ASIAN DEVELOPMENT BANK

Regional Economic Co-operation in Central Asia

RETA 5818

FINAL REPORT

ELECTRIC ENERGY

December 2000

LAHMEYER INTERNATIONAL

Table of Contents

Abbreviations

ADB	Asian Development Bank
AMC	State Agency for the Regulation of Natural Monopolies and Protection of Competition
ASPR	Agency for Strategic Planning and Reform
AVR	Automatic Voltage Control
CAEC	Central Asia Economic Community
CAR	Central Asian Republic
CHPP	Central Heating and Power Plant (English)
EBRD	Economic Bank for Reconstruction and Development
EDRC	Economic and Development Resource Centre, ADB
EMS	Energy Management System
EP CA	Electricity Pool of Central Asia
GKI	Committee for State Property Management and Entrepreneurship Support
GOK	Government of Kazakhstan
Goscominvest	State Committee on Foreign Investments and Econom. Develop., Ky.
GOU	Government of Uzbekistan
HB	Hagler Bailly
HPP	Hydro Power Plant
HV	High Voltage
Ka	Kazakhstan
KEGOC	Kazakhstan Electricity Grid Operation Company
KPA	Kazakhstan Petroleum Association
Ky	The Kyrgyz Republic
LV	Low Voltage
Minenergo	Ministry of Power Industry and Electrification, Uzbekistan
MV	Medium Voltage
NDC	National Dispatch Centre
OGRA	Oil and Gas Regulatory Agency
RDC	Regional (National) Dispatch Centre
REC	Regional Electric Company
SCADA	Supervisory Control and Data Acquisition
SDPP	State District Power Plant
SEA	State Energy Agency
SIC	State Investment Committee
SO	USAID Strategic Objectives
SPF	State Property Fund
SSC	State Stock Company
Ta	Tajikistan
TA	Technical Assistance
TES	Central Heating and Power Plant (Russian)
TO	Task Order
Tu	Turkmenistan
UDC	Unified Dispatch Centre in Tashkent
USAID	United States Agency for International Development
Uz	Uzbekistan

1 Report of Activities

1.1 Details of Activities

For the period up to dispatch of the Draft Report the Consultant's activities are defined with the following dates:

06.07.1999	- 07.07.1999	Preparation works in the home office in Frankfurt
08.07.1999		Flight from Frankfurt to Tashkent
09.07.1999	- 16.07.1999	Studies in Uzbekistan
17.07.1999		Flight from Tashkent to Bishkek
18.07.1999	- 23.07.1999	Studies in Kyrgyz Republic
24.07.1999		Flight from Bishkek to Tashkent
25.07.1999	- 09.08.1999	Continuation of studies in Uzbekistan
10.08.1999		Flight from Tashkent to Frankfurt
11.08.1999	- 18.08.1999	Finalisation of Inception Report in the home office in Frankfurt
18.08.1999		Dispatch of **Inception Report**
16.08.1999	- 27.08.1999	Invitation letter, travel, and visa arrangements for second field trip
30.08.1999		Flight from Frankfurt to Almaty
31.08.1999	- 03.09.1999	Studies in Kazakhstan
05.09.1999		Flight from Almaty to Dushanbe
31.08.1999	- 03.09.1999	Studies in Kazakhstan
06.09.1999	- 11.09.1999	Studies in Tajikistan
13.09.1999	- 15.09.1999	Studies in Kazakhstan
15.09.1999		Travel to Bishkek
16.09.1999	- 22.09.1999	Studies in Kyrgyzstan
23.09.1999		Flight from Bishkek to Tashkent
23.09.1999	- 27.09.1999	Studies in Uzbekistan
28.09.1999		Flight from Tashkent to Frankfurt
29.09.1999	- 29.10.1999	Finalisation of Intermediate Report in the home office in Frankfurt
29.10.1999		Dispatch of **Intermediate Report**
23.11.1999		Dispatch of ADB's comments on the Intermediate Report
10.01.2000	- 19.01.2000	Final definition of selected project, preparation of invitation letter, travel, and visa arrangements for last field trip
20.01.2000		Flight from Frankfurt to Almaty
21.01.2000	- 03.02.2000	Studies in Kazakhstan
04.02.2000		Flight from Tashkent to Frankfurt
05.02.2000	- 10.03.2000	Finalisation of Draft Report in the home office in Frankfurt
10.03.2000		Dispatch of **Draft Report**
06.08.2000	- 19.08.2000	Joint ADB/Consultant country mission for discussion and approval of Draft Report

A time schedule of the performed works is shown in Annex 1.

1.2 Persons Contacted

In Annex 2 are listed the persons contacted in Kazakhstan, Kyrgyz Republic, Tajikistan and Uzbekistan during the study.

1.3 Remarks on the Course of the Study

The Consultant visited the four countries for data collection and discussions of the projects. During the first mission, data collection was difficult and extremely slow, since the ADB's introduction letters had not been forwarded within the local administration and these authorities only moved after having received a Russian translation of the terms of reference of the study and the Consultant's questionnaire.

A further delay in data collection was due to the fact that in some countries data of the utilities are still considered as a secret, although they are printed in numerous other studies. The Consultant is not informed about the existence of these studies and if he knows about their existence they cannot be examined, except after a written request to receive the desired page. With the increasing co-operation with financing institutions, this attitude is gradually improving and information more easily available.

Data collection and the definition of possible projects was finally made easier since presentation letters and Russian translations of the necessary information and terms of reference were sent to the authorities concerned by the ADB Resident Mission. Additionally, a retired Engineer from Uzbekistan advised the Consultant of whom he should contact and he also informed key personnel in the various countries of the Consultant's visit. Thanks to his assistance, meetings with these people and especially those of strategic importance, were made possible, the Consultant introduced to the countries and the reason for his visit made known.

Supreme efforts had to be made in order to determine which projects or group of projects are a likely candidate for future financing. Through discussions in the participating counties the Consultant identified various projects in the Intermediate Report and the Bank gave the recommendation regarding which projects to further investigate. After definition of the future project, the Consultant proceeded with project evaluation according to the terms of reference.

2 The Central Asia Countries

The five independent states of Central Asia have many years of common history and look back on a long interwoven past including 130 years under Russian rule with almost 70 years as part of the Soviet Union. Due to this recent periods they shared a rather long technical and economic development, but now, each of the countries searches for its own way for development within a more or less market oriented system. In this search each country looks back on quite different economic and energy data, although many similarities exist within the countries, as can be seen in the following table of project related data:

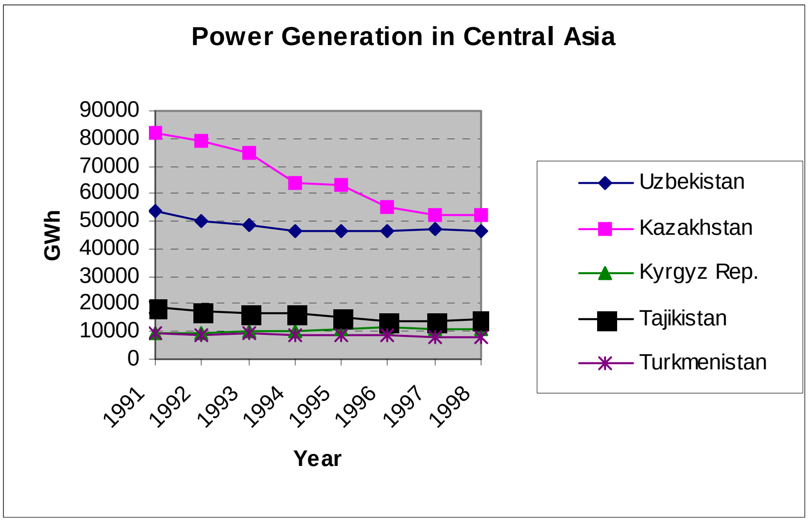
Table 1. Major National and Power Data of the Central Asian Countries

	Kazakhstan	Kyrgyz Rep.	Tajikistan	Turkmenist.	Uzbekistan
Surface area (thousand km^2)	2,717.0	198.5	143.1	488.1	447.4
Population (million)	17.2	4.8	6.3	4.2	23.3
GNP in 1998 (million US$)	46,800	11,600	4,500	5,300	47,500
GNP per capita (US$)*	2,721	2,417	710	1,270	2,041
Electricity production in 1998 (GWh)	52,900	10,847	14,663	8,071	46,090
Electricity production per capita (kWh)	3,076	2,260	2,327	1,922	1,978
Hydro production (%)	6 - 7 %	91 %	98 %	15 %	15 %

* Source: Economist Intelligence Unit

The table shows that the Central Asia Republics can be split, in relation to population and energy production, into the two big countries Kazakhstan and Uzbekistan and the three smaller ones Kyrgyz Republic, Tajikistan, and Turkmenistan. In addition, power generation in Kazakhstan, Uzbekistan as well as Turkmenistan is mainly based on thermal units, Kyrgyz Republic and Tajikistan are big hydro power producers.

A further key element of the Central Asian countries is the dramatic decline of the complete economic system that also resulted in the respective reduction in the demand of electrical energy. The following production figures documented by the Unified Dispatch Centre in



Tashkent show the size of power production for the different countries and give a visual impression of the decrease of electricity production of the Central Asian Grid (only in the Kyrgyz Republic did the overall demand remain stable).

Although Turkmenistan is geographically a part of Central Asia, it is not included in the following study as it is not yet a Bank member.

3 Central Asia Transmission Grid

3.1 Past Development

The Central Asian transmission grid was planned and developed mainly during the Soviet times in order to inter-connect generation plants and consumers.

On the generation side the transmission system interlinked the huge hydro power stations in the mountains of Kyrgyz Republic, Tajikistan and several small hydro plants in Kazakhstan and Uzbekistan with the thermal power plants located next to the coal mines in Kazakhstan and Uzbekistan or at the oil and gas fields in Turkmenistan, Kazakhstan, and Uzbekistan. Close to the great cities, such as Tashkent, Buchara, Samarkand, Bishkek, Osh, Almaty, Dushanbe, etc, further thermal power plants were built and connected to the grid in order to provide thermal and electric energy in combined heat and electricity plants.

Within the scope of interconnections between the power plants, the only transmission system in the world with a nominal voltage of 1,150 kV was constructed in the north of Kazakhstan. This connected the Siberian and the Ural Interconnected Power Grids of Russia. This system served to transport electrical energy from the huge Siberian hydro power stations to the load centres further west.

Concerning the supply to consumers, the transmission system was extended to connect the large industrial consumers, in particular the mines widely dispersed in the countries at the location of the deposits. These deposits of ore or minerals that are found in the region include among others copper, silver, gold, uranium, lead, zinc, tungsten, and the sources of primary energy mentioned above i.e. coal, gas and crude oil.

In addition, the HV power grid provided electrical energy for the large towns and interconnected the large urban load centres. Also, the agricultural sites needed power supply both for domestic use and irrigation purposes and required extensive transmission lines, since farmers and the whole agricultural sub-sector developed along the rivers and irrigation canals or flourished at the foot of the high mountains where abundant rainfall is conducive to farming.

Due to these reasons, the regional transmission grid in Central Asia geographically forms an irregular structure extending over many countries, partly as an interconnected grid, partly as an isolated power system or sub-system of the Russian grid. The post-soviet era with new borders and new planning criteria makes it necessary to analyse and reconsider the structure and the operation of the existing transmission system.

Annex 3 shows on one sheet the Southern interconnected grid of the Central Asian countries, as well as on a separate sheet the northern grid, mainly the grid of Kazakhstan.

3.2 Need for Improvement of the Transmission System

The West European power grid is operated according to market criteria and presents a highly meshed power system with high load density, short distances between consumers and power stations and the highest transmission voltage of 400 kV.

Contrarily, in the Central Asian Countries and in almost the whole of the former Soviet Union, the power grid was designed and oriented according central Soviet planning and the transmission system is characterised by a low load density and long distances between the generation plants and the load centres. This brought into existence a power grid with long transmission lines, transmission voltages of 500 kV and above and numerous single lines instead of looped circuits. Due to the long distances, often the investments were too high for loop connections. They would offer an increased security of supply, since in case of failure of one transmission line the second branch maintains the supply

Due to this situation the following improvements of the transmission system are necessary:

- In the past, the design and line routes were oriented according to strategic planning criteria defined in Soviet planning. These criteria referred to the degree of reliability, losses, need for maintenance, priority of supply, quality of supply, etc. In addition, the location of switching and transformer stations, as well as the routes of transmission lines, did not consider the present national borders. Therefore, the existing planning criteria and the design must be analysed and redefined and investments must be made to update the grid according to new criteria and standards.

- Apart from the technical planning criteria, the organisational structure and organisation of the grid must be reconsidered, and it must be decided if the central planning system and hierarchical organisation of the power system are still appropriate.

- In addition, planning and construction of the power system was brought to a sudden halt at the end of the Soviet Union. Several schemes are not completed or do not fulfil their planned purpose since the program was not completed. This also necessitates the review of the present status of the transmission system.

- Analysis of the transmission system shows that modern technologies need to be further used, such as micro processors for system operation, electronic protection schemes, fast telecommunication system, etc.

- Finally, during the last years of Soviet rule and even more in the following years, maintenance and rehabilitation of the electrical equipment were neglected so that an enormous demand exists in these areas.

New planning and rehabilitation and uprating of the power system must be undertaken both at a national and a regional level. All countries are already investigating the improvements which are needed for their transmission system, however, regional improvements are also necessary and their regional planning should prevail over the national.

4 The Current Electricity Pool of Central Asia

4.1 General

The Electricity Pool of Central Asia (EPCA) in the existing borders was completed in 1991 after the 500 kV electricity ring, a very important element of the Electricity Pool, had been constructed. The main 110 kV, 220 kV and 500 kV transmission lines unite, for parallel operation, the electric power systems of the five countries: Uzbekistan, Tajikistan, Kyrgyzstan, Turkmenistan and South Kazakhstan.

