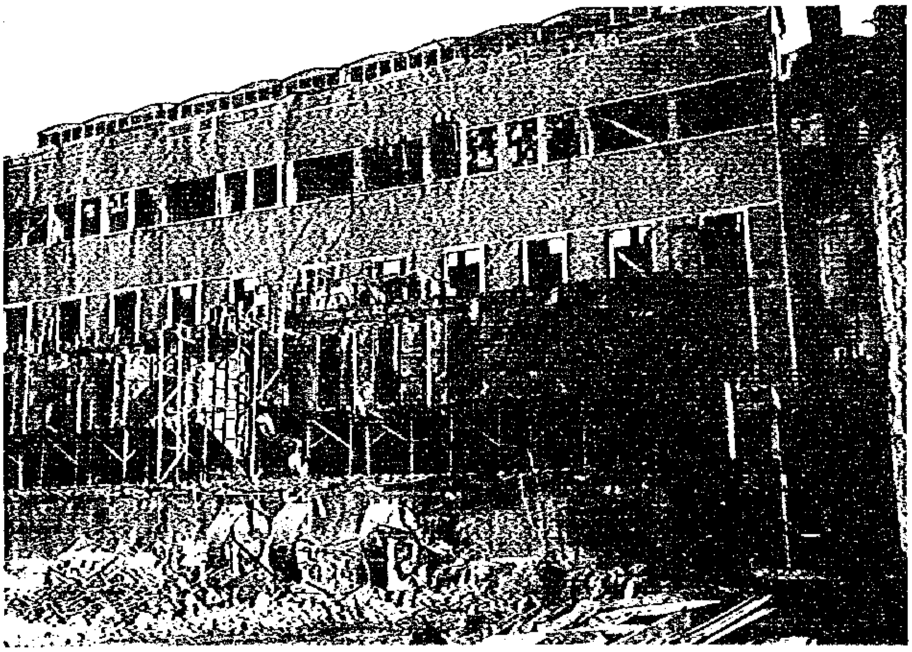


Ash Disposal Area No.1
(A Site Proposed for Coal and Limestone Storage Yard)

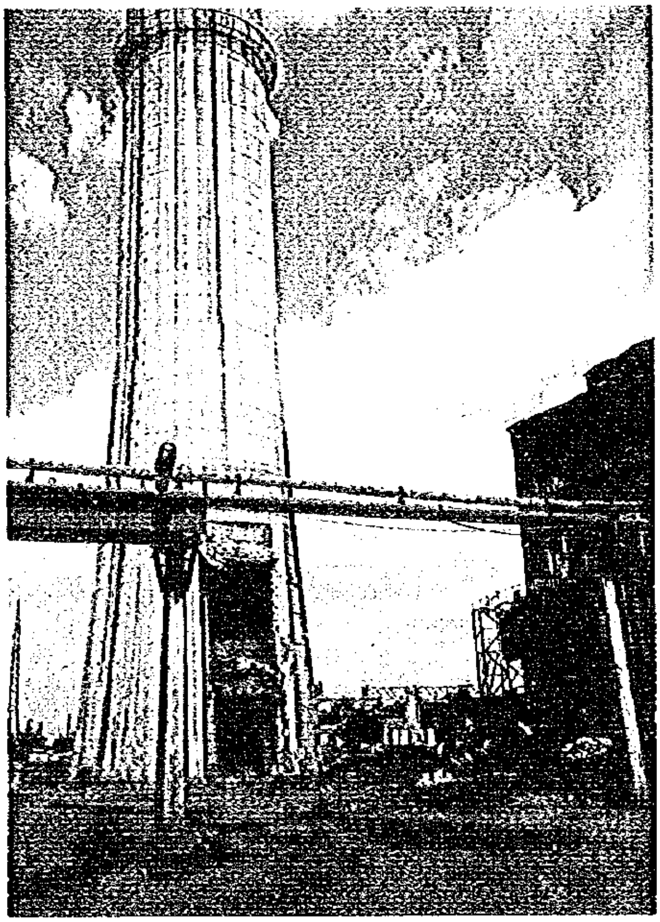


Ash Disposal Area No.3 A (for Existing Plant 4×50MW)

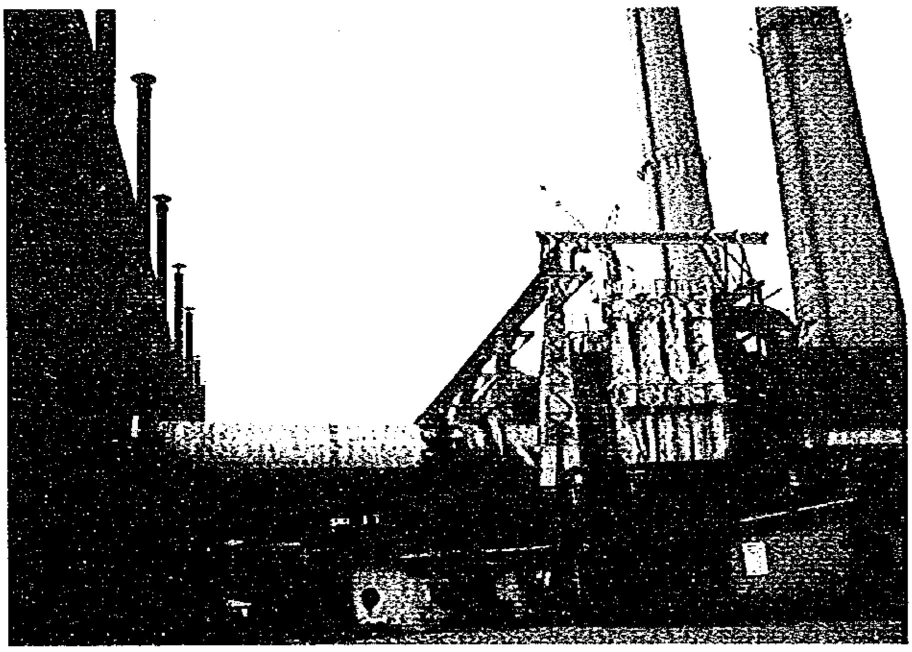
Removal of Boiler House for Old Nos. 7~10 (INSIDE)



Removal of Boiler House for Old Nos. 7~10 (OUTSIDE)

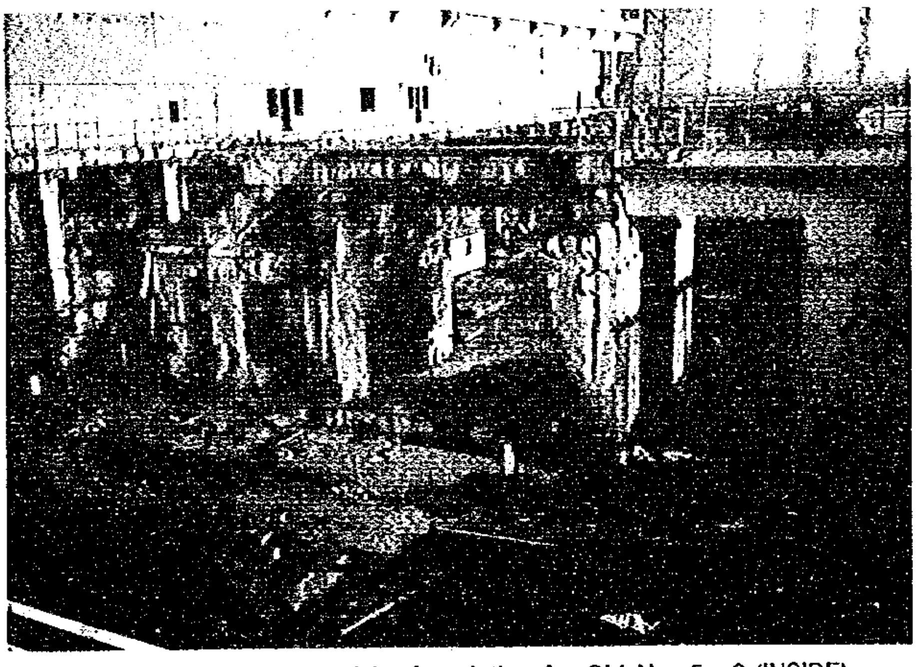


180m High Stack for Old Boilers Nos.7～10
(removed in April, 1996)

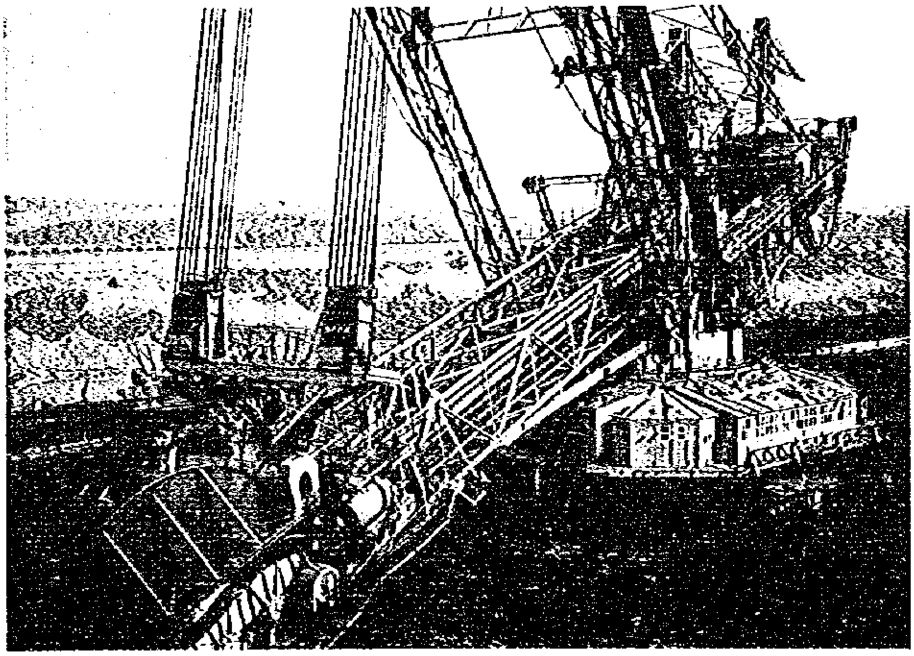


Rotary Kiln for Coal Drying and Cyclone Precipitator
(These Facilities and 120m High Stack for Old Boilers will be removed)

Reusable Crane in Turbine House for Old Nos. 5~6 (INSIDE)

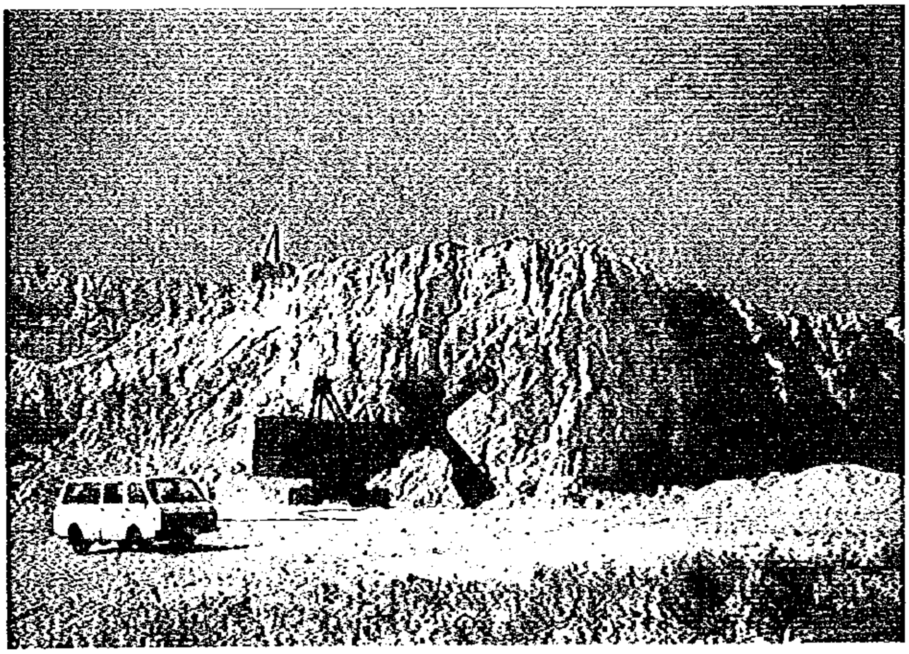


Removal of Turbine and its foundation for Old Nos. 5~6 (INSIDE)