The EPCA was formed in the eighties as a Power Grid of four Central Asia republics and South Kazakhstan and was part of the Soviet United Power System extending from Prague to the far east. The EPCA was designed according to the Soviet planning principles and is a continuously developing highly-automated complex of electric power plants and electricity networks. The complex has a common operation regime, integrated centralised operational dispatch and service management, common planning development system, an integrated system of economic ties, information channels and necessary technological control.

The parallel operation of the EPCA unites 83 power plants, including 29 thermal, 48 hydro-power plants of 25,122 MW of installed capacity and allows advantage to be taken of the joint operation of the energy system. The main advantages are:

- the decrease of the maximum aggregate load;
- lower needs for installed and reserve capacity of power plants, and rationalisation of structure;
- optimisation of the power plants operation modes to reduce fuel demands and improve environmental characteristics for power production;
- maintenance of high reliability of voltage and frequency and sustainability of energy systems.

The EPCA characteristic feature is the structure of generating capacities which is essentially different in the different Central Asia countries. The power and capacity equilibrium is maintained within the Electricity Pool, and this defines their integrating role as the basis for energy security in the region. This is very important for the region, as the EPCA is functioning and developing owing to the richest water and fuel energy resources, which are located both in the territories of a single country and in the various countries. However, after disintegration of the Soviet Union each country is heading towards an autonomous power supply.

4.2 Kazakhstan

Kazakhstan enters the world's top ten countries for the supply of coal and hydrocarbon raw materials. Ninety-eight percent of explored reserves of crude oil with gas condensate are concentrated in the West of Kazakhstan, and they are evaluated as much as 12-13 billion tons of oil, and 2 trillion m^3 of gas. 7 billion tons of oil underlay in the Kazakhstan sector of the Caspian Sea and 20 % are associated with natural gas.

Coalfields are concentrated in South and Central Kazakhstan. These are the Ekibastuz, Karaganda, and Shubarkol basins, which have 77% of total coal reserves in the Republic. Coal industry satisfies over 80% of the fuel demands for the energy sector, but gas and fuel oil are used only within 12-13%.

Hydropower resources are concentrated in the East and South East of Kazakhstan, and they are used only within 11 % of the total potential of hydropower. The share of the hydropower plants in power generation is 6-7%.

On the whole, the installed capacity of power plants is 18,500 MW, 93% of this is generated in thermal power plants. For 1991-1995, only 50% of the installed capacity was used. A greater part of power plants were built 25-30 years ago the equipment is outdated "morally and physically", the wear and tear of the capital assets is 51 %.

In the year 1998 the electric power generation dropped to 52,000 GWh and is 63% of the 1990 level. Total consumption amounted 54,000 GWh including losses and imports from abroad that reached a long term minimum in 1998. Coal-dust power plants constitute 79%, gas-and-oil-burning power plants are 12-13%, hydro power plants 6-7%, atomic power plants are 0.7 percent.

The length of the electricity HV transmission lines totals approximately 67,900 km, including about 42,000 km of 110 kV lines, 19,000 km of 220 kV lines, 5,435 km of 500 kV, and 1,423 km of 1150 kV lines. The Kazakhstan energy system was developing within the Power Grid of the Soviet Union, in which the power plants were located based on obtaining the over-all-system effect and in the areas of big fuel fields. Therefore, the energy system of the Republic comprised of three regional systems:

North Kazakhstan, which networks supply six oblasts and where 1,900 km of the uniquely main transmission lines of 1,150 kV and 500 kV exist. They provide strong electric communications with the Ural and Siberia energy systems. This system is being developed in a southerly direction to electrically connect North and South Kazakhstan, and strategically link the system with the EPCA. In this area main electric power sources have been concentrated, they constitute 13,123 MW, or 73 % of total capacity. The region has basic coal fields (167.7 billion tons of geologic reserves and 38.6 billion tons of balance reserves). Thus, this region is energy-excessive.

South Kazakhstan, pooling four oblasts by an electricity network does not possess sufficient primary energy resources. The region is tied with the energy systems of Kyrgyzstan and Uzbekistan, and forms a part of the EPCA. Simultaneously it has an electric tie line with the North Kazakhstan's energy system, which does not completely ensure the energy system reliability and sustainability. South Kazakhstan tried to operate with the grid disconnected from the remaining EPCA system but up to 50 power cuts within one day obliged the re-connection to the Central Asian grid. The power plants capacity is 3,093 MW: they operate based on imported fuel (coal, gas, and fuel oil). The region is about 40 % energy-deficient.

West Kazakhstan also pools four oblasts by an electric network, and has extended energy ties with the Russian energy systems. This region is 90% energy-deficient which is compensated by supplies from Russia. West Kazakhstan is equipped only with 10.5% of installed capacity (1,917 MW), and the region is chronically undersupplied with energy. Nevertheless, the region has 98% of carbon raw material resources, and the targeted industrial complex *crude oil production - oil refinery - petroleum chemistry - organic synthesis industry* will require a sharp increase of electric power capacity.

The capacities existed in the past were not sufficient to fully satisfy the electric power needs, and the deficit of balance of trade in 1990 was 12,400 GWh, including 4-5,00 GWh supplied from Kyrgyzstan to the South Kazakhstan users. Transition to foreign currency for inter-system power transfers caused the decrease of inter- system transfers from EPCA.

Because of the economic crisis and the fall of the electric power demands, the home capacities seemed to cover the electric power needs completely. However, deficient financial funds, break-up of economic ties, intermittent supplies of equipment and procurement of spare parts sharply decreased the quality of repairs and maintenance and, in 1998, this caused the reduction of electric power production in South Kazakhstan to 51 % of the 1990 value.

The crisis situation has been worsened due to raised fuel prices, and this caused a subsequent rise in electricity and heat cost value, and correspondingly, profit reduction and operation at a loss of the energy utilities despite the tariff increases. The consumers' inability to pay brought to huge bill receivables for all user categories, and therefore account payables for the energy utilities.

To ease the deadlock and implement economic reforms the Republic of Kazakhstan restructured and privatised the energy industries and facilities. Since 1995 foreign companies privatised 28 power plants including State District Power Plants (SDPP), Central Heating and Power Plants (CHPP), Hydro Power Plants (HPP). The Kazakh Electricity Grid Operating Company (KEGOC) was established, Regional Network Distribution companies (RDC) and district electrical networks (DEN) were formed as independent agencies. Because of those reforms, over 70% of energy capacities appeared to be the private property of the AEC Corporation (USA), Tractebel (Belgium), etc.

At stage I of the reform program, the electric power sector crisis aggravated and caused the maximum electricity load transmission in the autumn-winter period, supplemented by mass power cuts, because of electricity and heat payment defaults, raised fuel prices, and capacity and electricity deficits. During that stage, the laws on Electric Power Industry and Energy Savings have been developed and approved and the Energy Development Concept for Kazakhstan was developed. It laid down the guidelines for the development and restructuring of the power sector.

Stage II is remarkable for the development and approval by the Governmental Decree *Of 31* July 1997 the Program of a Future Development of the Electricity Market for 1997-2000. The Program determined main directions for the establishment of the electricity-market model, and the phased Plan of Action of the Kazakhstan Government for the Electricity Market Development. The Plan is being implemented to gradually improve the situation and establish the wholesale and retail electricity market associated with a free formation of wholesale electricity prices. Large energy users have now the right to choose the energy supplier on a contractual basis, hence. the establishment of the competitive market is in progress and it contributes to stabilisation of the energy-carrier tariffs and prices.

To form the reliable and effective electricity market Stock Company, Kazakhstan Electricity Grid Operation Company (KEGOC) developed the rules for the wholesale electricity and capacity market in the Republic of Kazakhstan.

4.3 Kyrgyzstan

Main water resources of the region are formed in the territories of Kyrgyzstan and Tajikistan by the rivers Syr Darya and Amu Darya, which flow into the Aral Sea. The Syr Darya basin is highly regulated by the Toktogul long period storage reservoir, located in Kyrgyzstan and also by the down stream reservoir Kairakkum (Tajikistan), Chardara, Andizhan and Charvak (Uzbekistan) with seasonal storage. The reservoirs are regulated based on the irrigation farming interests. The hydropower potential of the rivers' basin in the region is about 554 billion kWh per year, including 293,000 GWh (or 53 %) of the Tajikistan share, and 142 billion kWh (or 30 %) of the Kyrgyzstan share. In Kyrgyzstan about 9.5% of potential hydro resource have been developed, in Tajikistan 4.6%.

The Kyrgyzstan oil and gas reserves are not significant. Coal reserves are mainly concentrated in inaccessible mountain regions under difficult mountain and geological conditions; thus, the reserves are evaluated as inefficient and not competitive in comparison with other energy carriers. The Kyrgyz Republic ranks the best among the Central Asian countries with its estimated coal reserves. However, in the recent years the crude, gas, and coal productions have nose-dived.

The energy system of Kyrgyzstan operates in parallel with the Electricity Pool of Central Asia. The installed capacity of electric power plants in the Kyrgyz Energy System is 3,586 MW, including 82 % of hydropower and 18% of thermal power capacities. The extent of the HV electricity transmission lines is 6,421 km including 546 km 500 kV, 1,364 km 220 kV and 4,511 km of 110 kV transmission lines. The Kyrgyzstan energy system is tied with the energy systems of adjacent countries by the main transmission lines, and it forms the constituent of the 500-220 kV electricity ring in the EPCA.

The Naryn cascade of hydropower plants with a total capacity of 2,800 MW includes long-period, seasonal and short-time (daily) storage reservoirs. The Kyrgyz hydropower plants cover the variable electricity consumption schedules for the adjacent countries and frequency regulation in the EPCA. The EPCA optimum operation regime is that of mutual electricity supplies and maximum power generated at the hydropower plants during the growing season, in this respect taking into account the comprehensive use of the Naryn - Syr Darya hydropower resources. The concerted activities of all EPCA entities addressed to electric power mutual supplies and transit, frequency regulation and tariff policy play the crucial role in obtaining such a regime.

The HPP share in total power generation did not exceed 70% in 1990-1991, but for the recent six years, it increased to 91 %. The storage releases from the Toktogul reservoir for energy needs increased from previous 0.3 m^3/sec to the present *5.5* m^3/sec in the winter-autumn time. In this period the Toktogul Reservoir is operating in the energy regime to cover Kyrgyzstan's increased electric power need. In summer it is operating in the irrigation regime to satisfy irrigation water needs of Uzbekistan, Kazakhstan, and Tajikistan. As from 1991 the international relationships and mutual accounts became more complicated, national currencies were introduced, prices for crude oil, coal and gas grew, rail transport tariffs increased, fuel and power deliveries from the adjacent countries in winter reduced, and thus affected the structure of the fuel and energy balance. The decrease of fuel mining, and cut of heat supplies by boiler houses and TES (Central Heating and Power Plant) caused the growth of electricity use for household needs, as people used electric power for heating, hot water and cooking meals.

Hence. the electric power consumption in the autumn-winter time has grown from 53% (in 1990-1991) to 70 % (in 1996-1997) of the annual volume.

Since 1992, under these operation conditions the Toktogul reservoir had a forced transition from the irrigation to the energy operation regime. The existing heat and power pricing system does not cover the production and delivery costs, and imperfection of billings and charge records causes a "red-ink" position for the Reservoir and the accruing of considerable non-payments. The hard financial situation in the energy sector was the result.

In order to raise efficiency of the energy facilities based on new market forms of economic and management activities, to provide stable functioning of the energy system, choose the optimum management structure, reform the competitive environment and invest external investments, the Republic of Kyrgyz developed the Program of the Kyrgyzstan Energy Sector Restructuring and Privatisation. The Program proposes several sequential mutually connected stages, which stipulate the necessitating of structural reforms and establishment of economically independent projects, subject to future privatisation.

At Stage 1 (1996-1997) SC Kyrgyzenergo was established, it is responsible for and implements electric power generation, transfer and distribution; design, construction and repair subdivisions are set apart as independent joint stock companies. Laws *on Energy Sector and Electric Power Industry* have been approved by the Parliament; the regulatory Body *State Energy Agency* under the Government of the Kyrgyz Republic was established.

Stage II (1998): The Financial Model for the SC Kyrgyzenergo Restructuring was approved by the Government; compliant to the Model, tariffs increase stepwise to ensure the profitability of energy utilities. However, the implementation did not proceed and the restructuring came to a halt since 1998. The Kyrgyzenergo restructuring is assumed to separate electricity distribution utilities and small hydropower stations, and form independent stock companies with anticipation of future privatisation.

Stage III (planned for 1999 and further) proposes formation of state companies, on the SC Kyrgyzenergo base that will generate and transfer electric power:

> State Stock Company (SSC) *The Naryn Cascade,* which will comprise the Toktogul cascade of hydropower plants, *Bishkek and Osh TES,* and the HPP facilities under construction with the right to separate any HPP under construction as a concession, joint utility, or withdraw it for the strategic investment management.
>
> *SSC National Electricity Supply Network* comprised of the Central Dispatcher Service, high-voltage transmission lines with all substations, material and technical supply enterprises.

Under the transition to the market economy direct guidance of the current economic activities on the part of central state bodies should be essentially curtailed. At the same time, their role in determining the energy policy is increasing.

In this connection, in accordance with the draft laws *On Energy Sector and Electric Power Industry,* functions of the Government, the regulatory Body and energy utilities should be differentiated.

4.4 Tajikistan

The Tajikistan Energy System also works parallel with the EPCA, the installed capacity is 4,354.5 MW, including the HPP's 4,000 MW (or 92%). The annual average power generation of the hydropower plants is 15-17,000 GWh. The Nurek hydropower plant of 3,000 MW installed capacity is the biggest in Central Asia. It has the seasonal-storage reservoir of 10.5 billion m^3, and it regulates the Vaksh flow for the irrigation needs in the Amu Darya basin countries. The Nurek hydro structure operates in the irrigation regime in the beginning and in the middle of the growing season (June - July), and the direct electricity losses make up 310 GWh.

The Kairakkum hydro-structure on the Syr Darya River operates in the irrigation mode meeting the interests of the Republic of Kazakhstan and Uzbekistan, and does not generate 88.5 GWh of deficit winter electric power, so the Republic has to buy power in Uzbekistan, Turkmenistan and Kyrgyzstan, and pay high prices. Because of isolated work in the Central Asian energy system, Tajikistan generates about 7-8,000 GWh in summer, having 1,500 GWh of excess electric power, and experiencing the power deficit in winter. The former electricity transfer system was destroyed. Under such conditions, Tajikistan, following the international norms intends to require the operation cost compensation for the Kairakkurn reservoir and for regulating the Syr Darya flow. The country means to require compensation for the direct losses of 398.5 GWh of electric power at Kairakkum and Vaksh cascade of hydropower plants, and for annual 60 GWh of lost energy intended for the drain wells operation in the inundation areas.

The Tajikistan oil and gas reserves are not fully explored nor yet exploited. Coal reserves are mainly concentrated in inaccessible mountain regions under difficult mountain and geological conditions.

The length of the electric transmission lines is 4,268 km, including 226 km of 500 kV HV lines, 1,203 km of 220 kV lines and 2,839 km 110 kV lines. As of now, the North is supplied by electric power from Uzbekistan. Tajikistan compensates by the same electric power amount in the south. The 500 kV single circuit electric transmission line *South-North* is being designed to transmit power and capacities of the Bolshoy Vaksh cascade to the north of the Republic, its throughput capacity is 1,500 – 2,000 MW. It is also planned to connect the isolated energy systems of Central Tajikistan and Leninabad Oblast

The break of international relationships and the civil war caused huge economic hardships. Under these conditions, the electricity supply system is the only industry that works continually during these bad years and ensures continuity of power service for industrial, agricultural sectors and population. Nevertheless, low tariffs, consumer debt receivables, and lack of equipment stores and investments resulted in the crisis in the sector and frequent load cut-off. To ride out the present, tense situation radical improvement of the economy is essential, taking into consideration market reforms and the staged restructuring of The State Stock Energy Holding Company *Barki Tojik.*

Stage 1 (1998-1999) stipulates separation of electric power plants and electric power networks by means of detachment of the Cascade of the Varzob HPPs from the Central Electric Networks, and establishment of several stock enterprises, including *Cascade of Varzob Hydropower Plants, and Electricity Networks of the Republican Value Regions;* privatisation of the projects under construction and the ones not participating in generation, transmission and distribution of electric power; and the withdrawal of Nurek from the SSC Barki Tojik's balance.

Stage II considers the establishment of stock companies assigned for the construction of hydropower plants and the 500 kV transmission line *South-North;* separation of the power plants from electric networks and establishment of stock companies, giving the right to energy consumers to choose the power producer; the Barki Tojik converting into a stock company possessing the right to sell the excess summer electric power at negotiated prices.

The association of construction and operation of small hydropower plants was established to attract private investments, the Kofarnikhon Mechanical Repair Plant took a position of a stock-holding company, Sangtudin hydropower plants under construction also have stockholders.

After the normative and legal basis was advanced, in 1999/2000 the Draft Law on Energy was developed, ADB's remarks were included and the slow restructuring process continued.

4.5 Uzbekistan

Uzbekistan has unique fuel and energy resources, and it is a foremost country in the world for crude oil and natural gas reserves. The explored reserves are about 2 trillion m^3. The accent is given to five dominant oil and gas-bearing regions: Ustyurt, Bukhara-Khivin, South-West-Gissar, Surhandarya, and Fergana regions, in which 160 oil- and-gas-promising fields have been explored. About 60% of the territory in the Republic has good exploration prospects. Special attention must be given to the fact that oil and gas fields in Uzbekistan are remarkable for different factors such as well efficiency and production prime cost, as opposed to the deposits of the adjacent Republics, and allows reliability on efficient deposit development and high profitability.

Uzbekistan has huge coal deposits, and it is the second best in Central Asia for the geological holdings. The coal is mined from three deposits: Angren, Shargun and Baisun, having 2 billion tons of projected reserves. Technically exploitable hydropower resources are evaluated which can generate estimated-88,300 GWh a year, but only 6% are being generated.

The installed capacity of power plants makes up 11,260 MW including 87.4% of thermal-power and 12.6% of hydropower plant capacities. The thermal power units are concentrated in huge power plants with few new units, most of plants operating at the end of their lifetime (i. e. 1,860 MW in Tashkent installed between 1963 and 1971; 3,000 MW in Syrdaria installed between 1972 and 1981, and 2.100 MW in Novo Angren, installed between 1985 and 1995). The smaller power plants have even older units. In total 69 hydro generation units are installed. The greater part (84 %) of hydro plants were built 48 years ago.

The length of the HV electric transmission lines is 22,163 km, composed of 1,657 km 500 kV lines, 5,688 km 220 kV lines, and 14,818 km of 110 kV lines.

46,100GWh were generated in 1997; this constituted 85.8 % of level of 1991. The cross-border electricity transfers essentially decreased, and this resulted in an unfavourable transfer balance; the energy consumption was as much as 87 % of the 1991 level.

About 85 % of electricity production is provided by thermal power plants. In the structure of the primary resources used for heat and power generation, natural gas makes up 82.6 %; fuel oil amounts to 13 %, and coal adds up to 4.4 %.

For 1997 the cost of electric power increased 1.5 times, heat power - 1.3 times, owing to the raised prices for fuel, material resources and equipment. Because of the rise in prices, electric and heat power tariffs are being reconsidered, based on the decisions of the Government of Uzbekistan. The Uzbek Government set payment terms based on contract prices. Consequently, in August 1997, electric power tariffs were changed for the population. The increase of heat and power prime costs caused the decrease of profit in the energy sector.

However, the inventory ruled by the Uzbekistan Cabinet of Ministers (02/19/98) revealed that no unprofitable enterprises existed, and the economic conditions of the enterprises were satisfactory.

Since 1997 the Republic has started privatisation of heating system enterprises that do not affect the system operation and which supply heat to groups of users. On the base of the enterprises and agencies that carry on design and survey, construction, erection, repair and supply works, 13 joint stock companies were established, in which Minenergo still manages the government shares. The "restructuring" of the controlling block of shares is to increase their share for free trade, including their sale to foreign investors, however, commitment to reform by Government is weak. Currently, the Government owns main energy projects, and as they are strategically important for the economy and population, the energy sector will be restructured in two stages:

At Stage 1, it is intended to transform the enterprises, entering the energy system and being structural units, to independent economic entities.

At Stage 2 Minenergo will be transformed to a holding company, based on the projects restructuring.

4.6 Ongoing Changes in the Electricity Pool of Central Asia

The electric power sector in the Central Asian countries experiences hard times, with conflicting situations in many instances. In particular the breakdown of industrial demand, rises in the price of fuel and transport and interruption of fuel supplies disturbed the technical and financial situation of the power utilities.

On one part, the Central Asian independent countries came into the possession of the electric power base, which is able to satisfy internal electric power needs. Under sovereignty, and with rich energy resources, each country aims to gain energy independence and use home resources to a maximum. In Kazakhstan, for instance, most of the electric power plants burn coal, in Kyrgyzstan and Tajikistan they use hydropower, in Uzbekistan and Turkmenistan natural gas.

On the other part, all Central Asian countries put energy limitations both on industrial and household consumers, and this causes economic losses and social strain. One of the reasons for limitation is poor fulfilment of contractual obligations and energy consumers' default of payments for electricity and heat, and credit and debit indebtedness both on the national and international level.

Consequently, the economic efficiency and operation reliability of the EPCA diminished. The capacity allocation of the power plants upon formation of the EPCA was based on hydro- and fuel-energy resources available. The electricity demand and supply margins did not correspond to the state borders. Hence, the energy, systems of north and central oblasts of Kazakhstan were operating in parallel with the adjacent Russian energy systems, and south energy systems were operating with the Electricity Pool of Central Asia. The hydropower resources of Kyrgyzstan and Tajikistan were used as the peak energy resources for Kazakhstan, Uzbekistan and Turkmenistan; coal-fired, gas-and-oil-burning heat power plants met the Kyrgyzstan and Tajikistan basic power demands. Thus. the optimal operation schedule of the EPCA hydro- and thermal power plants was provided, and correspondingly, fuel and energy industries, water management systems in the region were functioning appropriately.

In addition, it can be observed that in the recent years power trade among the Central Asia countries concentrated more and more on exchanges caused by the irrigation schemes and that the other possibilities and advantages of power pool operation had been abandoned.

The leading frequency-regulating role of the Kyrgyzenergo and Barki Tojik hydropower plants should be emphasised. In the non-growing season the regulating range of the Kyrgyzenergo hydropower plants was from 400 MW to 2,600 MW, of the Barki Tojik hydropower plants was from 550 MW to 2500 MW.

SC Kyrgyzenergo plays the leading role in frequency regulation. The Nurek reservoir decreased storage to 861 m; thus, the hydropower plant was involved in frequency regulation only during the evening peak. Regime difficulties arose because some energy systems did not have contracts for rendering frequency regulation services, and because of the contract payment defaults. To a greater extent it refers to the Kazakhstan users (south Electricity Grid Operating Company KEGOC, Zharnbyl Regional Energy Company (Zharnbyl REC), and South Kazakhstan REC.

Uzbekistan generates 51 %, Kyrgyzstan – 13. 8%, South Kazakhstan - 9.1 %, Tajikistan - 15%, Turkmenistan - 10% of total Central Asian electric power.

A total decrease of fuel and energy production in Central Asia by 32% in 1991-1998 occurred in all Central Asian countries, including the decrease of natural gas production by 39 %, oil by 3%, coal by 35%, electric power by 20%.

Mining and production of main fuel and energy resources decreased in most of the Central Asian countries, and this, together with the tendencies and measures for economic stabilisation and growth, may put the republics into the situation when the deficit of fuel and energy resources will become a constraining factor for their social and economic development.

It is pertinent to note that in 1998 the power consumption decrease was a little less intensive compared with the previous years, and according to the economic strategy scenarios energy consumption is projected to increase in the Central Asian countries. In addition it is observed that in the past years power trade among the Central Asia countries concentrated more and more on exchanges caused by the irrigation schemes and that the other possibilities and advantages of electricity pool operation had been abandoned.

The organisational changes and restructuring efforts of the state power monopolies are described in more detail in Annex 4, Restructuring of the CA Power Sector. The document demonstrates the development of reforms in the countries concerned, ranging from small changes of the monopoly to complete unbundling and restructuring of the power subsector.

The electricity tariffs in the CA countries are highlighted in Annex 5, Tariffs. The document shows the chronic low level of tariffs in all CA countries, except for Kazakhstan.

4.7 Power Trade in the Central Asian Electricity Pool

The regional dispatch centre for the power grid of Central Asia was founded in 1960. The present Unified Dispatch Centre (UDC) for Central Asia is located in Tashkent in the building of the Ministry of Power Industry and Electrification. It was built in 1975 and slightly modernised during the past years. The UDC operates the power grids of the four Central Asian countries and South Kazakhstan that are interconnected and are synchronised with the Russian power grids and with North Kazakhstan.

The UDC is designed according to Soviet technology of the mid seventies and does not permit modern operation, data processing and control of power. As an example, line monitoring is foreseen only for few trunk lines, outdated computers are operating, multi-tariff meters do not exist, etc.

Power trades are made only due to interstate agreements between the Central Asian States. In addition payments are made for trade in power frequency regulation. All other power exchanges due to load variations or short term power shortages are not foreseen. If deficits or surplus of power are accounted in one country the deviations are compensated immediately. These compensations are based on the good relations which exist between the dispatchers of the different countries. They know each other and rely upon the fact that deviations are balanced.

On the distribution level (35 kV, 10 kV and 6 kV) numerous transmission lines cross the borders, especially in the Fergana valley. There, the load dispatchers at district level ensure that at least at the end of each month the balance of imports and exports is levelled. These power exchanges play a vital role for the rural supply but they do not enter in the statistics.

In the operation of the system no difference is made between peak power and base load power, nor between kWh supplied during working day and Sunday, winter or summer. Furthermore, prices for ancillary services, such as spinning or non-spinning reserve, system control, frequency regulation, or others are not used.

Concerning power trade due to interstate agreements, the past years showed the following scope for the different countries:

Since Uzbekistan borders with each of the other Central Asian countries most of the power trade passes through the Uzbek HV power grid. Various power exchanges are recorded throughout the year, however, in the average, the annual power balance is zero for Uzbekistan. In detail the following power trades were recorded during the past years:

Power flows between the northern and the western part of Tajikistan have to pass via the 500 kV lines and substations of Uzbekistan. In addition Tajikistan produces the bulk of its energy needs with large hydro power plants that have only a seasonal storage capacity. Therefore, in spring the country has to import power from Kyrgyz Republic and from Uzbekistan. This energy is returned in summer with a discount, when abundant hydro generated energy is available due to the forced water flows for the irrigation system.

In former times Tajikistan exported large quantities of electric energy but both volume of export and balance between export and import diminished during the recent years.

Table 2 Electricity Trade Balance of Tajikistan in GWh

Year	**1980**	**1985**	**1990**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Import	4,100	5,500	6,900	6,428	5,200	5,571	4,860	3,978	4,345	3,591
Export	8,000	5,900	5,600	5,596	5,600	6,072	4,198	4,890	4,247	3,346
Balance *	3,900	400	-1,300	-832	400	501	-662	912	-98	-245

* + export surplus,

In 1996 a contract to export 1,500 GWh energy to Kazakhstan for a value of about 22 million US Dollars could not be implemented because of Uzbekistan refused the wheeling of this energy through its network.

The water released for irrigation from the Naryn River generates an excess of electric energy in the Kyrgyz power system. The interstate agreement specifies that both Uzbekistan and Kazakhstan receive electric energy in proportion to the amount of water received for irrigation purposes. Therefore Uzbekistan imports electric power from the Kyrgyz Republic that is returned in winter mainly in the form of gas, some years in electricity. Some years Uzbekistan received 200–250 GWh from Kyrgyz Republic in summer and returned about 500–600 million m^3 of gas in winter.

In summer the Kyrgyz Republic also supplied electrical energy to Kazakhstan. This energy is returned from Kazakhstan to Kyrgyz Republic in form of coal for the combined heat-and-power plant in Bishkek.