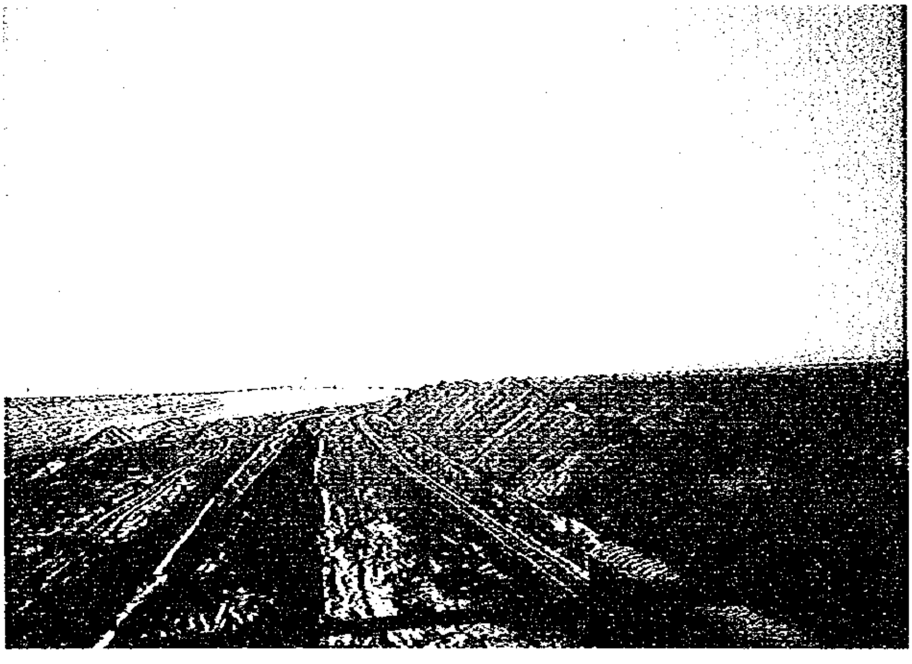


Troyanovo Coal Mine (Lignite: Open-Cast)

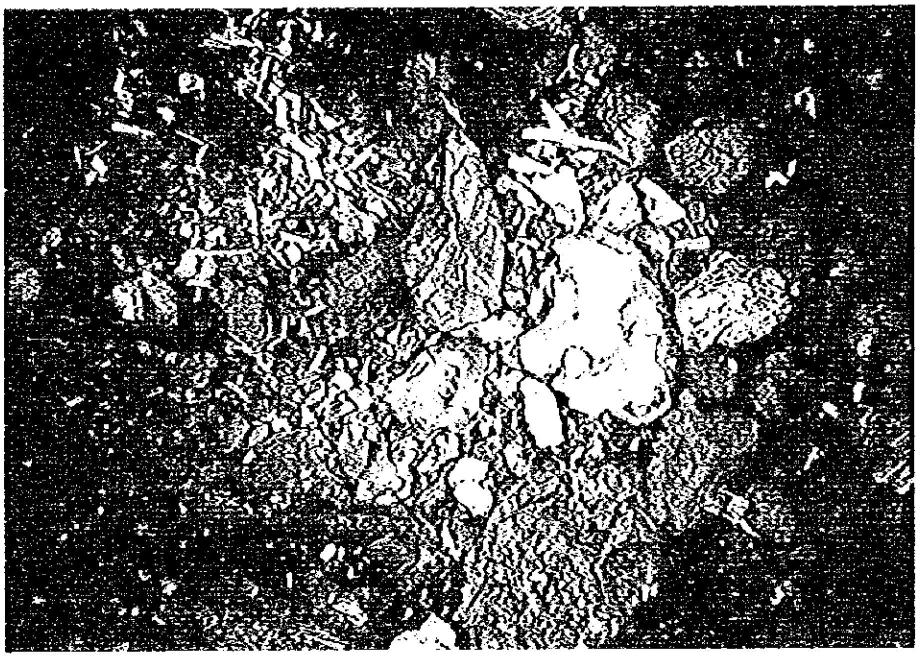
Limestone Mine to be developed (Bratyakunchevi)

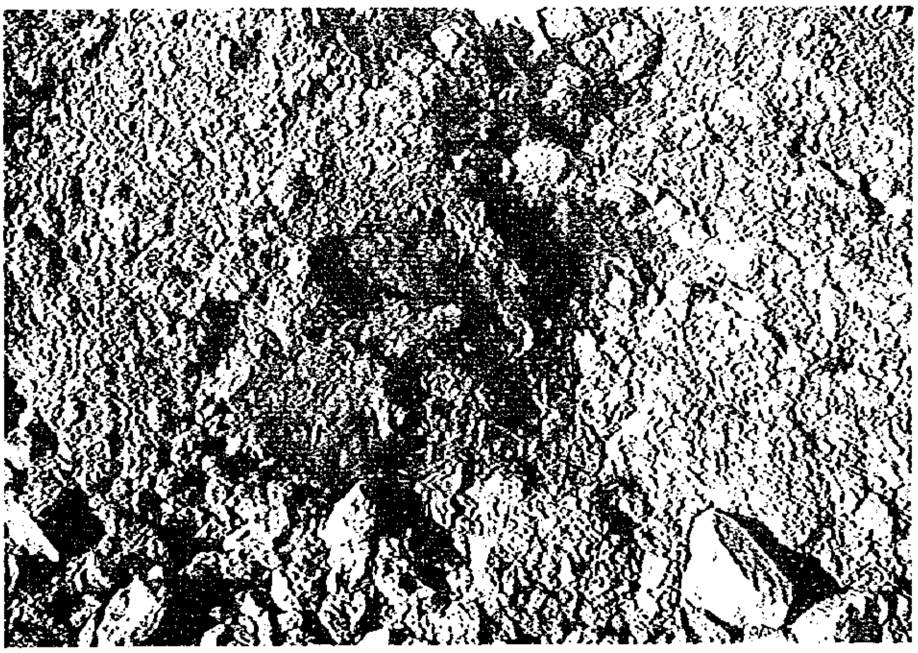


Existing Limestone Mine (Yurdere) for Cement Industry



Topsoil Disposal Area
(To be Used for Ash Disposal Area of Replacing Plant, too)


Lignite (Incompletely Carbonized)


Topsoil (Sand, Clay, Lignite, etc.)

## Contents

## ABBREVIATIONS

| | | |
|---|---|---|
| AD | : | Air Dried Basis |
| AFT | : | Ash Fusion Temperature |
| AH | : | Air Pre-heater |
| AR | : | As Received Basis |
| AVR | : | Automatic Voltage Regulator |
| BOD | : | Biochemical Oxygen Demand |
| Cap. | : | Capacity |
| CB | : | Circuit Breaker |
| CIF | : | Cost, Insurance and Freight |
| COD | : | Chemical Oxygen Demand |
| COE | : | Committee of Energy |
| CW | : | Circulating Water |
| CWP | : | Circulating Water Pump |
| DC | : | Direct Current |
| DD | : | Detail Design |
| DWT | : | Dead Weight Ton |
| ECR | : | Economical Continuous Rating |
| EGP | : | Energoprocket Ltd. |
| EIRR | : | Economic Internal Rate of Return |
| EPDC | : | Electric Power Development Co., Ltd. |
| ESP | : | Electrostatic Precipitator |
| FC | : | Foreign Currency |
| FDF | : | Forced Draft Fan |
| FIRR | : | Financial Internal Rate of Return |
| FL | : | Floor Level |
| FOB | | Free On Board |
| FS | : | Feasibility Study |
| G | : | Gal |
| Geo. | : | Geothermal |
| GDP | : | Gross Domestic Product |
| GIS | : | Gas Insulated Substation |
| GNP | : | Gross National Product |
| Grid | : | Electric Power System |
| HGI | : | Hard Grove Index (Index of Grindability) |
| H•O | : | Heavy Fuel Oil |

| | | |
|---|---|---|
| HV | : | Heating Value |
| Is. | : | Island |
| IDF | : | Induced Draft Fan |
| JICA | : | Japan International Cooperation Agency |
| LNG | : | Liquefied Natural Gas |
| LC | : | Local Currency |
| Max. | : | Maximum |
| MC | : | Metal Clad Switchgear |
| MCR | : | Maximum Continuous Rating |
| Min. | : | Minimum |
| MOEER | : | The Ministry of Energy and Energy Resources in Bulgaria |
| MSV | : | Main Stop Valve |
| NEK | : | Natsionalna Elektricheska Kompania |
| NOx | : | Nitrogen Oxides |
| NPV | : | Net Present Value |
| PAF | : | Primary Air Fan |
| PF | : | Power Factor |
| R1 | : | Replacing No.1 unit |
| R2 | : | Replacing No.2 unit |
| S | : | Sulfur |
| SCR | : | Short Circuit Ratio |
| SOx | : | Sulfur Oxides |
| SPL | : | Sound Pressure Level |
| SPM | : | Suspended Particulate Matter |
| SS | : | Suspended Solid |
| S/S | : | Substation |
| TEPSCO | : | Tokyo Electric Power Services Co., Ltd. |
| TL | : | Transmission Line |
| TM | : | Total Moisture |
| Tr. | : | Transformer |
| VAT | : | Value Added Tax |
| VM | : | Volatile Matter |

# 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 |
| kWh | : | kilowatt-hour |
| MWh | : | megawatt-hour |
| GWh | : | gigawatt-hour |
| Btu | : | British thermal unit |

**Units of Heating Value**

| | | |
|---|---|---|
| kcal/kg | : | kilocalorie 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**

| | | |
|---|---|---|
| L | : | Leva |
| US$ | : | US Dollar |
| ¥ | : | Japanese Yen |

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# CONCLUSION AND RECOMMENDATION

# CONCLUSION AND RECOMMENDATION

## [CONCLUSION]

This survey was conducted as a feasibility study of a replacing project to construct at the area where old unit nos. 5 and 6 (each rated 150MW) in the Maritsa East No.1 Thermal Power Plant new units firing the lignite, main energy resource of the Republic of Bulgaria (hereinafter referred to as Bulgaria), satisfying environmental requirements stipulated in the Bulgaria or EC standard, and having an optimum design from technological and economic point of view.

As a result of studies and evaluations made from technological economic, financial and environmental aspects in the feasibility study, it has been concluded that the proposed replacing project is feasible. The contents of the conclusion are as follows.

1. In Bulgaria, the demand for the electric power for industrial use has been smaller than that for private use since the political change in 1989, or so to speak a sort of reversal of demand structure has been seen, but it has been increasing slowly since 1994. It is predictable that the total demand for electric power will be increasing steadily if the demand for electric power for industrial use increases accompanying the steady economic growth of Bulgaria from now on. The demand for electric power in 2010 is estimated based on the GDP and the change in population (1993 as base year), as follows.