The southern part of the power grid in Kazakhstan suffers from power shortage in winter. Therefore from September to spring Turkmenistan sells electrical energy to Kazakhstan wheeling power through Uzbekistan. In 1997 250 GWh were sold. The wheeling charge amounts to 0.5 US cents per kWh and 1 000 km.

In some years Tajikistan buys power from Turkmenistan during the spring period. However, the purchases depend on availability of money for the purchase of electric energy.

The Unified Dispatch Centre is responsible for the synchronous operation of the 5 Central Asian countries. It is located in Tashkent. Every three months the Electro Energy Council meets in rotating order in one of its member's capitals. The respective host minister acts as chairman for the meeting. This council agrees on the rules of power trade between the countries. It also fixes the wheeling charge.

Power trades are performed mainly via the 500 kV transmission lines and to a smaller extent via the 220 kV system. For the power transfer the wheeling country is remunerated with 0.5 cents per kWh and 1000 km of the dedicated transmission line route.

Frequency regulation is performed as well by the UDC. The centre designates one country with vast hydropower capacity to perform the power frequency regulation for the five countries, generally either the Kyrgyz Republic or Tajikistan. The remaining countries operate their systems in such way that the load remains within the planned margins scheduled for the day. If the countries exceed the margins they have to pay for the power deficit in the peak periods or excess production in the minimum periods. The payment is performed according to the formula calculated by the UDC and the tariff approved by the Council.

In view of the weak power trade and the lacking infrastructure and experience with transactions of electric power, USAID launched a program to develop the Central Asian Power Market.

Summarising the power exchanges in the Central Asian grid, it is evident that only little scope of power trade exists and that the possibilities of power trade as practised in industrial countries are not used. In addition, the UDC load centre is not equipped according to the state of the art of modern on-line dispatch centres.

4.8 USAID's Involvement in the Regional Energy Sector

The United States Agency for International Development (USAID) started with technical assistance for the energy sector in Central Asia after the break up of the Soviet Union and helped the newly independent countries in the identification of rehabilitation needs and development and implementation of structural reforms. The assistance covered oil, gas and electricity. The activities for Central Asia are regionally directed from Almaty in Kazakhstan.

USAID's involvement covered equally all five Central Asian countries but in the past activities concentrated more and more in those countries, where legal, regulatory and policy framework achieved an environmentally sound, market oriented energy sector that is conductive to private investment. Consequently Kazakhstan with its far reaching structural reforms benefited most from the Agency's assistance and is taking a lead role for the other countries.

The Agency's Workplan for the year 1999 covered USAID's involvement in

- Kazakhstan in oil, gas and electricity;
- Kyrgyzstan in electricity;
- Uzbekistan in oil and gas; and
- Central Asia Region in electricity.

The detailed workplan highlights the background for the different tasks including the necessary reforms, encountered difficulties and envisaged benefits of the different tasks. In addition, the government counterparts and planned output are described. The activities in the gas and oil subsector are presented in the document as well in order to give an overall view of the energy sector and in view of the interrelation between the sub-sectors, i. e. if the legal frame work for privatisation of the oil sector is created, the electricity sector can follow that established road. Due to the civil war in Tajikistan, USAID only started with smaller activities in this country.

USAID prepared the budget for the financial year 2000. Due to reorientation and the change in personnel, in the present planning it is envisaged that USAID will no longer focus on legal, regulatory and institutional reform of the energy sector but will concentrate on hydrology and the development of hydropower resources. Therefore, according to the present planning, the ongoing sector reform will come to an end and the Consultant Hagler Bailly will resolve his offices in the CA countries.

5 Project for the Rehabilitation and Uprating of the CA Power System Operation

5.1 Identified Regional Power Projects

The West European power grid is a highly meshed power system with high load density, short distances between consumers and power stations and the highest transmission voltage of 400 kV. Contrarily, in the Central Asian Countries and in almost the whole of the former Soviet Union, the power grid is characterised by a low load density and long distances between the generation plants and the load centres. This brought into existence a power grid with long transmission lines, transmission voltages of 500 kV and above and numerous single lines instead of looped circuits. Due to the long distances, often the investments were too high for loop connections. They would offer an increased security of supply, since in case of failure of one transmission line the second branch maintains the supply. Finally, as mentioned in chapter 3, Need for Improvement of the Power System, the Central Asian power grid suffers from under-investments in maintenance, rehabilitation and use of modern technology during the past years.

The high voltages, the long distances, the single line connections and the under-investments formed the basis of different proposals for regional power projects. These projects were presented to the Consultant in each of the visited countries and they are described in Annex 6 in alphabetic order of the concerned countries. The geographic location of the different projects can be seen from the drawing of the Unified Power Grid of the Central Asian countries, presented in Annex 3:

Some of the proposed projects are of similar nature or show similar financial, political consequences so that it is possible to screen the projects and classify them in categories for further evaluation:

- Environmentally Oriented Projects
- Co-operation Projects through Construction of Regional Hydro-Power Plants
- Transmission Line and Substation Projects with high Regional Relevance
- Transmission Line and Substation Projects with minor Regional Relevance
- Medium Term Improvement of Power Pool Operation
- Long Term Improvement of Power Pool Operation
- National Projects

In the Intermediate Report these projects were presented to the Bank with the request to provide comments which regional project shall be evaluated in the continuation of the study and in accordance with the terms of reference. After consultation within the Bank, it was decided that it would be preferable to give more emphasis to the improvement of the power pool operation which was performed in the following evaluation of the rehabilitation and uprating of the CA power system operation.

5.2 Project for the Rehabilitation and Uprating of the CA Power System Operation

In a power pool of several countries each country is responsible for its own generation, transmission and distribution equipment and each partner of the pool fulfils his obligations to his best. However, for operation of the different plants, several systems must be maintained that are needed for interaction with the neighbouring systems or that must be co-ordinated with them. The Project for “Rehabilitation and Uprating of the CA Power System Operation” will improve and make operational all those services that are necessary for proper functioning of the power pool, so that the partners can take advantage of the benefits of their joint operation.

The parallel operation of the systems always has two sides, namely the organisational agreements between the parties and the need to provide special technical devices or to harmonise existing technical equipment. The proposed project covers the technical equipment for power pool operation. The institutional side must be agreed upon prior to the start of the technical project.

5.3 Technical Issues to be Agreed upon for Stable Power Pool Operation

In the Soviet times, the five power systems of Central Asia and southern Kazakhstan were physically interconnected by the 500 kV Central Asia loop and various 220 kV lines. The electrical systems worked in parallel, as an interconnected system and they continued to do so after independence under a “Parallel Operations Agreement” that was signed in November 1991 in Ashgabad by all five new countries. From a technical (though not economic) perspective, they were operated much as a tight power pool would be, with central dispatch of the generation and transmission system from Tashkent, hierarchically organised with strict command structure. Now, after independence of the countries, the National Dispatch centres have more autonomy, the technical obligations are less respected, discipline of operation decreased, funds for maintenance and rehabilitation are scarce, and market oriented issues play more and more a role.

If several countries want to switch in parallel their electricity grids, they have to fulfil a number of pre-conditions in order to achieve a technically stable grid. In the Soviet times Moscow fixed these pre-conditions and now, after the disintegration of the Soviet era, new rules and standards have not fully been developed. Especially in view of the nascent power market new rules and standards must be defined and all partners must respect these. Consensus and agreements must be reached on:

- Co-ordinated planning
- Co-ordinated dispatch, maintenance and monitoring of operation
- Generation capacity reserves
- Power frequency control
- Possibility of black starts
- Load shedding and emergency control
- Voltage regulation
- Provision of reactive power
- Co-ordination of protection equipment and of short circuit power
- Communication Links

Concerning the parallel operation of the power systems of the CA countries, for each of the above mentioned issues agreement must be reached among the participants of the power pool and then each country must accomplish the defined recommendations both institutional and technically.

5.4 Existing Situation of the Equipment for Joint Power Pool Operation

5.4.1 Dispatch of the EPCA

In the three level structure of the operation and dispatching system, the Unified Dispatch Centre (UDC) in Tashkent is in charge of all questions that concern the complete system, the inter-border lines issues and questions that must be respected by all partners of the interconnected system. The National Dispatch Centres (NDC) are responsible for operation within the states and the Regional Dispatch Centre (RDC) control power system within their dedicated national supply area. The data from the system (generation plants and transmission system) are transferred to the lowest possible dispatching level. There they are selected and concentrated for the next hierarchy and finally processed for information and display in the UDC.

The energy system of each country performs the load estimation for its supply area, schedules the generation of their plants and sends this data to the UDC. The UDC is not engaged in the planning of electricity generation and consumption but verifies the scheduled generation and transmission operation on overload and system violations. For that purpose ODC makes a full balance of power of the EPCA, based on the information received and provides, if necessary, the load flow between the countries of Central Asia and South Kazakhstan. Then, the information is sent to the national power organisations to submit and sign agreements for purchase of electric energy; the Integrated Energy System Council of Central Asia is informed too. Such practice of planning is carried out for a year, quarter of a year and for every month.

5.4.2 SCADA and Telecommunication System

In the CA grid about 900 analogue values are measured for the UDC, such as voltage, load, active and reactive consumption, etc and in addition, about 1,500 binary telemetric signals are collected concerning switching positions of switchgear, tap changers, voltage regulators, etc. The UDC data collection scheme extends to NDCs, substations and power plants:

Table 3 Information Collection for the UDC

	S. Kazakh.	Kyrgyzia	Tajikistan	Turkmenistan	Uzbekistan
NDC	Almaty Shimkent	Bishkek	Dushanbe	Ashgabad	Tashkent
RDC					Fergana North – West Samarkand
Power Plants	Shambul	Toktogul Uchkurgansk	Nurek	Maryi	Navoi Tashkent Syr Daria Angren Novo Angren
Substations	Shambul 500 Shimkent 500	Bishkek 500	Regar		Lochin Tashkent 500 Guzar 500 Karakul 500

The number of recorded values and signals are constantly changing according to the modifications and development of the power system. The following table provides an approximate estimate of the share of each country:

Table 4 Number of Values and Signals Transmitted to the UDC

	S. Kazakh.	Kyrgyzia	Tajikistan	Turkmenist.	Uzbekistan	Total
Values	210	100	200	85	305	900
Signals	200	135	200	200	765	1500

These signals are transferred via the SCADA and Data Communication System to the dispatchers. The SCADA system is generally designed for single-directional data flow, transferring analogue and binary data from the power plants and substations within the entire CA power system to the controlling RDCs, NDCs and the UDC. Only few data is processed with return on-line data flow. The ODC developed a computer program to monitor on the screen the present load flow with warning signals for overloaded lines and overvoltage. In addition, the production of each power plant and statistics about voltage profile, frequency and dispatch are monitored, recorded and stored for ten days.

Due to the slow telecommunication channels the values are updated only every 30 sec. No fully automatic telecontrol or telecommand is sent out of the UDC. For telecommunications power line carrier (PLC), underground cables, leased Public Telephone and Telegraph (PTT) lines, microwave and others are used.

Telephone communications between ODC and the national dispatching centres pass via telephone links, which are mostly government owned. All these links are redundant. Moreover, in each dispatching centre equipment is installed for “emergency supply and communication” to avoid communication blackout. Experience has proven that the communication system is reliable.

But most of the technology is rather old, between 20 to 30 years, so that precision is not very high, accuracy of data collection is low, the data transmission speed is low and spares are hardly found. The existing SCADA system, designed to provide tools for monitoring the power system, load monitoring of power lines and transformers, logging of events, and process data is no longer acceptable, because it cannot cover the wide range of services required by today’s operating standards. In addition the communication channels are too slow and cannot cater for enhanced fault analysis of modern substation automation and network control systems. The present equipment of system control and monitoring does not provide the environment under which a modern electricity market can operate. Furthermore, it is highly labour-intensive, and does not provide the analytical tools necessary for efficient operation of a complex international transmission network.

5.4.3 Power Frequency Control

5.4.3.1 General

Control of frequency in power systems is generally managed by a three level system whose goals are security of the interconnected system and security and economy of the different subsystems. These three levels are primary, secondary and tertiary controls.

- Primary power/frequency control together with the turbine governor is used to restore rapidly the balance between generation and load. Maintaining the frequency near to its nominal value is important for the security of the system. All partners in the interconnection are jointly liable. In normal operation primary frequency control maintains a balance between generation and consumption by suitable actions on generation units (gates of hydro units, valves on thermal units, power set points on HVDC links, etc.), or by demand side management, by automatic disconnection of pre-heaters on certain power plants and/or by overload operation (i. g. gas turbines).

- The secondary power/frequency control has to bring the frequency back to nominal and the exchanges of electricity back to programmed values. With the secondary control load change or generating failure is compensated by the system controller of only the network section in which the change or failure occurred. The subsystems have to restore the power either manually or with an automatic generation control (AGC).

- Tertiary power/frequency control is not defined uniformly in the different countries. Mostly it is understood as the manual control actions that are necessary when secondary control reaches its point of saturation or when a secondary control reserve has to be re-established after failures.

5.4.3.2 EPCA Situation

In the EPCA an automatic power frequency control system exists for primary frequency control, consisting of a central device, located in the UDC and executive devices, located in the hydro power stations Nurek (3000 MW in Tajikistan), Toktogul (1200 MW in Kyrgyz Republic), Charvac (776 MW in Uzbekistan), and Kapchgai (434 MW in Kazakhstan). Frequency is kept constant through automated control of the output on one or more of these stations. Nurek power plant control is supplemented by a special power control on the 500 kV line Regar – Guzar to avoid overload on other lines if it trips.

The centralised automated power/frequency control system cannot operate at maximum or minimum water flow. **If enough reserve power is available** the system operates in a very reliable mode and the frequency oscillations are smaller than ± 0.1 Hz.

The development of frequency is constantly recorded over the full day and stored for 10 days in order to be able to check for any irregularities during this period. In this way the Consultant controlled as a random sample the quality of frequency over 10 days which presents a typical picture of the quality of frequency:

- The lowest frequency was recorded with 49.1 Hz, occurring twice that day;
- 49.2 Hz was reached on four days sometimes several times within 3 hours;
- 49.5 Hz lasted over 3 hours.
- The admissible frequency level of 49.9 Hz was not respected on 2 days over a period of 5.2 hours each time.
- In the average of the recorded ten days, frequency was below 49.9 Hz during 2.4 hours every day.

These figures show the weak performance of the EPCA concerning regulation of frequency, especially bearing in mind that in the West European UCPTE frequency variations generally remain in the range between 49.95 Hz and 50.05 Hz. The frequency regulation must be improved according to modern technologies as to reduce the big frequency deviations. If the calculated average period of 2.4 hours of frequency below 49.9 Hz is summed up over the whole year, additional 259 GWh could be sold within one year, taking into account that a frequency drop of 0.1 Hz corresponds to about 300 MW missing generation capacity.

Maintaining the frequency near to its nominal value is important for the security of the system and all partners in the interconnected system are jointly liable. In the Central Asian grid however, only the four above-mentioned power stations are equipped and able to perform the primary power/frequency regulation. Turkmenistan has no power station for primary power/frequency control and is therefore dependent on the other states and particularly on the only 500 kV transmission line that connects the Turkmen with the Uzbek grid and those of the other countries.

These four hydro stations are not always able to offer the full range of power regulation. In summer Togtogul and Nurek have to operate occasionally with full output due to the irrigation needs and can during that period only cover a reduced regulation range. In winter Nurek has only small inflows into the reservoir and can only contribute to a small extent the regulation requirements. Chervak is only working in the evening hours as peak power plant and runs idle during daytime. In addition Nurek power plant is connected to the grid through one single circuit line only, if this line trips, the power station is not available for power/frequency control. Out of these reasons mainly Togtogul with its 1.5 fold annual reservoir provides power frequency regulation for the complete Central Asian power grid.

Consequently the regulation capacity of these four hydro power stations is not sufficient and further power stations including the large thermal power plants should be equipped with primary power/frequency control. (In the UCPTE system 2.5 % of the present load is operated for primary control.) Better primary control also results in a substantial improvement to the voltage profile in the whole system and the reduction of power flows due to power/frequency regulation requirements. Only a joint understanding of all partners of the system of the need to improve the primary control and to pay for received primary control capacity will allow the improvement of the system. Else one partner might operate his system on the expense of the other partners.

5.4.4 Reserve Capacity

5.4.4.1 General

Reserve Capacity is defined as the use of generation to respond to a loss of a system resource (generation or transmission line) in order to restore system balance and normal operation frequency. Various power pools have a somewhat different classification of reserves, usually differentiated by the speed of response of the particular reserve classification. The three technical classifications for reserve capacity are:

- Primary reserve, spinning, equipped with Automatic Generation Control (AGC), that is on line, synchronised to the grid and activated in less than 10 minutes to correct generation/load imbalances due to generation or transmission outages. The primary reserve is generally shared by all partners of the pool;

- Secondary reserve, hot not spinning, equipped with AGC that is not synchronised to the net and activated in less than 30 minutes to correct generation/load imbalances due to generation or transmission outages. Generally the secondary reserve is activated by the partner where the imbalance occurred in order to free the blocked primary reserve; and

- Tertiary reserve, cold not spinning consists of the use of generation (or voluntary interruptible load) with longer start-up times especially for cold thermal plants. Cold reserve is used to back-up and replace primary and secondary reserve.

Reserve should not be confused with capacity committed to load balancing. The technical data of reserve capacity (MW, MVAr, availability, etc.) varies from unit to unit as well as the economic data which include the fixed cost of generation capacity, variable cost of energy produced, increased maintenance cost of frequent changes in output, increased heat rate of operating at part load and opportunity cost of not producing energy for sale.

5.4.4.2 EPCA Situation

In the EPCA, the hydro power stations provide most of the time primary control reserve for automatic frequency control, namely **Toktogul and Nurek**. Primary reserve is not more than 5 % of the total maximum load of the integrated system. The primary reserve is used if the frequency drops below 49.4 Hz and is activated from 10 – 30 seconds up to 2 – 3 minutes depending on the type and construction of units. Sometimes during peak periods it even reduces to zero. The dispatcher defines the share of each power station on the primary frequency control.

In years after abundant rainfalls the power plants worked at full load, so that frequency control was performed by the thermal power stations of Syr Daria and Jambul. However regulation proved to be not stable. Primary reserve is irregularly distributed within the whole network, especially as the transmission lines are not redundant and it is necessary that primary reserve is shared by more power plants, distributed evenly over the country.

Concerning the primary reserve capacity, the same remarks apply as stated for the primary power/frequency control that only few hydro power stations participate in the regulation, they are not always fully operational and that the few are not evenly distributed over the power pool grid. Reliable reserve capacity must be provided, evenly distributed over the pool countries. This is only partly a technical constraint, the discipline to keep the reserve is the crucial question.

Secondary reserve capacity is provided by hydro and thermal power plants. On hydro stations the response time for the useful secondary reserve amounts from 1 – 5 minutes, on thermal units the ramp rate is from 2 – 5 MW/min, depending on the unit type, its thermal insulation and state. The ODC dispatcher gives permission to use the secondary reserve.

The start up time for tertiary reserve varies from 5 to 15 minutes for hydropower units, depending on the type of the unit, particularly the water intake, the electric connection scheme etc. For thermal power units the start up time depends on their type of machine, their thermal state (hot or cold), and on the type of fuel used and ranges from 7 to 37 hours for cold state and 1.5 to 4 hours for hot state.

5.4.5 Flexibility of Generating Units, Possibility of Black Starts

Each sub-system must have the possibility to start operation even if no connection to the remaining network exists. For that purpose, so called black start must be possible for a number of dedicated units and the start-up and shut-down cycles of the plants must be respected, namely:

- 300 MW units restart is possible in 3 – 4 days;
- 210 MW units restart is possible in 2 – 3 days;
- 160 MW units not more than one start within 24 hours.

For stable continuous generation, the minimum load to be kept on the units are:

- 300 MW units: 200 MW;
- 210 MW units: 100 MW – 120 MW;
- 150 MW units: 80 MW.

The partners of the EPCA must provide the respective black start reserve and co-ordinate the dispatch of the plants in order to respect the limiting operation conditions.

5.4.6 Load Shedding and Emergency Control

5.4.6.1 General

The CA power grid is not designed according to the n – 1 principle. Therefore, if an important load carrying line drops, one part of the former interconnected system is in excess of generation capacity, the other experiences excess load. The system is so designed that a sophisticated scheme tries to compensate the unbalance in each subsystem and to bring back the frequency to normal value. In the event of a serious drop in the system frequency due to the loss of a transmission line, a major generation unit or other severe incident, the CA grid is designed to automatically separate into asynchronous operating areas in order to prevent a cascade failure of the entire system. The system essentially islands itself into individual areas of balanced load around various generating units through a process referred to as under-frequency load shedding in which customers are disconnected from supplies. Voluntary and involuntary load shedding is employed to re-establish system frequency in the isolated islands.

The stability of operation of the transmission system lines is guaranteed through various automatic systems by:

- Avoidance of a disturbance to stable parallel operation (AS);
- Elimination of asynchronous operation (AA);
- Limitation of voltage drop (AU);
- Reduction of loading (or avoidance of inadmissible overload) of equipment (AE).

Each system consists of several automatic subsystems, which are sometimes interlinked. The first fundamental system is the most important and guarantees the stability of the power system. The AS system alone includes:

- Automatic system for reducing the load of the grid after disconnection of lines or transformers,
- Automatic load reduction system in the event of overload on the lines due to active power,
- Automatic load reduction systems if generators are shut down,
- Automatic systems for load reduction in the case of nearby or long duration short circuits.

The remaining systems have further sub-systems and, due to its complexity, the whole stabilisation system is not further explained here. The under-frequency load shedding system is supplemented by an automatic load restoration system, whereby shed load is picked up again once frequency exceeds a pre-set value and remains stable.

5.4.6.2 EPCA Situation

The load shedding and emergency control system is a thoroughly developed and well-experienced system that has repeatedly proven its efficiency. In the CA grid, due to the emergency control, the frequency stability is such that if one of the biggest generation units of 300 MW trips (Syr-Daria, Novo-Angren, Toktogul, or Nurek) an instantaneous drop of 0.2 Hz occurs, lasting 2 to 3 minutes. 500 kV lines can carry more load and present a more severe incident if they trip and other lines have no spare capacity to take over load. This unique ex-Soviet load shedding and emergency control system presents the possibility of operating the CA power grid without the n – 1 principle for key transmission lines.

However, the automatic emergency system is based on the existing slow telecommunication channels, old data acquisition equipment and the use of outdated computers with reduced software capabilities. It can be made more effective through introduction of fast digital telecommunication systems and up-to-date computers with modern algorithms. This allows an increase in the transport capacity of transmission lines that would otherwise be reduced due to spurious or late tripping of relays in the existing antiquated system. Furthermore, a modern automatic system could re-establish stable conditions much more quickly in the event of a system disturbance and after drop of system frequency.

5.4.7 Voltage Level and Reactive Power Regulation

5.4.7.1 General

The local nature of the reactive equilibrium of the system operated at nearly constant voltage, requires operating a large number of control means: generation units, continuous or discontinuous acting compensation devices and transformer tap changers. The aim of the regulation is to keep the voltage within set limits, reduce losses due to reactive power flow and maintain a zero power flow across the interstate borderlines. The state of the art in this field is an automatic hierarchical control:

- Primary control: Automatic Voltage Control (AVR) which controls the terminal voltage with possibly some step-up transformers impedance compensation;

- Secondary control, based on dispatcher actions to adjust the reactive compensation and tap changers in the system;

- Tertiary control, based on optimisation program which computes the set points of the different devices in the system corresponding to the application of the voltage/power (U/Q) control policy.

The state of the art of this three level control system considers, at top level, a centralised system, the tertiary control which defines the set points for all the devices playing a role in the U/Q control. Tertiary control operated through SCADA systems to adjust discontinuous control devices (capacitors, shunt reactors, and tap changers), and through MIMO controllers (multiple inputs multiple outputs) and control links to adjust operating points of generating units. These controllers form the secondary control level, adapting at regular time interval the set point of generating units. Finally the AVRs (primary control) of the generators and their limiters guarantee locally the ultimate operating security.

5.4.7.2 EPCA Situation

The dispatcher of the UDC controls the voltage level of the 500 kV and 220 kV lines in 10 selected points of the EPCA. The points have been chosen by the UDC as crucial points for the interconnected system. The NDC might control further points they judge necessary for the security of their national grid. The voltage level and reactive power regulation is performed through comparison of the actual values displayed on the monitor with those of commonly agreed voltage charts approved for each quarter of a year and adapted to the prevailing operation conditions of every day. These voltage charts are calculated by the UDC.

To provide the necessary voltage levels the dispatcher uses the following control means:

- Control of generator excitation;
- Control of tapping positions of transformers equipped with on load tap changer;
- Switching of shunt reactors;
- Off-loading of active power at the generators and increase of reactive generation;
- Transfer of load from strongly loaded lines to reserve lines;
- Switching off scarcely loaded lines.

Control of generators is automated but the system is old and outdated. The remaining controls and switching are made by hand. These procedures of visual control of selected points in the monitor and manual regulation do not comply with a modern, automated voltage regulation system with SCADA. Such a modern system would pay for itself in a short time through the reduced active and reactive losses. Other advantages which cannot be evaluated easily on an economical basis are far more important: the time spent by operators to manage reactive power and voltage , the improvement of voltage quality, the reduction of risk of voltage collapse by either reactive margins and by dynamic management of reserves.

Due to reduction of industrial load the dispatcher of the UDC has not sufficient shunt reactors and shunt reactors that are switchable as needed to guarantee the necessary voltage profile. Also, not all transformers are equipped with tap changers or the tap changers are not switchable due to lack of maintenance. Therefore, network studies must justify what additional compensation equipment is needed, so that the voltage levels can be maintained by reactive loading.

5.4.8 Provision of Reactive Power

The voltage control of the HV networks of the CA countries is co-ordinated by the UDC which determines the voltage levels to be applied by the National Dispatch Centres. These NDCs are responsible for their own compensation by means of synchronous compensation and static capacitors and reactor banks. The reactive power flows are minimised as much as possible between the neighbouring countries.

The provision of reactive power is closely linked with the voltage control and described in the chapter above. The major problems of the EPCA are:

- The lack of shunt reactors in the 500 kV and 220 kV networks;
- Insufficient reactive capacity regulation opportunities.

5.4.9 Co-ordination of Protection Equipment

Each country of the CA power pool is responsible for the protection scheme of its system, so as to ensure that faults are immediately detected, the defective equipment switched off and the eliminated part reduced to the smallest possible section. The UDC co-ordinates the protection scheme of the CA countries in a three-fold way:

- Operation, management, and control of all 500 kV and of the 220 kV interconnection lines;
- Monitoring of all equipment adjacent to the protection scheme (circuit breakers, current and voltage transformers, lightning arresters, etc.);
- Development of schemes, regulations, diagrams and operational management for dispatch.

Most of the installed relays are old and of the electro-mechanic type that require careful maintenance. Few relays are installed of the modern micro electronic principle and the first micro-processor relays will now be introduced in the CA power system. The protection scheme is old but performs its duties. Overall improvements are needed in respect of introduction of new technologies.

In Soviet times, Energosetproject defined the standards for the protection scheme. These standards are still valid but should be updated for modern micro-process electronic protection schemes and higher standards for the quality of power supply. Therefore, the UDC will have to take over a leading role in developing new standard schemes for all 500 kV and 220 kV interconnection lines. For that purpose respective software and hardware must be procured in order to perform the necessary network calculation for the definition and setting of the system protection. In the following the actual settings must be updated to the calculated values and necessary rehabilitation shall be performed.

5.5 National Developments Influencing the Pool Operation

In all CA countries efforts are being made to rehabilitate the national power grids. These planned and ongoing construction works will also influence the operation of the complete power pool and the UDC and will make it necessary to include the national planning in the development of the system. Presently two major projects will influence the power pool operation.