   (1) Low case (GDP growth rate: 3%)

   2,100 US$ per capita → 4,100 kWh per capita → 37,000 GWh (Increase by 16% more than in 1995)

   (2) Middle case (GDP growth rate: 4%)

   2,400 US$ per capita → 4,200 kWh per capita → 38,000 GWh (Increase by 19% more than in 1995)

   (3) High case (GDP growth rate: 5%)

   2,700 US$ per capita → 4,300 kWh per capita → 39,000 GWh (Increase by 22% more than in 1995)

   There are many problems relating to the future electric power supply. The import of Ukrainian coal as the fuel for the thermal power plants has been unstable. Besides, the wear of existing generating facilities has progressed to a considerable extent; for instance, it is anticipated that the superannuated No. 1 and No. 2 units (2 x 440MW) at (Kozloduy) nuclear power plant will be compelled to be dismantled from around 2000. NEK's electric power source development schedule based on the estimate of the demand for electric power (to be completed by around 2005) is as follows:

(1) Scale of electric power source development: 951MW (Increase by 9%) → Generating facilities: 11,540MW

| | | | |
|---|---|---|---|
| (Thermalpower) | To be increased by 1,275MW | → (Thermalpower) | 6,130MW (53.1%) |
| (Hydropower) | To be increased by 476MW | → (Hydropower) | 2,710MW (23.5%) |
| (Nuclear power) | To be decreased by 800MW | → (Nuclear power) | 2,700MW (23.4%) |

(2) The electric power supply potentiality will be lowest from 2000 through 2001 due to decrease in the capacity of nuclear power plant.

Thus, there is a possibility that the supply-demand relation of electric power in Bulgaria will become considerably tight around 2000, and so there will be very pressing need for early development of new electric power supply sources. Also, in formulating the electric power supply plan in Bulgaria, it is important to incorporate replacing as well as repairing and remodeling of the existing power plants as a means to increase power generation capacity.

The result of analysis of electric power supply system in 2001 when the operation of the replacing plant will be commenced is as follows:

(1) Electric power current calculation:

No difficulties will be seen in the voltage of bus bar and current of transmission line of each substation.

(2) Short-circuit capacity: 535MVA (3-phase short-circuit current: 1.4kA)

(3) Transient stability: Stable without difficulty

2. Currently, the coal is supplied to the power station by railway wagon from the north mining area of Maritsa East coal mine (an open cast lignite mine) with the largest domestic deposit (85% or more). The total deposit of the coal is about 520 million tons which is large enough to meet annual consumption of about 5.2 million tons / year for 30 years or more. Besides, the existing mining facilities and railway system therefrom to the power plant can be utilized as it is.

However, the prior arrangement or conference with the coal mining companies concerned at the following points will be required:

(1) In concluding coal purchasing agreement with the coal supplier, it is important to include a conditions concerning sulfur content in addition to those concerning the contents of ash, water and calorific value.

(2) Since the existing coal storage yard is planned to be converted to No.1 ash disposal yard, the additional railway for incoming coal needs to be laid. Also, it is necessary to clarify the scope and responsibility of the construction work to be executed for such railway between the power plant and coal mining company. Furthermore, the construction work for new railway should be coordinated with the work for the replacing plant and operation schedule of the currently operating power plant.

(3) The clay content in the coal is the worst hindrance to the coal conveyance and coal crushing processes in power plant, and so the purchasing department of power plant should require the shipping department in the coal mining company to do their best for eliminating the clay content from the coal before loading the freight train with the coal.

3. The limestone to be used as desulfurizing agent is distributed in various locations (4 locations) within the range of 100km from the power plant. Of these limestone fields, two fields (in Yurdere and Chala) are currently exploited as the raw material for the cement by cement plants currently operating there. Other two fields have not been developed yet for the aforementioned purposes, except one located in "Bratyakunchevi" which has been currently exploited as a gravel producing plant. The limestone field located in "Purachakunchebi" not only has a large deposit of about 90 million tons for annual consumption of about 1.1 million tons but also has a railway leading to the power plant, and hence has a potentiality for being developed as a dedicated field for desulfurizing agent.

Development of this limestone field, however, has to be promoted coordinating with the proposed construction plan of a flue-gas desulfurization system at Maritsa East No.2 thermal power plant (No. 8 unit), and geological survey should be conducted again following one conducted about 30 years ago.

4. Principal specifications of the optimum development plan are as follows:

(1) Electric output: 230MW x 2 units

(2) Hot water for local heating: 25 Gcal/h

* Hot water will be supplied from one of two units.
The electric output of a unit supplying hot water will be reduced by a output equivalent to the calorific value thereof.

(3) Steam conditions:
Main steam flow = 740 t/h (MCR)
Main steam pressure = 169kg/cm$^2$g (2,400 psig) (at turbine inlet)
Main steam temperature = 538°C (1,000°F) (at turbine inlet)
Reheated steam temperature = 538°C (1,000°F) (at turbine inlet)

(4) Properties of lignite, ash and limestone: (for design)
Refer to Requirement for Development Survey; TOR (Terms of Reference) of January 12, 1995

(5) Emission standard: ($O_2$ = 6%, dry base)

$SO_2$ = 650mg/m$^3$N (227ppm) or less (Bulgarian Standard), or 90% or more of desulfurizing efficiency (EC Standard applicable when coal having a high sulfur content is used)
NOx = 600mg/m$^3$N (292ppm) or less (Bulgarian Standard)
Dust = 100mg/m$^3$N or less (Bulgarian Standard)
CO = 250mg/m$^3$N (200ppm) or less (Bulgarian Standard)

(6) Water quality standard: To conform to Group A Class III of Bulgarian Standards for "Index and standard applicable to evaluation of the quality of surface running water".

(7) Annual use rate of plant: 70%

(8) Minimum load: 40%

(9) Overload:
Boiler MCR = ECR x 103% or less
Turbine TMF = Rated output x 105% or less
Generator = Rated output x 105% or less

(10) Deposits of lignite and limestone: Amount to be consumed to operate the plant for 23 days (as per Bulgarian Standard)

5. The following models are selected as the main equipment in the optimum development plan, based on the aforementioned principal specifications.

(1) Boiler: C-FBC (Circulating Fluidized Bed Combustion)

(Reason of Selection)
The three different types, namely, two types of fluidized bed combustion boiler (circulation type and bubbling type) and pulverized coal fired boiler plus flue gas desulfurization equipment (wet type limestone-gypsum method) were compared from technological and economic aspects on the condition that all these three types of boiler have actually been used commercially, are capable of conforming to flue gas standard value and are adaptable to the nature and conditions of the lignite.

As a result, it was found that technologically the circulating type fluidized bed boiler and pulverized coal-fired boiler plus flue-gas desulfurizing system (wet type limestone-gypsum method) are applicable, that economically the circulating fluidized bed boiler is advantageous and that, comprehensively judging, a circulating type fluidized bed boiler is advantageous.

(2) Dust collector: Electrostatic type

(Reason of Selection)
For comparison, electrostatic precipitator and bag filter were selected and compared technologically and economically. As a result, a electrostatic precipitator was chosen as having advantages as to maintenance, operation, economy and actual experience in the existing plants over a bag filter of which the performance is largely affected by reliability of bag.

(3) Turbine: TCDF (Tandem Compound Double Flow)

(Reason of Selection)
This type turbines have been used widely and are characteristic of highly efficient operation and control and easy maintenance. In addition, this type turbines have been used in Maritsa East No.2 and No.3 thermal power plants.

(4) Generator: Liquid-hydrogen-cooled, horizontal-shaft, cylindrical, revolving magnetic field, explosion-proof, 3-phase AC, synchronous type

(Reason of Selection)
The same as that for a turbine.

6. The old No.5 and No.6 generators of the existing thermal power plant are being dismantled currently. As a result of study of the existing equipment and facilities as to whether they are reusable or not in order to reduce replacing cost, the following items are found to be reusable, subject to some treatment as the case may be.

(1) Cooling water channel facilities

(a) Screening pump room needs to be reformed with respect to its guide walls for installation of the screen and concrete slabs of foundation incidental to replacement of the pump.

(b) Water intake channel:

1) Existing circular concrete culvert: Good for reuse

2) Existing steel pipe section directly laid underground: Required to be reinforced to cover the markedly reduced wall thickness (from 8mm to 5.5 - 7.4mm)

- Where some structure or disturbance exists on the relevant ground, the existing steel pipe should be reinforced by inserting new steel pipe into it, and the gap therebetween should be filled with mortar.
- Where no structure or disturbance exists on the relevant ground, the existing steel pipe should be replaced with new steel pipe and covered with concrete.

3) New water line: New steel pipes shall be installed up to the turbine and covered with concrete.

(c) Water discharge channel:

1) Existing box culvert: Good for reuse

2) New box culvert to be constructed: To be installed up to the turbine and reinstalled.

3) New circulating water channel to be constructed: New steel pipe should be laid from the box culvert up to the turbine and covered with concrete.

(2) Turbine room in main building

Concerning the existing turbine room, concrete neutralization is found to have progressed to a certain extent but not to a extent affecting its durability. However, the area where the old No.5 and No.6 turbines were located is not large enough for a layout of equipment to be installed for the replacing plant. Thus, such a space should be obtained by extending part of the existing building.

However, a combination of the existing building and new building will give rise to a problem such as difference in service life of the buildings, and so careful consideration and prior study are required for design of a new building e.g. adjusting the distribution of loads to act on the buildings and giving some restrictions in determining layout of various equipment.

(3) Stack

a) The existing stack (180m high) for old No.5 and No.6 boilers stands in the space required for the machines and equipment to be installed in a replacing plant, so that this stack cannot be reused.

b) The existing stack (120m high) for the coal drier cannot be reused because a difficulty of flue gas diffusion will be seen due to the downdraft effect caused by the boiler building and further because its outlet diameter is too small for the flue gas from replacing boilers to pass through.

(4) Machines and equipment

(a) Total capacity of existing river water supply pumps is not large enough, so that one of the existing pumps should be replaced with a new one. A part of the existing water supply piping can be reused, but the piping section to be reused should be branched for connection to the replacing plant.

(b) Existing overhead crane itself in the building house can be reused, provided that the additional rails are installed. But the load test shall be conducted prior to reuse of the crane.

(c) Existing crane for maintenance work in circulating pump room can be reused, provided that its capacity is not less than the weights of new pump and new motor.

(d) Existing piping for district heating system can be reused, but new piping should be installed, corresponding to extension of the building for turbines.

(e) Existing fire-fighting facilities can be reused, but new piping should be installed on the ground where the existing piping is interfaced with a replacing plant.

(f) The existing railway, building and tunnel for receiving coal for nos. No.7 through 10 can be used.

7. Based on the main equipment selected in the optimum development plan and the result of study for reusable existing equipment, the conceptual designs have been made for the following item and main equipment for a replacidng plant.

- Layout
- Turbine and auxiliaries
- Heat supply facility
- Ash and limestone handling facility
- Compressed air supply facility
- Fuel and limestone storage and transportation facilities (for coal, limestone, crude oil and LPG)
- Switchyard and power substation
- Boiler and auxiliaries
- Generator and auxiliaries
- Environmental equipment (ESP, waste water treatment)
- Water supply equipment for thermal power plant
- Electric, control and instrumentation equipment
- Building and stack

8. The processes of construction work of a replacing plant have been determined, taking into consideration the time by which the need of new power supply source is expected to arise, experiences of local contractors in executing the construction works of a scale similar to the construction work of a replacing plant and the effects of seasonal weather conditions on the progress of the construction work efficiency.