5.5.1 KEGOC Rehabilitation Program, Kazakhstan

Within the KEGOC rehabilitation program, financed by EBRD and the World Bank, the transmission system will be refurbished. This includes among others, the rehabilitation of switch gear, the replacement of protective relaying based on state-of-the-art microprocessor technology to improve the safety and reliability of the entire transmission system and the installation of further shunt reactors to improve voltage quality and reliability of power delivery in the transmission system.

In addition, the dispatch control within Kazakhstan will be upgraded by the installation of SCADA (Supervisory Control and Data Acquisition) at 9 Regional Dispatch Centres (RDC) and SCADA/EMS (Energy Management System) at the National Dispatch Centre (NDC) in Almaty. Furthermore, the telecommunication system between substations, RDCs and the NDC will be reinforced.

However, the protection system and especially SCADA/EMS must be improved for operation with the Russian and the Central Asian Grid in the same way as the system is reinforced within Kazakhstan, financed by the EBRD and World Bank. Driven by privatisation and the free market system for electric power, KEGOC is the first utility to rehabilitate and upgrade its national dispatch centre. But the refurbishment and improvement must be established also for international trade.

The signals from the RDCs to the NDC in Almaty will be partly in digital form, transmitted with modern telecommunication equipment. The ODC has to follow that technology, else it will be excluded from the information of Kazakhstan. The UDC should even have taken a lead role in planning of the standards for the Almaty NDC so that convertibility of data will be ensured in future.

The emergency control system for international operation must be co-ordinated with the national equipment that will be ordered and the existing and planned equipment in other countries. Since the other countries are not yet advanced in their planning for the international power market and the necessary equipment, the situation for design and procurement still must be solved.

5.5.2 Construction of Talimarjan, Uzbekistan

In two to three years time the first 800 MW unit of the EPCA will be commissioned in Talimarjan, Uzbekistan and up to that date the plant must be integrated in the load dispatches of the NDC of Uzbekistan and of the ODC. However, the new unit will considerably exceed the present maximum unit size of about 300 MW, so that power/frequency regulation and reserve capacity must be adapted to this new 800 MW unit. For that purpose the reserve capacity must be increased, power/frequency adjusted and the emergency control must provide for the loss of this new unit. It is doubtful if the new plant can be integrated in the existing soft- and hardware of the ODC, so that the update of the system makes it necessary to change to modern technology.

5.6 Description of Project

The project will provide equipment to rehabilitate and modernise the operation of the CAEP pool that will only work efficiently if new equipment for joint operation is procured and installed by all participants of the power pool. Implementation of this project should position the EPCA to support the further development of regional power trade and the development of a competitive electricity market in CA.

The proposed project includes the following five stages. Each stage is independent and built as a logical unit and may succeed each other. It is possible to choose any of the five project stages.

Table 5 Stages of the Proposed Project

Stage	Scope of Works	Stages
1	Basic works	1
2	Basic works + (Intra Regional Dispatch Centre) RDC Automation	1+2
3	Basic works + RDC Automation + Power Plants Data Connection	1+2+3
4	Basic works + RDC Automation + Substation Automation	1+2+4
5	Basic works + RDC Automation + Power Plants Data Connection + Substation Automation	all

Annex 7 presents the principal elements of the proposed project in a graphic form showing the interdependence of the different dispatch centres, power plants and substations and the necessary communication links.

5.6.1. Stage 1: Basic Works

Stage 1 is nominated the so-called basic work since it contains the necessary indispensable scope of works for improvement of the joint power pool operation. The basic works are characterised by the following features:

- The UDC urgently needs the installation of a new SCADA/EMS/Trading system. Such a new system is able to give support to protect the grid with intelligent system functions, such as state estimator, optimisation of current load etc. Through the new system, the UDC will guide and control all work for grid operation of the complete EPCA. The basic works contain the necessary features so that the UDC can play a special role as independent energy trading pool in order to safeguard the interests of the countries.

- Separate SCADA/EMS/Trading systems for the NDCs of Uzbekistan, Kyrgyzia, and Tajikistan are of greatest importance and foreseen in this stage. The NDCs need information exchange among each other and especially with the UDC in case of free energy trading. The necessary volume of data transmission with the modern systems is estimated at 10 times of the present volume of data exchange. Also installation of commercial meters and electrical metering system for NDC level will improve the grid operation.

- For connection with the ongoing SCADA rehabilitation and modernisation of the NDC in Kazakhstan only a computer data link is required. Co-ordination of the technical solution of the NDC Kazakhstan and the remaining EPCA is compulsory.

- The NDC in Turkmenistan will be connected to the remaining EPCA with a simple interface without modernisation of SCADA/EMS.

- A separate off-line-system is planned for the grid protection data covering the 500 kV and 220 kV levels.

- The grid frequency regulation the UDC needs quick data exchanges with the hydro power plants Toktogul and Nurek. The data link to the site frequency control require intelligent interfaces. Therefore, the necessary basic measuring and control system with new equipment including modern computer application is planned. This solution, together with satellite data transmission secures short reaction time between UDC and power plants.

- Communication System

  A reliable communication system is prerequisite to operate the described Trading system supported by several SCADA and EMS systems. Therefore it is proposed to install a Wide Area Network (WAN) between the NDCs, based on Satellite communication links. This guarantees high availability of the communication channels. Each ground station is able to communicate with the other. The traffic load will be shared between available connections and re-routed in case of failure. A communication management system located in the UDC will permanently control the system consisting of VSAT (Very Small Aperture Terminal) ground stations at UDC Tashkent, NDC Kyrgyzia, NDC Tajikistan, NDC Kazakhstan, NDC Turkmenistan, Hydro PS Toktogul and Hydro PS Nurek.

  The NDC Tashkent shall be connected to UDC via Optical Fibre Cable to supply high speed transmission links.

  The above mentioned WAN will carry the data delivered by local SCADA systems and the voice traffic produced by the telephone exchanges (PABX).

  For the planned system voice communication is as important as data communication. Therefore the existing telephone exchanges at the mentioned locations shall be replaced by modern digital telephone systems.

In case of selection of stage 1 only it is recommended to plan a budget for improved voltage regulation and upgrading of the 500 kV and 220 kV grid (refer to Stage 4).

5.6.2 Stage 2: Basic Works + RDC Automation

In addition to the equipment of Stage 1 the following extensions are included in Stage2:

- The five most important RDCs, namely in Uzbekistan Fergana, North – West and Samarkand, Osh in Kyrgyzia and Khodjand in Tajikistan will be equipped with new SCADA systems including simple functions of EMS.

- In substations, the remote terminal units (RTU) shall be replaced without a higher automation degree. The process interface is the same as the old remote terminal units have today.

- For communication purposes the five RDCs shall be linked to the NDCs via Power Line Carrier Systems (PLC) or via radio links depending on the existing local situations. Again the communication system will support the SCADA data and voice transmission. The existing telephone exchanges shall be replaced through modern digital systems.

5.6.3 Stage 3: Basic Works + RDC Automation + Power Plants Data Connection

In addition to the equipment of Stage 2 the following extensions belongs to the Stage 3:

- The 13 most important power plants of the EPCA will be equipped with new basic measuring systems and remote terminal units and with new equipment including modern computer application. These 13 power plants are in Uzbekistan (Navoi, Tashkent, Syr Daria, Angren, Novo Angren), in Kyrgyzia (Uchkurgansk) and in Tajikistan (Baipazin, Karakum, Golovnaja).

- The power plants shall be connected to the NDCs via Power Line Carrier and / or radio links to transmit the SCADA data and the telephone communication.

- The existing telephone exchanges shall be completely replaced. The wiring can be re-used as far as possible.

5.6.4 Stage 4: Basic Works + RDC Automation + Substation Automation

In addition to the scope of Stage 2 the following extensions are part of Stage 4:

- Seven 500 kV substations of Uzbekistan (Lodin, Tashkent, Guzar, Karakul, Sukhan), of Kyrgyzia (Bishkek) and of Tajikistan (Regar) will be fitted out with new high-voltage equipment, of protective relaying and of new monitoring and control equipment incl. remote terminal units.

- Installation of shunt reactors and further equipment to improve the grid operation and voltage level as well as supply of commercial meters and integration of substations into the electrical metering system.

- The 500 kV substations shall be linked to the NDCs through of Power Line Carrier (PLC) and / or radio links. All telephone systems except the wiring shall be replaced through a digital system.

5.6.5 Stage 5: Basic Works + RDC Automation + Power Plants Data Connection + Substation Automation

Stage 5 includes the works of all stages.

The most effective system would be implementation of stage 5 with the realisation of all proposed rehabilitation and uprating works.

Detailed site investigations must investigate the state of the different HV equipment, control, protection and monitoring system, telecommunication equipment and ancillary systems. Based on the site investigations and the envisaged rehabilitation level the final scope of works must be defined and a feasibility study must verify the technical, economic and environmental feasibility.

5.7 Institutional Development of the EPCA Initiated by USAID

In the Soviet system all technical and organisational issues of the power pool were well defined. After independence of the Central Asia States, Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan signed an agreement in November 1991 on the parallel operation of their power grids. This agreement clarified the main issues of the electrical co-operation and allowed continuing the joint exploitation of the power system but it could not by far cover all technical and institutional aspects of parallel operation of the power systems of the new independent states.

In 1995, in view of the difficulties of the transition from a mono- to a multilateral power pool, USAID began to provide technical assistance in Kazakhstan and Kyrgyzstan, focusing on legal, regulatory and institutional reform of the energy sector. For that purpose USAID, engaged the Consultant Hagler Bailly to define reforms on the oil, gas an electricity sector. Concerning power, by August 1996 the **Central Asia Electricity Working Group** started to provide Technical Assistance in the development of contracts for:

- Sales and purchase of electricity power and ancillary systems;
- Creation of an efficient wholesale market;
- Set-up an environment for economic central dispatch of electricity throughout the grid;
- Try to equitably resolve the exchanges of electric power, water resources, and fuel within the region;
- Wheeling of electricity;
- Trading of electric power (bilateral and multilateral);
- Parallel operations agreements;
- System pool operations.

Goal of the Working Group and USAID was to:

- Ensure reliable supplies of electricity for all customers;
- Stimulate an efficient wholesale market (power pool and/or independent system operator);
- Maintain low cost electricity supplies;
- Fully utilise electric power resources;
- Attract world-class investment for rehabilitation; introduce new technology, instil growth and expansion.

In 1997 a parallel **Working Group** was established on **Central Asia Region Water/Energy** issues, primarily focusing on the Syr Darya River basin and the efficient use of water as hydropower generation in Kyrgyzstan and agricultural needs in Uzbekistan and Kazakhstan.

Out of the working group documents, the five Prime Ministers of Central Asia have signed only the Parallel Operations Agreement. The other documents have either been adopted by the Working Group or are currently being revised as working drafts for the Central Asia Economic Co-operation Intergovernmental Council.

For further progress of the power pool it is indispensable that all five countries need to adopt and implement the “Conceptual Model for Central Asia Electricity Markets” as adopted and agreed upon by the Central Asia Working Group. For adoption, the political will of the five countries is necessary, and for the implementation technical assistance will be needed, similar to the TA granted until now through USAID.

The desired outcome of the Conceptual Model is:

- Competitive wholesale market (principles and concepts);
- Efficient market and price-clearing mechanism;
- Open and non-discriminatory access to the regional grid;
- Free Access for the purchase and sale of electricity and ancillary services, both bilaterally and through a power exchange;
- Redesign of the original former Soviet Union power pool operation, with central economic dispatch through UDC Energia
- Creation of Two Tier Governance system of market members (multilateral agreement) with
    - Elected Executive Committee
    - Member founded Independent System Operator (most likely UDC Energia)
    - Approval through the Central Asian Power System (Power Council)

In the present EPCA only prices for kWh, a simplified price for frequency regulation and a price for wheeling (losses) are applied. These simplified economic principles do no longer correspond to profit oriented power companies, however, the technical infrastructure must be created as well, such as dual tariff meters, telemetring, etc. The technical assistance concentrated efforts to introduce more economic terms in the relationship between the partners of the power pools and to define for application between the members:

- Prices for base load and peak power
- Prices for ancillary services
    - system control
    - reserve capacity (spinning reserve, non-spinning reserve)
    - energy balancing (frequency regulation, balancing capacity, load following)
    - transmission losses
    - reactive power
    - black start capability

Through the experience in other countries, where privatisation and a whole sale power market were implemented, the Consultant is convinced that by each country adopting and implementing this Conceptual Model, this should resolve future issues of:

- political will
- inadequate barter trade
- non-payments
- reliability

Under such conditions, the international community of investors would be attracted to invest with new technologies in the field of

- metering, telemetring
- information system
- SCADA and EMS
- market operations and relations

The existing governance of the power complex in Central Asia and its development is presented in Annex 8 as developed by electricity working groups. Concerning the present governance of the power complex in Central Asia, five countries signed the Energy Charter for parallel operation of their grids. For that purpose each national power system operates its own grid and maintains a national dispatch centre. These NDCs are connected the UDC. Only in Kazakhstan several generation and distribution companies and a network company (KEGOC) are in charge of the power system, in the other countries national stock companies (Kyrgyzenergo, Barki Tajik and Kuwat) are operating, in Uzbekistan even the Ministry of Power Industry and Electrification still runs the power sector.

The **first stage** of development of the governance of the power complex in CA, as designed by USAID, foresees that the five countries, signatories to the Energy Charter, sign the **Parallel Operation Agreement** as drafted by the working group. An **Interstate Energy Power Council**, composed of members of each country, controls the power grid with the **Interstate Power Dispatch "Energia"** acting as executive body for power dispatch. The national power systems are guided and directed according to the framework of the Parallel Operation agreement.

In the **second stage** of power pool development, as designed by USAID, the governments sign the **Memorandum of Understanding on the Central Asia Power Pool** in addition to the already signed Energy Charter and the Parallel Operation Agreement. The interstate Energy Power Council and the integrated power system of CA operate as in the first stage of development. However, the **Central Asia Power Pool** operates the power grid with the **Joint Stock Company "Independent International Dispatch Centre**" as executive committee and subcommittees for operation and planning.