However, the schedule of the proposed plan is probably subject to modification, depending on the time required for budgeting and progress of the work to be performed by NEK.

| | | (Unit R1) | (Unit R2) |
|---|---|---|---|
| (1) | Completion of F/S | End of Aug. 1996 | Same as left |
| (2) | Existing of financial source (about 6 months - 1 year) | End of Jun. 1997 | Same as left |
| (3) | Selection of consultant | Beginning of Jan.1997 | Same as left |
| (4) | Completion of basic/definite design and tender-documents | End of Aug. 1997 | Same as left |
| (5) | Completion of tender evaluation and contract award | | |
| | • Civil/Architecture/Erection Island | Beginning of Apr. 1998 | Same as left |
| | • Boiler, Turbine and C/H Islands | Beginning of Jun. 1998 | Same as left |
| (6) | Commencement of civil work | Beginning of Apr. 1998 | Same as left |
| (7) | Boiler steel erection | Beginning of Aug. 1999 | 6 months later |
| (8) | Boiler hydro-static test | Beginning of Sep. 2000 | 6 months later |
| (9) | Power receiving and commencement of trial operation | Beginning of Dec. 2000 | 6 months later |
| (10) | Initial firing | Beginning of Apr. 2001 | 6 months later |
| (11) | Synchronization | Beginning of Jul. 2001 | 6 months later |
| (12) | Commencement of commercial operation (Unit R-1) | Beginning of Oct. 2001 | 6 months later |

9. The replacing cost was estimated based on the design, work execution processes, materials, products and technological level expected to be available as in January, 1996, taking into consideration the actual costs of international construction works of a scale similar to that of the proposed replacing plant on the conditions that the machines and equipment are basically to be imported through successful contractors to be decided through a process of international competition tendering and works are to be undertaken by the local contractors through a process of domestic competition tendering.

The construction coat is as follows.

(unit: $10^6$US$)

| [Direct Construction Cost] | | (Foreign currency portion) | (Local currency portion) |
|---|---|---|---|
| • Boiler island | 226.0 | 192.1 | 33.9 |
| • Turbine island | 106.0 | 90.1 | 15.9 |
| • Coal and limestone handling island | 89.1 | 75.7 | 13.4 |
| • Civil architecture/erection works island | 144.2 | 62.0 | 82.2 |
| (Subtotal) | 565.3 | 419.9 | 145.4 |
| [Technological Cost] | 20.0 | 20.0 | - |
| [Reserved Budget Cost] | 20.0 | 15.0 | 5.0 |
| (Grand Total) | 605.3 | 454.9 | 150.4 |

The operation maintenance cost and electric power generating cost of the replacing plant are as follows:

[Operation maintenance cost]

- Fuel cost: 30,312 x 103 US$/year = 1.1 cent/kWh
- Utility cost such as costs of limestone, labor and repair: 28,141 x 103 US$/year = 1.0 cent/kWh

[Electric power generating cost]

- Cost at power generating end: 4.6 cent/kWh
- Cost at power transmission end: 4.9 cent/kWh

10. The effects of the operation of a replacing thermal power plant on the neighboring environment (effects through atmosphere, waste water, noise and heated waste water) were estimated and the following results were obtained.

(1) Air pollution

The substances to be estimated are SOx, NOx and dust. The results of estimates of the short-period diffusion (for only the time period immediately after replacement) and long-period diffusion (during operation of No. 1 through No. 6 units, during operation of No. 1 through No. 4 units i.e. current conditions, and after replacement) are as follows:

Note that the effects of the pollution-causing substances from Maritsa East No.2 and No.3 thermal power plants on their neighboring environments are considered to be extremely large, but the effects of these power plants are not included in this estimate, since their effects will be estimated separately.

[Short-period diffusion estimate]

- Maximum ground concentration:
  Estimated values of all the substances satisfy the requirements of the national standards of Bulgaria.

- Distance from the source of pollution-causing substance where its maximum ground concentrations is seen:
  About 17.6km away from the stack

[Long-period diffusion estimate]

- During operation of No.1 through No.6 units: Ground concentrations of SOx and dust largely exceeded the national standards of Bulgaria.

- During operation of No.1 through No.4 units: The same as the above.

- After replacement: The national standards of Bulgaria are supposed to be satisfied.

Furthermore, the emissions of sulfur oxides and dust after the replacing work (for units R1 and R2) are estimated to decrease as follows compared with those during operation of No.1 through No.6 units and during operation of No.1 through No.4 units, respectively.

| | |
|---|---|
| Sulfur oxides: | 54.4 t/h - 5.3 t/h = 49.1 t/h (decrease by about 90%) |
| | 32.5 t/h - 5.3 t/h = 27.2 t/h (decrease by about 84%) |
| Soot and dust: | 8.28 t/h - 0.2 t/h = 8.08 t/h (decrease by about 98%) |
| | 4.54 t/h - 0.2 t/h = 4.34 t/h (decrease by about 96%) |

(2) Pollution caused by waste water

The pollution of river caused by the drainage from the thermal power plant can be expected to be reduced if appropriate waste water treatment facility is provided within the premises of the power plant, but the real solution to this problem will not be possible unless a total pollution control plan and measures covering the whole locality including the controls of other pollution sources are executed.

In addition, it is expected that the effluent control should be made at an early stage, based on the revision of the existing laws and regulations.

(3) Noise

The predicted noise level within the premises of the power plant, if low-noise machines and equipment were adopted and installed in the buildings, would not be so high as to cause problems.

The existing noise control attaches greater importance to the environmental noise level to which the workers in the power plant are exposed rather than the noise level along the boundary of the plant.

On a long-term basis, however, if the noise control measures are taken after noise problem actually occurs, it would require greater cost and works of greater scales. Therefore, it would be wise to take appropriate noise control measures for the machines and equipment which are considered to be the sources of noise, at the planning stage.

(4) Hot waste water

Concerning the possibility of rise of the water temperature in Rozokuranetsu Lake caused by discharge of the condenser cooling water, the hot waste water diffusion analysis was conducted assuming that the difference in water temperature between intake channel and discharge channel is 7°C. The result of analysis indicates that the water temperature tends to be higher near the outlet of cooling water discharge channel, but the area of higher water temperature is limited in the vicinity of the outlet of discharge channel. Therefore, the lake was found to be capable of functioning as the cooling water source. Also, there will be little influence on the environment, as the warm discharged water can be used for the fish firm.

11. It is revealed that the replacing project is better in economic evaluation than the alternative plan; construction of the coal-fired thermal power plant using the imported coal, and that the former has advantages over the latter in terms of all the indexes.

Also, the result of sensitivity analysis (sensitivity to affect the construction cost, equivalent discount rate and fuel cost) indicates that the replacing project has advantages over the alternative project.

(1) Considering the two indexes, namely, net present value (benefit minus cost) and benefit/cost ratio (benefit/cost), the construction cost, maintenance cost and fuel cost for the replacing

project has economic advantage over those of alternative coal-fired thermal power plant using the imported coal.

(2) The equivalent discount rate (economic internal rate of return or EIRR), in terms that the investment in the replacing project and the investment in the alternative project are equal in the first year of the replacing project, is 25.3%, which is larger than the opportunity cost of the capital. Therefore, it is revealed that the proposed project is feasible.

12. For the purpose of financial evaluation, the revenues from the sales of the electric power and steam for district heating, to be compared with the investment cost (construction cost and operation maintenance cost), are calculated on the conditions that the standard electric power rate (4.5 cents/kWh) and steam rate (31.4 dollars/Gcal) as in 2001 will remain unchanged, that the interest rate of borrowing in foreign currency is 8.0% for 20 years, and that the interest rate of borrowing in domestic currency is 10% for 15 years. As a result, the financial internal rate of return (FIRR) is 8.8%, indicating that there will be no problem for the repayment of the borrowing in foreign currency, but the repayment will be difficult if the discount rate of 10% prevailing in the domestic financing market.

Thus, the feasibility of adopting new electric power rate system is currently studied. If the unit price of the electric power rate in 2001 is revised to 5.0 cents/kWh based on the present rate, the FIRR will exceeds 10% assuring better financial conditions.

13. The socioeconomic effects of the proposed replacing project are as follows:

(1) Favorable effects of increase in investment on economy and opportunity of employment can be expected.

(2) The replacing project introduces for the first time a circulation type fluidized bed thermal power plant Bulgaria, contributing to the development of new electric power source utilizing domestic lignite and spread of related technology.

(3) Vitalization and growth of construction, mining, iron and steel, electric machine, transportation, communication and other industries relating to electric power generating industry can be expected.

(4) A method for macroeconomically evaluating the socioeconomic effects of the execution of environmental protection measures has not been well established yet, but the favorable effects of such measures on the health, declining of disease, living environment, social

environment and natural environment of the local inhabitants can be expected judging from the favorable effects that the environmental protection measures actually proved in other countries.

**[Recommendations]**

The proposed replacing project is not only technologically and economically feasible but also capable of contributing greatly to the solution of the local environmental problems. And, this project should be executed as soon as possible judging from the prediction of the supply-demand relation of the electric power around 2001.

For earlier materialization of the project, the following matters should be considered.

1. For the successful execution of the replacing project, the financing for the project will play a vital role. For this purpose, it is important that involving the coal mining and limestone industries, the replacing project to be promoted substantially as one of the national projects by seeking the positive effort of the Bulgarian government in winning the cooperation of the international financing institutions.

2. Scheduling of repayment is equally important to the borrowing plan. It is preferred for the costs relating to the investment construction cost, operation maintenance cost to be surely recovered by the electric power rate. For this purpose, it is necessary to reconsider the existing electric power tariff system as soon as possible in order to establish the schedule for the repayment of borrowing.

3. In order to reduce the replacing cost as much as possible, it is necessary not only to use the domestic materials, machines and equipment but also to employ local contractors for the execution of the works to the largest possible extent. For this purpose, it is also necessary to conduct prior detailed investigation and evaluation of the capacities, experiences and potentialities of major domestic manufacturers and contractors who are expected to participate in the replacing project.

   In view of the importance of this project, as well as in order to make the project feasible, the application of the preferential tax rates is essential. Thus, it is necessary to have prior conferences with the governmental organizations concerned with regard to the exemptions of taxes on the salaries and allowances to be paid to the instructors and trainers of foreign nationals, and simplification of the related procedures.

4. Sincere technical consultants who have adequate experiences and are familiar not only with domestic regulations but also with various local situations in Bulgaria should be employed as soon as possible. Various matters and problems should be discussed or solved in promoting and implementing this project.

Furthermore, some local consultant has the custody of and controls all the drawings, data, etc. relating to the designs and executions of works for the retrofit and dismantling of all the existing electric power generating facilities owned by NEK. Further he has undertaken all the engineering works relating to the retrofit and dismantling of the existing facilities at the start of this project. In order to reflect on the new designs the solutions to the problems which have caused various troubles experienced in Maritsa East No. 1 thermal power plant and neighboring No. 2 and No. 3 thermal power stations, as far as the principle formation of contract is not jeopardized, close involvement of such a company would be contributory to effective and successful project implementation.

5. This study comprises the initial environmental evaluation (IEE) and environmental influence assessment (EIA) on Maritsa East No.1 thermal power plant. However, it is necessary for an environmental influence assessment report to be prepared in accordance with the form specified in the regulations of Bulgaria, consulting with the Environment Ministry prior to its publication, further for monitoring of environmental condition to be executed, if necessary, and for approval of the Environment Ministry and local inhabitants to be obtained prior to the publication of the report.

   Furthermore, it is desirable to prepare for and maintain necessary system for the future need of environmental influence assessment on Maritsa East complex as the whole (including Maritsa East No.2 and No.3 thermal power plants), since such need seems to arise in the future.

6. Before commencing the execution of the proposed project, conference with coal mining companies and limestone mining companies concerned should be made on the following subjects.

   (1) Subjects of conference with coal mining companies:

   - Adjustment of the conditions concerning the properties of coal stipulated in the sales agreement.
   - Agreement to severer quality control against the clay ingress to the coal.
   - Agreement to conditions for the use and operation schedule of freight wagons to be used for the transportation of coal.

- Agreement to use of the surface soil disposal yard owned by the coal mine as ash yard of the power plant and the conditions for the use and operation schedule of the freight wagons for this purpose.

- Agreement to sharing of the responsibility for the work execution processes relating to the modification of existing railway or laying new railway incidental to the construction of new coal yard of the power plant.

(2) Subjects of conference with limestone mining companies:

- Since the limestone deposit expected for use for the power plant is still left undeveloped, the limestone mining company concerned should draw up its development plan and take necessary measures for financing the development plan in order to meet the progress of the replacing project.
  The limestone mining company should also consider alternative measures against possible delay of limestone mining development.

- Agreement to conditions for the use and operation schedule of freight wagons to be used for the transportation of the limestone.

7. The circular and box concrete culverts of the existing intake and discharge channels have been used as common facility to all units in the thermal power plant. The soundness test of these culverts have never been conducted, and the progresses of the deteriorations of individual culverts are not known.

   Thus, in this feasibility study, those culverts are assumed to be in sound condition judging from that the power plants has been operated without troubles. For this reason, it is necessary to examine the soundness of these existing culverts prior to the start of the execution of this project.

# CHAPTER 1. INTRODUCTION

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# CHAPTER 1 INTRODUCTION

## 1.1 Background and Process of the Study

### 1.1.1 Outline of Power Demand in the Republic of Bulgaria

The power demand in Bulgaria increased and reached its peak in 1989. Since the national revolution toward democratization and introduction of a market economy in 1989, however, a reverse phenomenon occurred; power demands fell at an annual average of 8% in the industrial field as a transient phenomenon, and with this, the industrial demand fell below that for public services. However, considering the movement toward a market economy as promoted by the Bulgarian Government, it is certain that power demands will increase in the future.

### 1.1.2 Power Supply in the Republic of Bulgaria

Regarding the power supply in the Republic of Bulgaria, the installed capacity is approx. 12,000MW; 51.7% by thermal power, 29.5% by nuclear power, and 18.8% by hydro power. This proportion ratio has remained almost the same for the last few years.

The majority of thermal power plant facilities were manufactured in the former U.S.S.R. or other East European countries. These facilities are now aged. In the case of nuclear power plants, the initial two units (440MW each) of the Kozloduy Nuclear Power Plant will be forced to shutdown in the near future.

Regarding the seasonal demand/supply balance, the supply capacity in winter is especially severe although its reinforcement is expected in the future in line with an ongoing economic recovery.

### 1.1.3 Outline of Energy Conditions in the Republic of Bulgaria

The major share of energy consumed in the country depends on imports. Natural gas and petroleum were previously acquired from the former U.S.S.R. and coal from the Ukraine, due to the close relationship with the former U.S.S.R. In response to the market economy, however, a stable supply from other countries has become difficult, and such a situation has already begun to affect the thermal power plants which use Ukrainian coal.

Dependency of Bulgaria on other countries for the primary energy source was 74% in 1995. It is predicted that this will reach 75.3% in 2000, 77.2% in 2010, and soar to 84% in 2020.

Today's most important measure is, therefore, to promote the effective use of domestic energy resources, namely the effective use of lignite which represents almost 85% of Bulgaria's entire domestic coal production. Domestic lignite is characterized with a low calorific value, a high moisture content and a high sulfur content.

### 1.1.4 Present Environmental Problems in the Republic of Bulgaria

Lignite produced in the Maritsa Region is the main and relatively sufficiently acquired domestic energy resource in the Republic of Bulgaria. At this time, its reserve is believed to be approx. 1.7 billion tons.

Regarding the fuel used at NEK's thermal power plants with a total of 6,415MW installed capacity, coal overwhelms all other fuels; 4,118MW or 64% by domestic coal, 1,847MW or 29% by imported coal, and 450MW or 7% by petroleum.

The Bulgarian Government has promoted the construction of coal-fired power plants as well as the development of nuclear power plants. Due to a high sulfur and high ash content, however, air pollution and other environmental problems have now become matters of serious concern.

Currently, various data estimate the following air pollutive substance generation: $SO_2$; 2.38 million ton/year, $No_x$; 0.42 million ton/year, and dust; 0.65 million ton/year. Approx. 25% - 50% of this is believed to be generated by thermal power plants. In comparison to other east European countries, air pollution in Bulgaria is, however, relatively low although Bulgaria's $SO_2$ level is higher among all European countries.

The Ministry of Environment issued an 'Urgent Environmental Improvement Program in the Republic of Bulgaria' in April, 1990. The anti-air pollution project in this Program is regarded as an important move toward water quality improvement and forest protection.

The Bulgarian Government has also indicated that they follow the guidelines of the EC toward joining the EC. Following talks between the Bulgarian Government and the EC concerning air pollution and the reduction of sulfur oxide, a reduction goal has been determined based on the record of 1980. Sulfur oxide will be reduced by 33% in 2000, 40% in 2005, and by 45% in 2010.

In this Program, all anti-pollution measures for thermal power plants are practiced under the responsibility of 'the Committee of Energy'.

### 1.1.5 Environmental Restrictions for Thermal Power Plants

According to the Environment Protection Law of the Republic of Bulgaria, all new power plants installed in and after 1993 must meet the environmental standards of the Republic of Bulgaria.

The existing power plants installed prior to 1993 continue operation and pay a penalty for $SO_2$ and dust emissions exceeding the standard values.

### 1.1.6 Maritsa East Power Plant Group

The Maritsa Region is located approx. 40km southeast of Stara Zagora, Bulgaria's 6th largest city and approx. 250km east of the capital city, Sophia. The Toroyanovo Coal Mine which produces lignite, is situated in this region. The Maritsa East Power Plant Group is located nearby and is operated with this fuel.

The existing power plants are the Maritsa East 1, Maritsa East 2, and Maritsa East 3 with a total generation capacity of 2,280MW; 200MW, 1,235MW, and 840MW respectively. Approx. 35% of the Republic of Bulgaria's thermal power generation facilities are concentrated in this area.

### 1.1.7 Maritsa East No.1 Thermal Power Station

This power plant has operated for approx. 35 years since 1960 and its aging is significant. Especially, the service lives of its major components, the boiler/turbine have almost expired due to advancing metal fatigue. This situation is extremely critical in the continuance of the plant's operation.

This power plant is also equipped with a lignite drying plant which reduces the moisture of lignite from 55% to 40%. The efficiency of the dust collector is now only 60% due to its being of a cyclone type. Also, with no desulfurizer, $SO_2$, $No_x$, and dust emissions from this plant exceed the environmental standards by more than 10 times.

Two 150MW units were shut down approx. 5 years ago and are currently in the final stage of removal. Four 50MW units are presently in operation. Shutdown of this plant is difficult as it is obliged to supply 450t/h steam to a neighboring briquet plant as a public service.

This power plant was the first plant to use lignite from the Maritsa Region. Because of this, the plant has been well used to train a great number of high level engineers who are very experienced in all aspects related to lignite. The skills of these engineers are utilized in the construction and maintenance of other two power plants.

This power plant has approx. 1,200 employees including 110 experienced engineers, together with many skilled workers such as mechanics, electricians and welders.

### 1.1.8 Request for this Project

Considering the conditions described herein, on January 12, 1994, the Bulgarian Government requested the Japanese Government to conduct a study concerning the development.

### 1.1.9 Preliminary Study

JICA dispatched a Preliminary Study Group in November, 1994, as the Request from the Republic of Bulgaria included many unspecified factors. The preliminary study was conducted for the framework regarding the scope of F/S prior to an S/W agreement with the NEK which is the counterpart in the Republic of Bulgaria.

### 1.1.10 Preparatory Study

Based on the agreement after the Preliminary Study in November, 1994, JICA dispatched a Preparatory Study Group to the Republic of Bulgaria in January through February, 1995 to discuss the on-site study, consignment, and other matters related to the S/W agreement with the NEK. Both parties reached a unanimous agreement and an S/W and M/M were signed and exchanged on February 9, 1994.

### 1.1.11 Feasibility Study (F/S)

F/S was conducted over two fiscal years. The primary year F/S (fiscal 1995) started in June, 1995. All studies at the Preliminary Study and Detailed Study stages, and the major part at the Feasibility Design stage were conducted.

In the secondary year (fiscal 1996), study is conducted for the economic/financial analysis in the Feasibility Design stage. The result of this study is summarized in the Draft Final Report. The Final Report shall be submitted within one month after explanation/discussion to/with the counterpart in July, 1996. In the meantime, two technical transfer seminars were provided for related personnel of the Republic of Bulgaria.

## 1.2 Purpose, Outline, Scope and Period of the Study

### 1.2.1 Purpose

The purpose of this Study is to re-develop the optimum power generation facility at the area of the former Units 5 and 6 (150MW x 2) in Maritsa East 1.

### 1.2.2 Outline, Scope and Period

The main subject area of this Study is the Maritsa East 1 site in Galabovo approx. 40km southeast of Stara Zagora located approx. 250km east of the capital city, Sofia, and neighboring the coal mine(s).

The relevant facilities include the Toroyavo 1, 2 and 3 coal mines which lie to the northeast of Maritsa East 1, the Maritsa East Coal Mine Management Company, Maritsa East 2 and 3 where the lignite from these local mines is used, the Energoremont machinery plant, and limestone mine, etc.

This Study is based on the Scope of Works (S/W) signed on February 9, 1995, and the Minutes/Memorandum (M/M) regarding the S/W.

The main points of this study are to make examination and evaluation of technology for replacement of optimum power generation facilities based on the technical and economical factors in response to the environmental standards of Bulgaria or the EC and to execute Feasibility Design and F/S including the economic/financial analysis.

The Study was conducted in the following three stages.

(1) **Stage 1:**

Preliminary Study stage; June - October, 1995

(2) **Stage 2:**

Detailed Study stage; November - December, 1995

(3) **Stage 3:**

Feasibility Design stage; January - June, 1996

Job sections and Name of person of JICA team

* Management (Team Leader) : Juro INOUE
* Co-management
  (Assistant leader, Power generation development plant) : Zenjiro TSUTSUI
* Thermal power generation facilities
  (Boiler and Environment Protection Facilities) : Koichi KOBAYASHI
* Thermal power generation facilities
  (Boiler and Auxiliary Facilities) : Masanori MORISHITA
* Environmental protection facilities
  (Facilities/Chemical Engineering) : Ryoichi SAKANISHI
* Thermal power generation facilities
  (Turbine Generator and Auxiliary Facilities) : Hideyuki OKANO
* Thermal power generation facilities
  (Electrical, Instrumentation and Control) : Shunichi KIYOSAWA
* Power generation architecture : Yasushi ISHIKAWA
* Power generation civil engineering : Naoto AKIKUNI
* Environment : Masayoshi ONO
* Transmission plan : Takaya NOMURA
* Economical/financial analysis : Hirohito ARAKI
* Measurement/analysis : Jun MITSUHASHI
* Project coordinator : Yusaku YOKOYAMA

### 1.2.3 On-site Study

The following study was conducted in response to the precision level in each stage. The study was conducted by a Study Group consisting of experts in each field.

**(1) Preliminary Study Stage**

(a) Collection and analysis of necessary data and information
(b) Coal/petroleum/gas supply
(c) Limestone supply
(d) Power development projects
(e) Power plant operation standards
(f) Initial environment (IEE)
(g) Existing fluidized bed (FBC) boiler and lignite fired boiler
(h) Existing facilities to be reused for a replacing plant
(i) Possibility of local procurement of fabrication and installation

(j) Transmission lines and substations
(k) Local consignment
(l) Transportation procedures of lignite for combustion test
(m) Existing power plants

(2) **Detailed Study Stage**

(a) Detailed site survey
(b) Environmental impact assessment (EIA)
(c) Equipment and materials
(d) Construction cost, etc.
(e) Design related restrictions
(f) Restrictions in interfacing with the operating facilities
(g) Lignite combustion test and analysis
(h) Progress state of local consignment

(3) **Feasibility Design Stage**

Economy/finance related supplementary study

### 1.2.4 Study in Japan

The following major items were studied from different aspects based on the information and data acquired from the on-site study and in Japan.