At the moment USAID is preparing the budget for the financial year 2000. Due to reorientation and the change in personnel, in the present planning it is envisaged that USAID will no longer focus on legal, regulatory and institutional reform of the energy sector but will concentrate on hydrology and the development of hydropower resources. Therefore, according to the present planning, the ongoing sector reform will come to an end and the Consultant Hagler Bailly will resolve his offices in the CA countries.

5.8 Alternative Development of the EPCA

The regulatory and institutional framework developed by the working groups under the guidance of USAID is based on a competitive model of a wholesale power market. The experience has shown that often, due to political pressure or to different legal systems, a fully competitive market is not introduced, that implementation of the competitive power pool is stopped half way to the full liberalisation or it is possible that the stage 2 will not be implemented. Therefore, in the following different steps for the reorganisation of the EPCA are examined and the necessary technical pre-conditions and changes of equipment are monitored which are necessary for effective operation of the respective step of power pool operation.

Concerning the development of the EPCA two major options exist according to the role of the UDC and according to the development of tasks over the time:

The first alternative development might occur in respect to the future role of the UDC. The set up proposed by USAID, assumes that the UDC will play a certain important part as Joint Stock Company "Independent International Dispatch Centre" with a central co-ordinating role within the power pool. However, it is also possible that only little power will be delegated to the international dispatch centre. In this case, more tasks will be performed by the national dispatch centres and as a consequence a small flux of information will be needed and processed in the UDC.

A second alternative development can be envisaged that the interconnection of the power system will be intensified over the years. In the beginning the grids work in parallel in normal operation without power exchange, followed by power exchange in emergency operation, power exchange in normal operation and finally full power pool operation. According to the profoundness of power pool operation the equipment needed for parallel operation will increase step by step.

5.8.1 Reduced Role of the UDC

If the CA countries reduce UDC's role to a minimum, UDC still will perform certain technical duties which are necessary for parallel operation of the system. In this case the NDCs have to collect and process the data of power plants and of 500 kV and 220 kV cross-border substations. The data concerning generation and cross-border lines is transferred to the UDC in order to enable it to verify if the overall system performs within the operational limits. If values are exceeded, the respective NDC is advised for corrective measures. If the UDC plays a more dominant role, more data are transmitted to the UDC and the UDC is directly performing the remedial actions. In both cases, data collection remains the same, only processing and transfer to the supervisory control is different.

A further variation of UDC's future role depends on the trade function, namely on the decision who will perform the registration and accounting of exchanged power and of provided ancillary services. If each country deals individually with its neighbours, the measured values must be transmitted to the involved partners for processing and billing. If UDC acts as an accounting unit, the measured values are to be transmitted and treated by the UDC. Data collection remains the same but the flux of information and the location of processing are different in each case.

5.8.2 Gradual Increase of Power Pool Operation

Parallel operation can be intensified from the low degree of international co-operation, namely interconnection without power exchange to an intensive international co-operation with joint generation and transmission operation. For each step the technical equipment must be provided and additional equipment is added on transition to the higher level of power pool, as to allow the respective pool operation The different steps might be:

5.8.2.1 Joint Operation of the Transmission System

The complex structure of the 500 kV grid was built without consideration of the present national borders. Therefore, as an example, the 500 kV line from Almaty to Tashkent starts in Kazakhstan, crosses to Bishkek substation in Kyrgyzia, leads back to Kazakh territory and finally continues to Uzbekistan. This interwoven structure does not allow the CA countries to disconnect their international transmission lines. Even for national supply the international lines must be used (i. e. the 500 kV line from south to north Tajikistan; or the 500 kV South Kazakhstan lines). In addition, the power lines need to operate as stand-by for emergency situations, even if no power is exchanged between the countries.

Therefore, the lowest degree of interconnected grid operation of the CA countries would be the parallel operation of the grids with zero power imports or exports under normal conditions, except for special agreed border supplies.

For the joint operation of the transmission system the protection system of the inter-country links, the power/frequency regulation and the reserve capacities must be co-ordinated among the members of the grid. In such system operation, each partner is responsible to provide reserve capacity of his own.

Concerning equipment for joint operation, the operation data of the national power system must be effectively collected and transmitted to the national dispatch centre and selected data are to be further transmitted to the UDC (establishment of SCADA system). Telecommunication equipment must complement the joint technical system. The absence of the n – 1 principle for the lay-out of the international 500 kV system requires that the emergency control is in operation, so that if a major transmission line or generator trips, automatic load shedding and, if necessary, separation of the defective subsystems is performed.

5.8.2.2 Provision of Generation Capacity in Emergency Operation

The next step of parallel operation would include the supply of generation capacity in the case of emergency operation. For that purpose the power/frequency regulation must be installed in the respective power plants and controlled by the UCD. Data exchange between generation plants and the UDC is to be ensured.

Although each country is presently moving toward self autonomy of power supply the state of the power plants and the lack of redundant HV lines obliges all countries to operate in parallel within the EPCA and to share the generation plants in case of emergency.

5.8.2.3 Provision of Generation Capacity in Normal Operation

In this stage of common operation of the power system, the national power companies buy generation capacity abroad due to lacking own facilities, cheaper prices abroad, or other contractual arrangements. A technical pre-condition is a common frequency regulation system, the metering system and the respective SCADA and telecommunication systems. This stage of power pool requires about the same volume of equipment as the previous step with an intensive exchange of system parameters between the partners and to the UDC. However, the automatic exchange is foreseen with increased exchange of generation capacity.

5.8.2.4 Wholesale Energy Trade

The wholesale energy trade operates as uniform system across all borders with free power exchange and common sharing of information of the status of the system. For that purpose the highest degree of co-ordination of system design, lay-out and operation is necessary.

5.8.3 Stages of Implementation with the Proposed Project

The chapters above treat in a more theoretical approach the different possibilities for co-operation within a power pool. The proposed stages of implementation allow the implementation of the project according to the degree of co-operation.

SCADA/EMS/Trading System (Stage 1)

In order to control the regional power grid, the UDC must be put into position to receive better data from the interconnected network and to perform more sophisticated processing. The most important task and first stage will be the implementation of a SCADA/EMS/Trading system in each country of the power pool with transmission of the collected data to the NDC and continuation to the UDC. In Kazakhstan such a system will already be implemented up to the national NDC level.

Such SCADA/EMS/Trading is foreseen in the stage 1, Base Work. During design, it can be decided up to what degree the UDC is authorised to perform switching operations and which actions remain entirely under the responsibility of the NDC. The hard- and software are adapted accordingly. In the same way the trading function will be integrated in the software of the new system and it is up to the participating countries if and up to what extent it will be used. In this way design and operation can be tailored to the future development.

Improvement of Power/frequency Regulation (Stage 1)

In view of the present frequency variations and the small defined area of intervention at the turbine and generator regulators and of the automatism, it is recommendable to improve power/frequency regulation in the first stage.

RDC Automation (Stage 2)

The automation of the RDCs is more or less a national project, since it enables the national utilities to control and operate their power grids. Therefore, the RDC automation will bring important benefits for the national dispatch. With the link from the RDC via the NDC to the UDC, the automation gains a regional level and enables the UDC to work more efficiently with a greater volume of information. The flow of information to the UDC will depend on the intensity of the regional co-operation.

Power Plant Data Connection (Stage 3)

The improvement of data flow from the major power plants to the UDC allows an optimum power plant dispatch with extended power exchange and the joint operation of the generation plant with provision of spare capacity under normal and emergency operation as well as the supply of peak power. In addition, the frequency can further be stabilised.

Substation Automation (Stage 4)

The benefits of substation automation are in the field of better voltage profile, reduced losses accompanied by better control and switching of the substations.

6 Economic Analysis

6.1 Cost Estimate

Each partner of the pool shall fund the equipment of the project that will be installed within the borders of his country. This applies for all equipment, including SCADA, telecommunication, measuring and control equipment, computers, protection equipment, etc. Although the power/frequency regulation equipment in Toktogul and Nurek power plant serves for all countries, the supply and erection shall be borne by the country where the equipment is to be installed. In return for the investments, each country must pay for the power/frequency regulation services rendered by the power plant. Presently these services are not compensated or insufficiently reimbursed.

The equipment to be installed in the UDC will be paid out of the funds of this organisation, which are shared in equal parts among the participants of the power pool.

In the cost estimate, the cost of equipment has been split according to the principles defined above.

Table 6 Cost Estimate of Works in Million US $

	Kaz.	Kyr.	Taj	Turk.	Uzb.	UDC	Total	Accumul. Total
Stage 1	0.7	5.2	5.5	0.7	5.2	8.0	**25.3**	
Stage 2		3.5	3.5		17.8		**24.8**	**50.1**
Stage 3		0.7	1.7		2.8		**5.2**	**55.3**
Stage 4		5.2	5.2		17.2		**27.6**	**77.7**
Stage 5	**0.7**	**14.6**	**15.9**	**0.7**	**43.0**	**8.0**	**82.9**	**82.9**
TA Project	0.04	0.73	0.80	0.04	2.15	0.40	**4.15**	
TA UDC	0.04	0.73	0.80	0.04	2.15	0.40	**4.15**	
Subtotal	**0.8**	**16.1**	**17.5**	**0.8**	**47.3**	**8.8**	**8.3**	**91.2**
Phy. Cont.	**0.1**	**1.6**	**1.7**	**0.1**	**4.7**	**0.9**	**9.1**	
Total	**0.8**	**17.7**	**19.2**	**0.8**	**52.0**	**9.7**		**100.3**

Stage 5 presents the realisation of the stages 1 through 4 and includes the total project costs of all four stages.

The technical assistance for the project (TA Project) amounts to 5 % of the total project costs and includes the feasibility and design of the project. The technical assistance for the UDC (TA UDC) amounts as well to 5 % of the total costs and includes costs for implementing the institutional reforms of the UDC and follow up of the different agreement. Physical contingencies are to be added with 10 %, according to the estimated risks.

6.2 Benefits

The proposed project has numerous and most evident benefits both on the technical and the organisational side, but all of them are most difficult to express in reliable monetary terms. In the following the different benefits are enumerated and as far as possible quantified for the economic analysis.

6.2.1 Technical Benefits

The technical benefits are easier to quantify than the operational ones and extend in the field of:

- Reduced number and length of outages;
- Less frequency variations;
- Better Voltage Profile;
- Reduced losses

6.2.1.1 Reduction of Outages

In the past year, about ten major breakdowns occurred in the EPCA, when synchronisation of the whole system could not been maintained, the EPCA broke into individual sub-systems, and a complete black-out was recorded. After the major outages it only took a short time to restart the first power plants but it can take hours until the last consumers are reconnected to the remaining system. Such major disturbances are analysed in detail in order to improve the system and they provide an indication of the kWh not supplied to consumers and the damages effected to the national economics of the countries. In the past, the most serious blackouts with detailed analysis of lost kWh were:

On **6.7.1999** a 500 kV line in Tajikistan (southern part of the EPCA) tripped with cascading effects on the Tajik, Uzbek and Turkmen grids. Frequency increased in parts of the network up to 51.5 Hz and the southern part of the grid was isolated and blacked-out, including chemical industries, refinery, and aluminium plant (835 MW the aluminium plant alone). After about 45 minutes the grid was stable and supply re-established with the start of Navoi power plant after 70 minutes. Overall 1.674 GWh could not be supplied to consumers (0.192 GWh in Tajikistan, 0.522 GWh in Turkmenistan, and 0.960 GWh in Uzbekistan).

On **6.3.1999** a 500 kV line was switched off at Bishkek (northern part of the EPCA) in order to reduce overvoltage caused by lightly loaded lines and missing reactors for reactive load compensation. This led to instability of the system with frequency rise up to 50.6 Hz. In the isolated parts frequency dropped to 47 Hz with tripping of further 500 kV and 220 kV lines. Bishkek heat and power plant was confined it its supply area as well as Shamyl power plant. Due to this incident 1.453 GW h could not be supplied to consumers.

On **28.4.1998**, an outage of the 500 kV line from Syr Daria to Tashkent in Uzbekistan interrupted supply on the complete 500 kV ring through Uzbekistan, Kazakhstan and Kyrgyzia. Tashkent power plant was separated from the remaining system at 52.1 Hz and restarted after only 10 minutes. However in Uzbekistan alone 0.160 GWh could not be supplied to consumers.

Further incidents had been thoroughly investigated from the technical side but not from the economic point of view, so that the kWh lost are not known. On **14.10.98** an interruption lasted 46 minutes, when in the Buchara, Samarkand region several lines tripped and, after several unsuccessful synchronisation attempts Navoi power plant was completely out and the southern part was disconnected from the northern EPCA. Chemical and metallurgical plants, mining industry and the refinery suffered most from the interruption of supply.

On **4.8.1998** the southern part of the system was disconnected from the remaining EPCA, due to stability problems in the 500 kV system. After 90 minutes the first 220 kV lines were switched on again and the 220 kV system was fully re-established after 2 h 45 min, so that finally the last 500 kV line was placed in service.

A faster emergency control system could improve stability of the system since it could detect faults more quickly, use a wider range of operation of the respective equipment, react faster to remedy the situation and avoid disconnection of problem areas. This allows prevention of cascade faults and avoids many power interruptions, even complete blackouts. In addition, the restoration system will act more quickly so as to bring consumers back to power supply.

Reduced outage time provides benefits both for the utilities and for the consumers. The utilities collect more revenues through uninterrupted sale of energy. The consumers benefit from uninterrupted power supply that is of special importance for industries with a continuous production process where not only loss of production is to be borne but starting and shut down of the process involves even more losses. Finally, indirect or sequential damages are also to be taken into account.

The unreliable power supply resulted in cost to the local economy. In the literature on economic costs of power outages, costs are generally broken down into short-term and long-term costs. Short term costs comprise:

- Opportunity costs of under-utilised production capacities
- Product spoilage and damage to machinery
- Shut down and restart cost
- In addition, secondary costs may arise as a result from the interdependence between one firm's output and another firm's input.