(1) Power development plan
(2) Fuel and limestone supply plan
(3) Lignite combustion test on bench scale fluidized bed
(4) Optimum replacement plan
(5) Conceptual design
(6) Construction plan
(7) Replacing plant construction cost
(8) Environmental impact assessment
(9) Economic/financial analysis

### 1.2.5 Study Flow Chart

The study was conducted according to the flow chart in Figure 1-2-5.

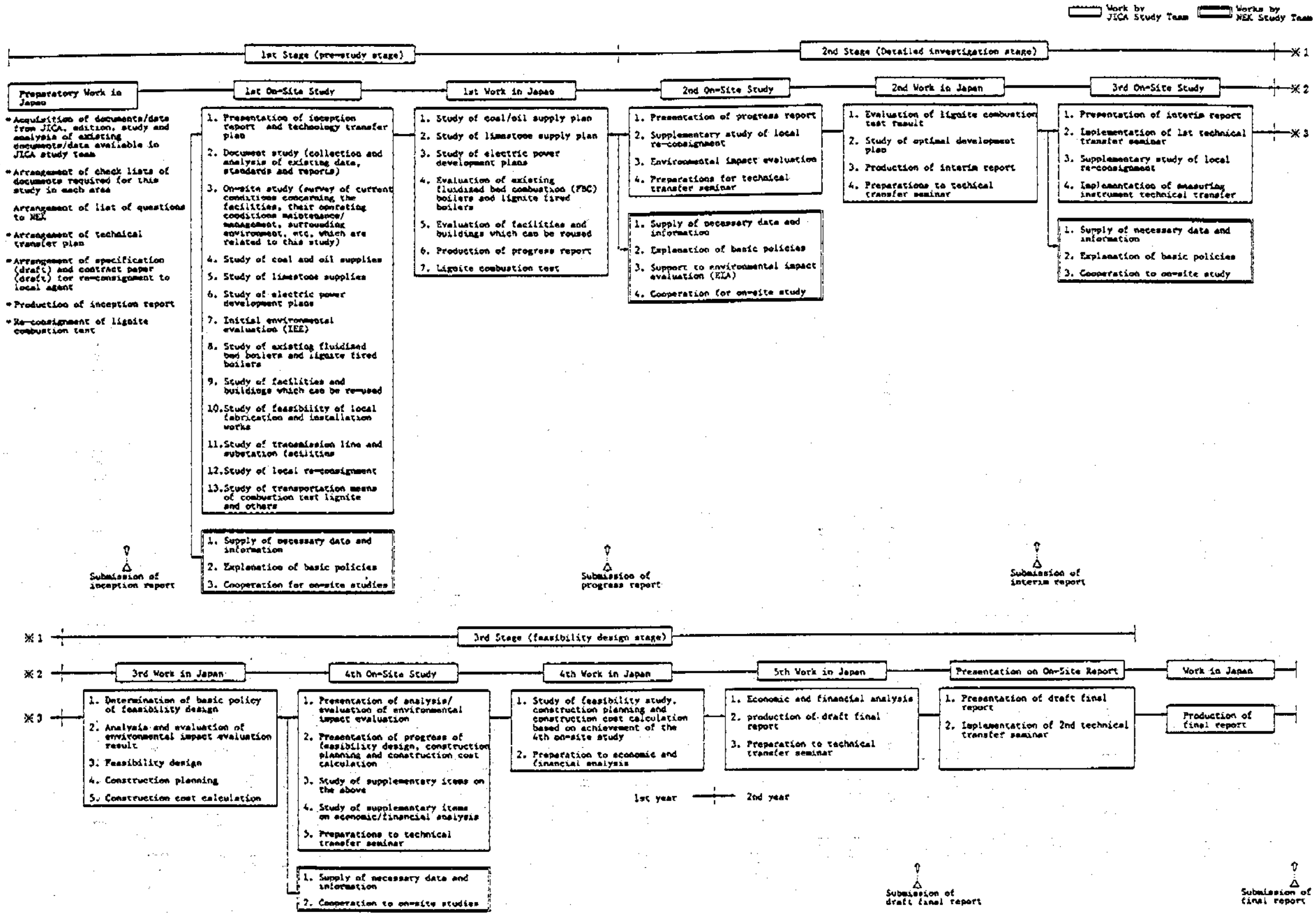


Figure 1-2-5. Study Work Flow Chart

## 1.3 Relevant Organization

The Nationala Elektricheska Kompania (NEK) was established on November 7, 1991, in accordance with a Cabinet Act. Its operation started in January, 1992.

The NEK is a stock company owned by the Government. It conducts an integrated operation ranging from power generation to transmission and distribution. Heat supply is also included in the operation.

The NEK mainly owns and operates the thermal power plants, hydro-power plants (pumped storage included) and the Kozloduy Nuclear Power Plant as well as all sub-stations, transmission lines and distribution networks nationwide distributed.

The NEK has 41 branches; 10 in the power generation division, 28 local power supply companies in the distribution division and 3 branches in the construction division.

As of 1996, the NEK employees approx. 32,000 people. Staffed by approx. 80 employees, the Command Center is located next to the NEK Head Office. The NEK Head Office is staffed by approx. 120 employees, which is rather a small number.

The NEK is supervised by the Committee of Energy which controls the entire electric utility industry. Electric charges are, however, controlled by the State Energy Regulatory Committee, established in June, 1993.

The National Assets, Privatization, and Finance Department was established within the Committee of Energy in June, 1993. This section is dedicated to the reform strategies of 1993-1997 and the privatization of energy related industries.

The government organization to which the NEK belongs is currently managed by the Ministry of Industry.

The NEK system is introduced in Figure 1-3-1.

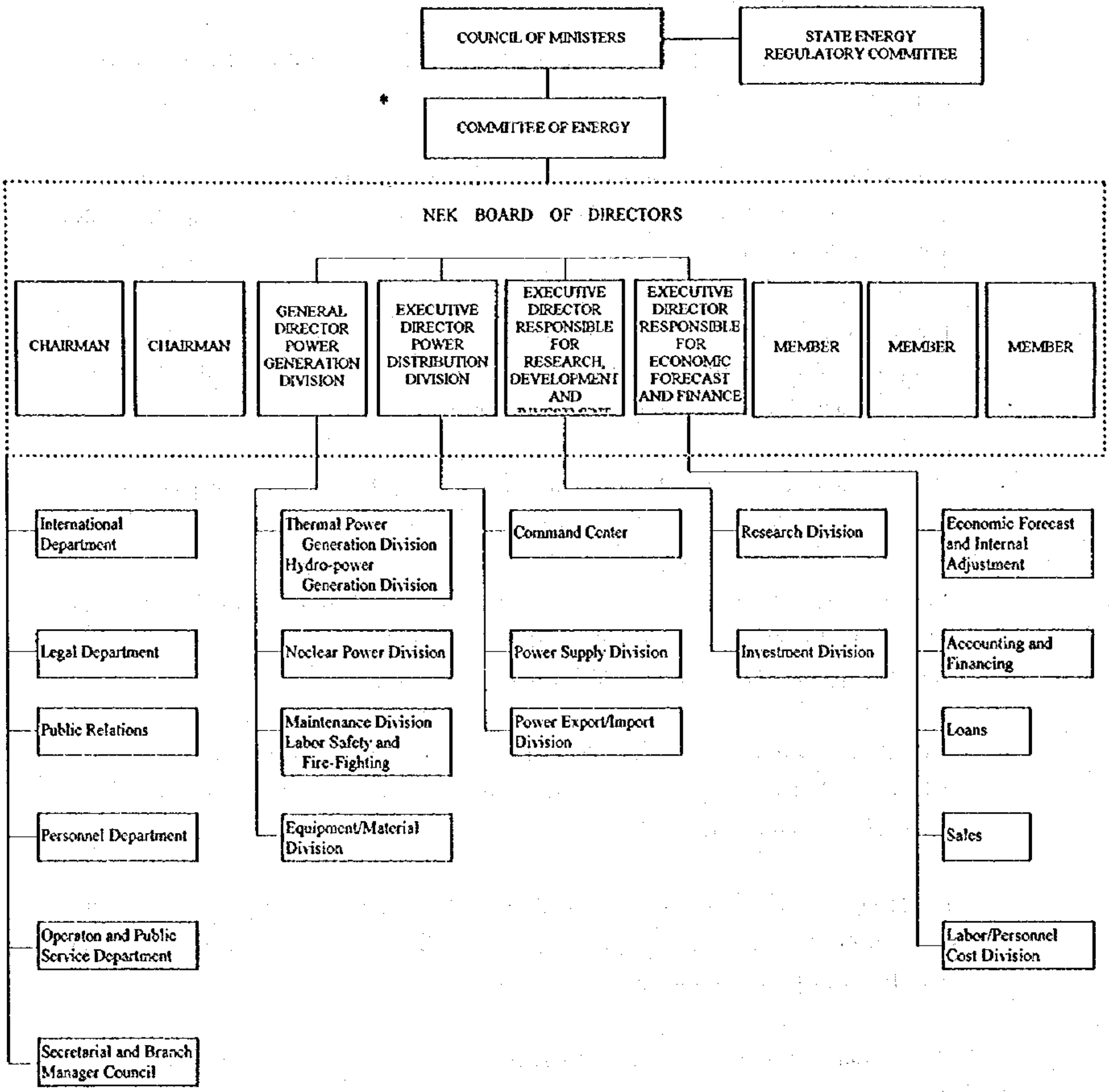


**Figure 1-3-1 NEK System**

* The Committee of Energy was reorganized into "the Ministry of Energy and Energy Resources" under the date of June 14th, 1996.

### 1.4 Acceptance of Trainees

As the counterpart, the NEK dispatched Mr. Dimitre Lubomirov Petrinski and Mr. Penio Jekov Penev to Japan as trainees. They were in Japan from March 23, 1996, to April 13, 1996.

### 1.5 Provision of Equipment

Equipment for atmospheric measurement and flue gas measurement listed below required for this Study were provided to the NEK by JICA. The equipment provided is listed in the Supplement.

| | | |
|---|---|---|
| 1. | Stack gas measuring instrument | |
| 1-1 | Portable NOx, $SO_2$, $O_2$ gas analyzer | 1 set |
| 1-2 | Dust sampling equipment | 1 set |
| | | |
| 2. | Air pollution measuring instrument | |
| 2-1 | $SO_2$ monitor | 1 set |
| 2-2 | NOx monitor | 1 set |
| 2-3 | Dust sampler and deposit gauge | 4 sets |

# CHAPTER 2. REPLACING PLANT SITE

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# CHAPTER 2 REPLACING PLANT SITE

## 2.1 Outline of Maritsa East No. 1 Thermal Power Plant

### 2.1.1 Outline

(1) Power Generating Facilities

This power plant has reached the limit of its service life so that it is in serious condition for further continued operation, because it has passed about 36 years since it started operation in 1959 and its major components such as boiler and turbine are seriously aged.

Additionally, the importance of this plant also exists in the fact that it is responsible for supplying drying steam (450t/h) to a private briquette factory and heating steam (50-60t/h) to nearby area. Environmental protection measure for this plant is urgent because flue gas (containing SOx, NOx, Dust, etc.) produced from combustion of domestic lignite exceeds national environmental standard extremely.

Figure 2-1-1 shows a layout and unit configuration of this power plant.

(a) Unit nos. 1 through 4 (started in 1959 through 1962)

1) Comprise 6 boilers (210 t/h each), common steam header, 4 turbine power generators (50 MW each) and turbine extracted steam supplying equipment (for briquette: 5-9kg/cm$^2$, 210°C, 450t/h, for area heating: 2.3-3.0 kg/cm$^2$, 50-60t/h).

2) Its major components were made in ex-Soviet and its electrostatic precipitators were made in ex-East Germany.

(b) Unit nos. 5 and 6 (started after 1964 and currently being removed)

1) Comprise 4 boilers and 2 turbine power generators (150MW each)
2) All its major components were made in ex-Soviet.

(c) Lignite drying equipment

Because total moisture content in lignite is about 55% (arrival basis), it cannot be burnt without any treatment in a boiler on this power plant (the existing mill system cannot play a role of drier concurrently). Therefore, lignite drying equipment for lowering moisture content to about 40% before loading on bunker is provided.

Drying equipment for boiler Nos. 7 through 10 are currently being removed alike boilers.

(d) Stack

All stacks are made of concrete. A stack (150m high) is provided for currently operating boilers (for unit nos .1 - 6), a stack (180m high) for boilers (for unit nos. 7 - 10) currently being removed and 2 stacks (120m high) for coal drying. The stacks for the boilers currently being removed will be removed.

(e) Other special matters

As for major equipments for unit nos. 1 - 4 currently being operated, their remaining service lives were diagnosed (1988 - 1989). As a result, it was revealed that the remaining service lives have almost reached their limits due to metallic fatigue.

However, because supply of vapor for briquette and local heating is required, the steam temperature has been lowered to continue the operation and further their service lives are extended by undertaking minimum repair (including replacement of pipes) on the existing equipment. The flue and electrostatic precipitator and other auxiliary equipment are seriously aged.

(2) History and Accumulated Result of the Operation

(a) Unit nos 1-4

1) It has passed more than about 36 years since start of the operation of these units and they are currently operating. Their accumulated operating hours and number of start up/stop up to October 1994 are as follows.

| | | |
|---|---|---|
| • Total operation time: | 190,000-210,000 hours | for boiler |
| | 240,000-250,000 hours | for turbine/generator |
| • Number of start/stop: | 600-950 times | for boiler |
| | 360-450 times | for turbine/generator |

2) Their operation will be continued as long as supply of steam for briquette and local heating is required.

(b) Unit nos. 5 and 6

1) Because these units were intended not to supply steam for briquette and local heating but to generate electric power in correspondence to electric power peak time, the number of start up/stop of the plant was extremely high.

- Total operation time: 160,000 hours
- Number of start/stop: 500-550 times

2) Because high temperature operation continued since commissioned, the service lives of the boiler and turbine were almost consumed. In 1991, the operation was stopped and the equipment are currently being removed.

(c) Generated power amount and amount of supplied heat (1993/1994)

Generated power amount ($10^6$kWh): 1,118/980
Amount of supplied heat ($10^3$Gcal): 1,553/1,102

### 2.1.2 Organization system

The total personnel in the power plant is 1,234 and its organization and distribution of personnel is shown in Table 2-1-1.

## 2.2 Site Condition

### 2.2.1 Location

This plant is located at the town "Galabovo" in the vicinity of lignite mine (open cast mine) at the Maritsa area about 40km south east of Stara Zagora (population about 300,000), which is the sixth largest city of Bulgaria, about 250km east of its capital city Sofia.

Maritsa East No. 2 thermal power plant (1,450MW) and No. 3 thermal power plant (840MW) exit around this mine and about 38% of the thermal power generating equipment in this country (including private power generation) are concentrated on this area.

### 2.2.2 Access

The accesses from the capital city Sofia to Maritsa East No. 1 thermal power plant are gained by vehicles through a highway leading to Stara Zagora (about 250km) main road (17km) running from south-east, ordinary road (20km) and return again to main road (3km). A main road running before this plant is an important truck line for industry connecting Turkish with Rumania.

A railway siding is installed in the power plant and railway is used for transportation of coal and construction material. This railway network is effectively used for this replacing plan. However, although ordinary passenger railway has Garabovo station near the power plant, use of this railway cannot be recommended in view of the current situation of Bulgaria (from the viewpoints of the operation and security, etc.)

### 2.2.3 Climate

(1) The climate of Bulgaria is relatively mild and four seasons are clearly seen. In a region in which this plant is located, the climate is of the Mediterranean type having mild temperature and high humidity, but no violent storm.

(2) The yearly average temperature, rainfall days and relative humidity, etc. observed for 10 years from 1983 to 1992 in a weather observation station located on the Lozoflanets Lake 1km south west of this plant are as follows.

| | | |
|---|---|---|
| • Temperature: | 12.5°C | [Monthly Ave. Max 23.8°C(July), Min 1.8°C (January, December)] |
| • Atmospheric pressure: | 1003.5 hPa | [Monthly Ave. Max 1007.9hPa (December), Min 998.9hPa (June)] |
| • Rainfall day: | 42 days | [Monthly Ave. Max 8 days (January, November, December)] |
| • Snowfall day: | 14 days | [Monthly Ave. Max 4 days (January, February)] |
| • Relative humidity: | 73% | [Monthly Ave. Max 84% (December), Min 63% (June)] |

• Wind direction, velocity: North east, 2.5m/s

### 2.2.4 Topography and geology

(1) Topography

(a) The project site is located on the Thracia Plain 100 m above the sea level and surrounded by a moderately sloped hill area where the land is used as framland (for wheat, potato, orchard and etc.) and, therefore, less forested.

(b) The Sazliika River flows north of the Maritsa East No. 1 Power Station.
As a tributary of the Sazliika River, the Ovcharitza River runs out of the Sazliika River adjacent to the Maritsa East No.2 Power Station.

From the direction of the Maritsa East No.3 Power Station, the Sokoritza River flows into the Sazliika River.

The Rozovkladenets Lake located south of the Maritsa East No.1 Power Station was constructed artificially by damming up the Sokoritza River to obtain cooling water for the power station.

(c) The underground water is used for irrigation of farmland and not for drinking water. The drinking water in the Galabovo District is taken in from the Sazliika River.

(d) Within the project site, there is no specified nature preservation zone or other particular area except one spot where the Thracia remains during the second through third century before Christ are located, and have been enclosed by protective palisade and preserved carefully after its explorative inspection was completed.

(2) Geology

The geological section within the power plant site is composed of alluvial deposits of the Sokolitza River. The surface layer being 4m deep consists of deposits of sand, clay, coal etc. and a layer under it up to GL-6m ~ -11m constituted with sandy clay and sand is formed on the hard clay layer of 30 ~ 40m in depth which has a N value of around 21 ~ 33 and plays a role of supporting layer of foundations.

The foundation of heavy structures in the existing power plant such a turbine house is of a direct supporting type utilizing the hard clay layer.

The underground water level in the area of a turbine house is GL-6m (101.2m above the sea water level) in average.

Underthere, hard clay layer with N value 21 - 33 exists throughout the thickness of 30 - 40m, thereby acting as plant Us foundation supporting layer.

The foundation of the heavy construction of this power plant is directly based on this layer. The average underground water of the main building of this plant is GL-6m (101.2m at altitude).

## Table 2-1-1 Organization and Personnel of ME-1 TPP

| Division | Description of Division | Personnel | Remarks |
|---|---|---|---|
| Manager of this plant | Administration of the entire plant | 1 | |
| 1. Reception and supply of coal | Reception of coal, storage, transportation and crushing | 145 | |
| 2. Drying of coal | Drying of coal | 105 | |
| 3. Operation and maintenance of boiler equipment | Operation, management and repair of boiler equipment, ash treatment, operation, management and repair of heavy oil equipment | 230 | |
| 4. Repair of boiler related equipment | Disassembly, inspection, repair and daily light repair of coal drying furnace, boiler and auxiliary equipment | 97 | |
| 5. Welding correction | Welding correction of the above mentioned equipment | 39 | |
| 6. Operation and maintenance of turbine equipment | Operation, management and repair of turbine equipment | 116 | |
| 7. Operation and maintenance of electric equipment | Operation, management and repair of electric equipment | 97 | |
| 8. Operation and maintenance of instrumentation equipment | Operation, management and repair of instrumentation equipment | 47 | |
| 9. Operation and maintenance of water equipment | Operation, management and repair of water equipment | 42 | |
| 10. Repair of rotatory machines | Repair of pump, valve and motor, etc. and production of reserved parts | 57 | |
| 11. Operation and maintenance of heat supply and drainage equipment | Operation, management and repair of heat supply equipment and construction of related buildings<br>Management and repair of drainage equipment (including sewage work) | 31 | |
| 12. Transportation and procurement | Transportation of machine and equipment in the plant and procurement of consumption materials, reserved parts and materials | 30 | |
| 13. Accounting, personnel affair and welfare | Accounting, personnel affair and management of other general matters<br>Operation and management of welfare facilities | 197 | |
| | (Total) | 1,234 | |

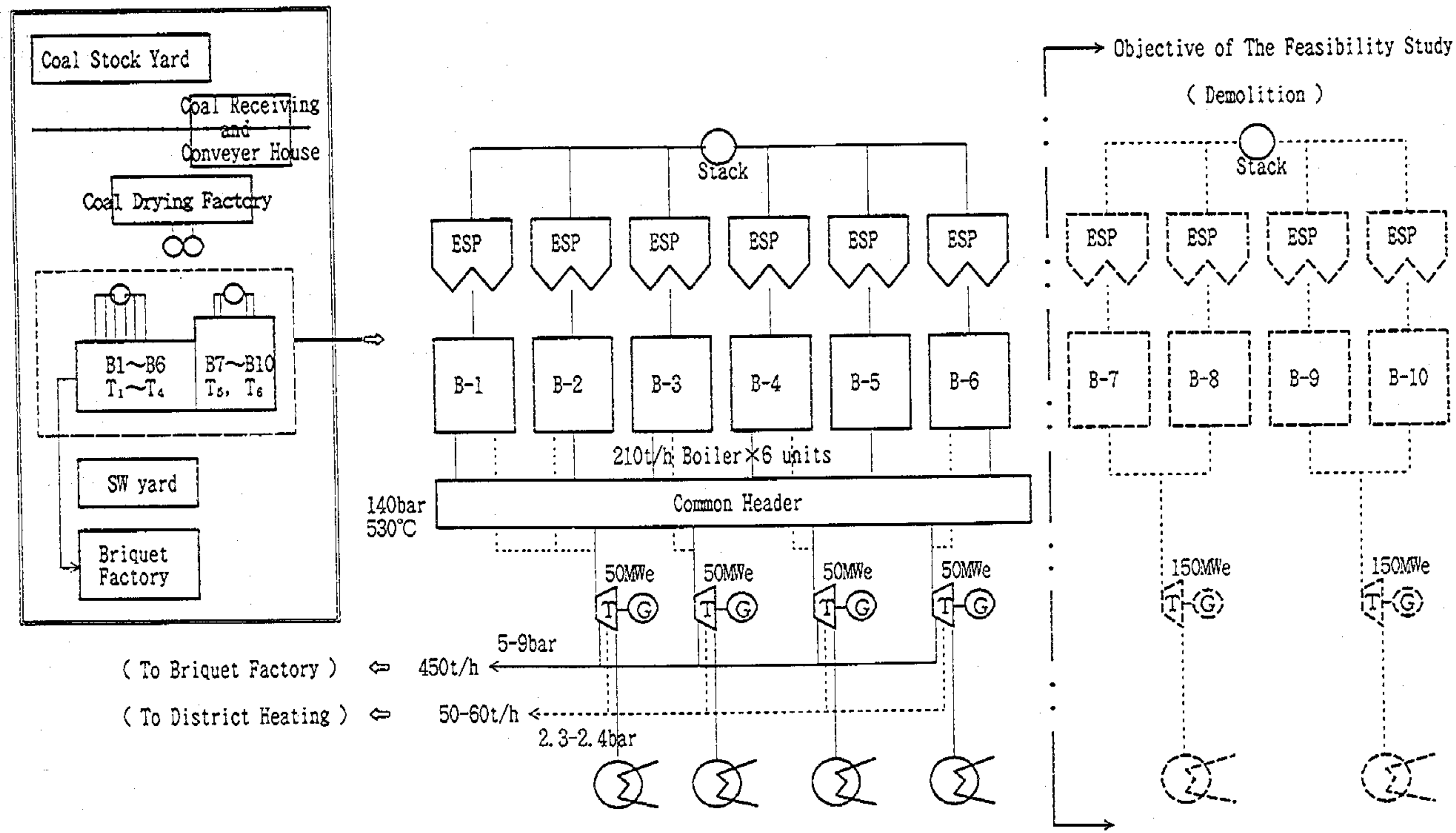


Figure 2-1-1 Layout of Unit for Maritsa East No.1 Thermal Power Plant

# CHAPTER 3. ELECTRIC POWER DEVELOPMENT PLAN STUDY

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# CHAPTER 3 ELECTRIC POWER DEVELOPMENT PLAN STUDY

## 3.1 Electric Power Facilities

### 3.1.1 Power Generating Facilities

Outline of electric power facilities in Bulgaria is indicated as Figure 3-1-1-1.
Table 1-1-1 shows the transition of installed generating capacity between 1985 - 1995.
In 1995, the total generating capacity was 12,751 MW, of which 11,112 MW is owned by NEK, and the remaining 1,639 MW by industry.

The power source percentages are 6,589 MW (51.7%) by thermal, 3,760 MW (29.5%) by nuclear, 2,402 MW (18.8%) by hydroelectric.

Table 3-1-1-2 shows the major thermal power plants.

Regarding the thermal power plants, the fuel composition of thermal power plants owned by NEK was lignite 64.09%, imported coal 20.69%, bituminous coal 14.21%, natural gas 1.01% as of 1993.

Table 3-1-1-3 shows the major hydroelectric power plants.

Of a total of 87 hydroelectric power plants, 58 are of run-off-river type (total output 176 MW), and the 29 are balance of pondage type (total output 2,226 MW).

In 1994, Chaira pumped-storage power plant Stage 1 with 2units x 216 MW was commissioned and Stage 2 with 2 units x 216 MW is under construction.

Bulgaria's sole nuclear power plant, the Kozloduy nuclear power plant has 6 Russian-made nuclear reactors (VVER); 3,760 MW (440 MW x 4, 1,000 MW x 2).

Repair work for the aged unit nos. 1 to 4 started in 1991. This work was completed for No. 2 unit in 1992, for No. 1 unit in 1993, and for unit nos. 3 and 4 in 1994.

The Bulgarian government has decided to put the aged unit nos. 1 and 2 (440 MW x 2) out of service, but the date of outage is not fixed up yet.

### 3.1.2 Transmission Lines and Substation Facilities

Bulgaria's trunk transmission system is 400 kV and 220 kV.
The 750 kV transmission line is used only for interconnection with the Ukraine via Rumania.
Table 3-1-2-1 shows an outline of the transmission line.

As of 1995, there was one substation in the 750 kV system, 10 in the 400 kV system, 16 in the 220 kV system, and 269 in the 110 kV system. The installed capacity was 31,527 MVA. Table 3-1-2-2 shows an outline of these substations.

## 3.2 Power Supply and Demand

### 3.2.1 Power Demand Analysis

(1) Power Demand Transition

Table 3-2-1-1 shows the transition in power demand from 1985 to 1995. The energy consumption declined from 1989 onward and decreased significantly in 1991, being only 14.4% less, compared with the previous year. Since then, however, the decline has been small. In 1994, the energy consumption increased only 0.3% compared with the previous year, but it indicated a major increase under influence of intense cold in 1995, amounting to 32,015 GWh.

On the other hand, however, in 1993, the annual energy consumption was 3,429 kWh/capita. The peak power demand reached the highest level (8,332 MW) in 1989 and declined since then to 7,520 MW in 1995.

Figure 3-2-1-1 shows the monthly energy consumption for 1994 and 1995. The maximum energy demand came out in December and January and the minimum energy demand in July and August.

(2) Energy Generation Transition

Table 3-2-1-2 shows the transition in energy generation from 1985 to 1995.
Energy generation decreased from 1989 but began to increase in 1993. That in 1995 was 42,003 GWh, a major increase of 10.2% over the previous year.

(3) Past Records of Power Interchange

When examining the net imported energy, which is derived from subtraction of the exported energy from the imported energy, it is seen that Bulgaria was a power importing country. Recently, however, the percentages of imported and exported energy are almost equal.

(4) Load Characteristics

Table 3-2-1-3 shows the power demand structure from 1985 to 1993. Power demands for the industry, construction, and agriculture sectors are decreasing considerably.

The consumption percentage for 1993 is 45.4% for industry sector, 1.6% for the construction sector , 2.7% for the agriculture sector, 4.8% for the transportation and communications sector, 11.0% for the public sector and 34.6% for the household sector, respectively.

The annual load factor shifts around 50%. The loss factor is practically stable. The average loss for the 11 years 1985 to 1995 is 4,474 GWh for auxiliaries and 4,680 GWh for network. On the other hand, auxiliary loss for 1995 was 4,353 GWh and the network loss, 5,415 GWh. The ratio of auxiliary loss to the gross generation is 10.4%, and a ratio of transmission loss to the sending end energy of 14.4%. The total energy loss is 23.3% to the gross generation.

Figure 3-2-1-2 shows the maximum and minimum daily load curves for 1994.

### 3.2.2 Power Demand Forecast

(1) Forecast Method

A macro forecast method which forecasts the demand for the entire nation was applied. A long range energy demand for the entire nation is estimated by finding a fixed law or trend line in the past energy demand records.

The following five methods are generally known as forecast methods.

(a) A trend line is found in the logarithmic trend of past demands and this will be extrapolated.

(b) Linear regression forecasting is used when a linear relationship is recognized between the GDP and the power demand.

(c) Quadratic regression forecasting is used when a curved relationship is recognized between the GDP and the power demand.

(d) Multiple regression forecasting using selling cost and population (or number of customers) other than GDP as explanatory variable (independent variable).

(e) Forecasting using the correlation between GDP/capita and kWh/Capita found in international statistics.

In method (a), the trend line derived from past records is simply extrapolated. This method can be used only for forecasting for the near future.

On the other hand, past records show that energy consumption increased from 1985 to 1989, then decreased from 1990 to 1993 and again increased from 1994. As seen, there are three trend line patterns and it would, therefore, be very difficult to use methods (b) - (d).

For the above reasons, method (e) will be used to make the demand forecast. The relation between Bulgaria's GDP/capita and kWh/capita from 1985 to 1993 will be used.

(2) Forecast Conditions

(a) Explanatory variable

The energy consumption record, and transition of GDP and population (1985 - 1993) which are explanatory variables are shown in Table 3-2-2-1. The relation between the GDP/Capita and kWh/capita is shown in Figure 3-2-2-1.
The power demand forecast term is limited to 14 years from 1996 to 2010.

(b) Economic scenario

The economic growth scenario is decided as follows. Bulgaria's GDP increased steadily up to 1989. From 1990, it started to decrease remarkably. However, this decrease stopped by 1991. The GDP started to increase again from 1991 and increased 2.5% in 1995, compared with the previous year.

Assuming that the GDP is flat in 1994, and then increase from 1995 onward, three cases are studied; low case (3% GDP growth), middle case (4% GDP growth) and high case (5% GDP growth).

The population was 8.472 million as of 1993 and is expected to be 8.897 million in 2000 and 8.902 million in 2010, respectively.

(3) Power Demand Forecast Results

Using the above conditions, based upon the data in 1993, the relation between the GDP and population, is anticipated as follows.

(a) Low case (3% GDP growth)

GDP : $10{,}812 \times (1+0.03)^{16} = 18{,}000$ (US$ million)
Population : 8.902 million
GDP/capita : 18,000/8.902 = 2,100 (US$/Capita)

From Figure 3-2-2-1, kWh/capita is 4,100 (kWh/capita), and the energy consumption in 2010 will be 4,100 x 8.902 = 37,000 (GWh)

(b) Middle case (4% GDP growth)

GDP : 10,812 x (1+0.04)16 = 21,000 (US$ million)
Population : 8.902 million
GDP/capita : 21,000/8.902 = 2,400 (US$/capita)

From Figure 3-2-2-1, kWh/capita is 4,200 (kWh/capita) and the energy consumption in 2010 will be 4,200 x 8.902 = 38,000 (GWh)

(c) High case (GDP growth 5%)

GDP : 10,812 x (1+0.05)16 = 24,000 (US$ million)
Population : 8.902 million
GDP/capita : 24,000/8.902 = 2,700 (US$/capita)

From Figure 3-2-2-1, the kWh/capita is 4,300(kWh/capita), and the energy consumption in 2010 will be 4,300 x 8.902 = 39,000 (GWh)

### 3.2.3 Power Demand Forecast by NEK

NEK has made an energy supply forecast up to 2010, based on three scenarios; low, middle and high. In the middle case it is predicted that the energy supply will recover to the 1989 level in the year 2005.

NEK's power demand forecast is made for the energy supply and will, therefore, be converted to energy consumption which is obtained by subtracting auxiliary loss and network loss from energy supply. The average auxiliary loss and network loss for the 11 years between 1985 to

1995 which are 4,474 GWh and 4,680 GWh, respectively, is used. The amount of imported and exported energy has been balanced for several years and will, therefore, is ignored in forecasting in these scenarios.

Figure 3-2-3-1 compares the demand forecasts of NEK and JICA Study Team. JICA's case locates between NEK's low case and middle case. An energy demand growth from 1995 to 2000 in NEK's middle case and high case is predicted to be so big; as much as 20% and 30%.

In the JICA forecast, the energy demand growth in 2010, compared with 1995, is, 16% low case, 19% middle case and 22% high case, respectively. While in the NEK forecast it is 9% low case, 34% middle case, and 47% high case.

In the low case of NEK, demand from 1995 to 2000 declines. This trend is opposite to recent trend. On the other hand, the high case of NEK indicates the growth rate of demand from 1995 to 2000 is very high. This is not realistic. From the above, the middle case of NEK which indicates same trend as JICA study team's forecast is adopted.

### 3.2.4 Electric Power Development Plan, and the Balance of Supply and Demand

Table 3-2-4-1 shows the electric power development plan (1995 -2005) and power demand forecast prepared by NEK in 1994. This power demand forecast is for the middle case.

The scale of electric power development from 1995 is 951 MW (a 9% increase), of which thermal will be increased 1,275 MW, hydroelectric 476 MW and nuclear 800 MW, respectively.

As a result, the installed capacity in 2005 will be 11,540 MW in total, which is broken down to 6,130 MW (53.1%) thermal, 2,710 MW (23.5%) hydroelectric, and 2,700 MW (23.4%) nuclear, respectively.

When the supply reserve to peak power demand is examined, it is seen that it will be at the lowest level between 2000 and 2001 when the installed capacity of the nuclear power plant is decreased.

In the future, Bulgaria's power demand is expected to certainly increase even if the lowest economic growth were to be the case. When the demand structure is examined, industry power demand is currently decreasing greatly. However, as economic growth progresses and industrial power demand increases, it is possible that power demand will grow rapidly. Also, the expected shutdown of unit nos. 1 and 2 at the Kozloduy nuclear power plant from 2000