Long-run costs consist mainly in the cost for mitigating the effects of power outages by installing standby generation or self generation.

Several studies have attempted to develop estimates of the cost of electricity outages. The values vary from country to country and according to the use of electricity:

Table 7 Cost of power outages in selected developing countries

Country	Sector	Cost of Outage (US$/kWh)
Bangladesh	All	1.00
Brazil	Households	1.95 – 3.00
Brazil	Industry	1.77 – 8.42
Chile	Households	0.53
Chile	Industry	1.5 – 6.00
Egypt	Industry	0.4
Pakistan	Industry	0.81
Paraguay	Households	1.87
Taiwan	Industry	0.06 – 2.27
Tanzania	Households	0.50
Tanzania	Industry	0.70 – 1.40

Source: Arun P. Shangvi, Power shortages in developing countries, Energy Policy, June 1991, p. 535

The same study presents outage costs in the industrialised countries US and Canada:

Residential	US $ 0.50 – 5
Industry	US $ 2 – 20
Commercial	US $ 5 – 35

Adding up the two major outages of the EPCA in 1999 and adding the same amount for the unaccounted smaller disturbances an estimated 6.2 GWh have been lost in the EPCA in 1999 due to regional outages. If the disturbances can be reduced to a conservative value of half of the present outages and assuming costs of US$ 1.00 per kWh lost, the annual benefit may thus be estimated at million US$ 3.100.

We are well aware of the shortcomings of this approach, but in the absence of any other data, the result may serve as a first approximation of the benefits reached through reduced outages.

6.2.1.2 Reduction of Frequency Variations

In western Europe and other regions with a high standard of power supply, frequency variations remain in the range of ±0.05 Hz. In the Soviet standards much higher frequency variations were permitted but these standards were respected. In the EPCA now, due to the absence of discipline, frequency variations grew even bigger. If frequency drops, the ohmic consumers continue to receive full power. However, the reactive consumers obtain less power, especially the motors that run slower. (Out of that reason Armenia even operated the power grid with a nominal frequency of about 45 Hz during the difficult times after independence in order to reduce the consumed energy.)

The utility which runs in the under-frequency range undergoes a financial loss since it might sell more kWhs with the same installed capacity. This situation can be quantified with figures taking into account that in the EPCA the drop of frequency of approximately 0.1 Hz loss corresponds to a generation deficit of about 150 MW. This ratio cannot be applied throughout the whole frequency scale but is valid for the close range of ±50 Hz. If the observed period of 2.4 hours of frequency below 49.9 Hz is extrapolated over the whole year, additional 131.4 GWh could be sold within one year (2.4 h x 365 days x 150 MW). Taking into account a net benefit of 1 US cent/kWh (production cost – revenues), the additional supply sums up to an annual benefit of million US$ 1.31.

The operation in the under-frequency range causes a further financial loss for the utilities since the turbines of gas turbine plants undergo an increased wear that reduces their lifetime. The same occurs to steam turbines, where steam condenses at the turbine ends, causing erosion in the steel and reduced time of utilisation. Furthermore, all motors and pumps in the power plants work with less power and/or draw higher currents.

Consumers that require a constant number of revolutions of their motors suffer from bad quality of supply with the possibility that production is disturbed, the motors even stop and the complete production process is blocked with consequential damages. Apart from losses in the production process technical damages are recorded since motors compensate the missing frequency through increased currents leading to burnt out motors and consequential damages. The damages caused by bad frequency are important, however they cannot be estimated in volume nor quantified in monetary terms.

6.2.1.3 Improvement of Voltage Profile

Voltage level of ten key points of the 500 kV lines and 220 kV interstate lines are registered every 30 seconds and transmitted to the UDC. The NDCs control further points according to national requirements. The permitted voltage band for the 220 kV system extends from 198 kV to 252 kV and that for the 500 kV grid covers the range from 450 kV to 525 kV.

Voltage checks at crucial points selected by the UDC showed that the maximum voltage of 500 kV lines is not always respected. In the documents received, voltages up to 531 kV were noted instead the permissible 525 kV. Dispatchers explained that overvoltages are also recorded at the 220 kV level and below due to missing regulation facilities. These overvoltages stress the equipment and cause a shorter lifetime of the equipment for power supply. In addition, if the set limits are exceeded, protection equipment disconnects the faulty equipment and causes interruptions of power supply.

But consumers even suffer more from unstable voltage. Most consumers are obliged to protect their modern electronic equipment (computers, TV sets, electronic devices) with voltage stabilisers as to avoid interruption of operation due to automatic tripping of the equipment. They even might completely lose their equipment due to overvoltages. Even simple electric equipment, such as lighting bulbs have an extremely reduced lifetime if operated at overvoltages.

The cost caused by overvoltages are important, both due to damages to electric equipment as well as the additional investments needed to protect electric appliances from over- and under-voltages. However, these cost cannot be estimated in volume nor quantified in monetary terms.

6.2.1.4 Reduction of Losses

The diminution of reactive power flow and the monitoring of on-line power flow in the transmission system will allow a decrease of the technical losses. However, the scope of reduction of losses cannot be determined exactly, since the level of losses indicated by the utilities are already doubtful. All countries give figures for the losses of the power system but in some countries the losses are extremely high (i. e. Kyrgyzia 40 %), mainly due to unmetered and unbilled consumption, other statistics show little losses (i. e. Tajikistan 14,5 %) as to come close to the figures given by the national planning offices. A close look at the data and the system gives reasons for the various irregularities (refer to TACIS Study EREG 1993, Improvements in Electricity Transmission, Distribution and End-use Efficiency in Central Asia Countries, Task 3):

- many feeders in switching and HV/MV transformer stations have defective or no meters at all, so that the transmission losses cannot be exactly evaluated;
- many pole mounted and ground mounted transformer stations have no meters, so that the distribution losses cannot be exactly evaluated either;
- industrial complexes, agricultural co-operatives, power plants often have only one single meter that records the complete consumption, including domestic or other use;
- the sums of consumption includes estimated quantities, since some consumers have no meters at all;
- non technical losses (theft, unbilled consumption, etc.) are generally high but the relation technical to non-technical losses is not known;
- billing and collection procedures are not satisfactory for modern utilities, so that the recorded data are not reliable.

The only way to judge the expected reduction of losses is to compare the envisaged measures with similar projects carried out in the past in other countries.

In 1998, Southern Kazakhstan, Kyrgyz Republic, Tajikistan and Uzbekistan produced 80,200 GWh of electricity. It is estimated that the transmission system losses amount as well to about 8 %, as recorded for the Russian transmission system. It is estimated that the diminution of reactive power flow and the monitoring of on-line power flow will certainly reduce the overall losses by at least 0.2 % per year. With the reduction of total losses by

0.2 %, 160.4 GWh can be saved annually which represents an equivalent saving of million US$ 16 (at US cents 10 per kWh).

6.2.2 Operational Benefits

The most important operational benefit is the improved information available to the dispatchers on the status of the power system, in particular of the loading of generators, transmission lines, and transformers. This allows one to judge if equipment is close to maximum rating or already overloaded and permits one to consider the consequences of switching operations, emergency cases, maintenance operations, additional power trades or other operational reasons. With the tool of the SCADA/EMS the state of the system is more transparent and switching operations are facilitated.

The most important effect of the improved information presents the better safety situation for personnel under normal as well as under emergency conditions. The dispatcher is better informed on the state of the network and the enhanced telecommunication system allows an exchange of information which is easier and more reliable. Improved telecommunication lines, better and reliable data are a pre-requisite for safe operation.

6.2.3 Possibility for Power Trading

The improvement of the SCADA system is a further pre-requisite for effective power trade between the countries of the power pool. Without proper metering, telecommunication and monitoring of availing production facilities and wheeling possibilities the power trading is not possible. The present bulk power transfer does not correspond to market oriented principles, since base and peak power are not differentiated and ancillary services are not reimbursed. The installation of trading functions in the EPCA will allow the achievement of savings through power trade, however, the scope of these will depend on the political freedom of the utilities to act as free market oriented enterprises.

The CA countries will take advantage of the possibilities of the power pool in varying intensity. This depends mainly on the geographic location of the countries, their pattern of production facilities, and the size of the national power system. The following table shows that large countries, centrally located countries and those with abundant hydro-resources benefit most from the power pool.

Table 8 Importance of the Power Pool for the Different Countries

Transactions	Kazakhstan	Kyrgyzia	Tajikistan	Uzbekistan
Wheeling of Power	1	2	0	3
Sale of Base Load Power	1	3	2	3
Sale of Peak Power	1	3	3	1
Sale of Frequency Regulation	1	3	3	1
Purchase of Base Load Power	3	2	2	1
Purchase of Peak Power	3	0	0	3
Purchase of Frequency Regulation	2	0	0	3
Total of Points	12	13	10	15

3 = high benefit for the country 2 = medium benefit for the country
1 = minor benefit for the country 0 = not relevant, not required

The table demonstrates that Uzbekistan, as biggest and centrally located country would benefit most of power trade. However, all other countries are closely following and would also benefit from the joint operation of the system since variation of the total of advantages is narrow.

6.2.4 Technical Need for System Update

The regional dispatch system needs to be improved and uprated for integration of the planned rehabilitation works in the Kazakh power system and the construction of Talimarjan power plant. The cost for these unavoidable works cannot be accounted to the project cost but must be deducted from the total project cost. However, at the present stage, only the cost for connection of the Kazakh system can be assessed, the integration of Talimarjan power plant cannot be estimated without a detailed study of the present and especially of the future system. Due to the increase from 300 MW to 800 MW for the biggest generation unit, the new plant can be integrated in the existing system only with a sensible deterioration of the security of supply and of frequency and voltage quality. The integration will be eased and technically feasible with a modern system.

In the description of the different subsystems for parallel operation of the EPCA it is mentioned that various subsystems are old or obsolete and need rehabilitation or complete replacement. The majority of the works of the proposed project is necessary to replace outdated equipment.

6.2.5 Summary of Benefits

We are well aware of the shortcomings in quantifying the benefits of the proposed project although they are numerous and substantial. The different benefits, mentioned above can be summarised as follows:

Table 9 Summary of Annual Benefits of the Proposed Project in Million US $

Item No.	Description	Annual Benefit million US $
6.2.1.1	Reduction of outages, benefits for consumers and utility	3.100
6.2.1.2	Reduction of frequency variations, benefit for utility	1.310
6.2.1.2	Reduction of frequency variations, benefit for consumers	Not quantified
6.2.1.3	Improvement of voltage profile	Not quantified
6.2.1.4	Reduction of losses	16.000
6.2.2	Operational benefits	Not quantified
6.2.2	Increased safety for personnel	Not quantified
6.2.3	Possibility for power trade	Not quantified
6.2.4	Need for System Update	Not quantified

6.3 Economic Analysis of Proposed Project

For the economic analysis the cost could be well determined and amount to:

Cost Estimate of Works in Million US $							
							Accumul. Total
Country	**S. Kaz.**	**Kyrgy.**	**Tajik.**	**Turkm.**	**Uzbek.**	**UDC**	
Mio US $	**0.8**	**17.7**	**19.2**	**0.8**	**52.0**	**9.7**	**100.3**

With an annuity of about 10 %, a life time of 20 years and an amount of investment of million US$ 100, a capital recovery factor of o.117 is reached and annual revenues of about million US$ 11.7 must be achieved. The above identified benefits will certainly exceed this figure.

Uzbekistan has to bear the biggest investment costs. This is mainly due to the geographic size of its power grid and the number of consumers. I. e. Uzbekistan produces about the same amount of electric energy as the remaining CA countries South Kazakhstan, Kyrgyz Republic, Tajikistan and Turkmenistan together. But Uzbekistan will also benefit most of the improved operation of the EPCA due to its central geographic location.

The cost structure of the proposed project corresponds strongly to the pattern of electricity production of the EPCA in 1998 (with the special cases of Turkmenistan, not member of the Bank yet and Kazakhstan, where rehabilitation is under progress already):

Comparison of Project Cost and Electricity Production							
	S. Kaz.	**Kyr.**	**Taj**	**Turk.**	**Uzb.**	**UDC**	**Total**
Cost Estimate of Works in Million US $							
Total Cost	0.85	17.7	19.2	0.85	52	9.7	100.30
Cost in %	1%	18%	19%	1%	52%	10%	100%
Cost incl. UCD works	3.275	20.125	21.625	0.85	54.425		100.3
Cost in %	3%	20%	22%	1%	54%	0%	100%
Electricity Production in 1998 (GWh)							
Production	8,600	10,847	14,663	8,071	46,090		88,271
Production in %	10%	12%	17%	9%	52%		100%
P. without Turkmen.	8,600	10,847	14,663		46,090		80,200
Production in %	11%	14%	18%		57%		100%

Since the shares of project cost closely follows the shares of electricity production among the different countries, it is recommended to pursue the practice that on an international level, always each country is financing its installations on its territory and takes as well all benefits from their operation.

7 Environmental and Social Aspects of the Project

7.1 Environmental Risks

There are no special risks from the environmental point of view, since the proposed project consists exclusively of rehabilitation and upgrading of old malfunctioned equipment with new modern replacements. In order to minimise the environmental impacts, the project must be prepared and implemented in compliance with all environmental requirements of the financing Bank in order to respect that design, manufacturing and construction fulfil the environmental needs.

The equipment will be housed in the existing power plants, substations and dispatch centres, so that visual impacts are eliminated. Issues of electric and magnetic field intensity and of noise emissions will not be affected and possible concerns as well as public safety can be addressed in both the design and operation phases. Disposal of all old and obsolete equipment and materials must receive due consideration.

If shunt reactors are to be installed, state of the art oil pits are to be foreseen. The project will not include removal/replacement or any other type of action with any equipment containing PCBs (polychlorinated biphenyl). When this equipment is to be replaced in the future, replacement equipment will not contain PCBs and specifications forbidding its use will be incorporated in all pertinent bidding documents. If circuits not related to the proposed project involve removal of PCB-containing capacitors, these capacitors will not be transferred to other substations. These capacitors, as well as any other capacitors that are removed from service because of technical failure, must be returned to the manufacturing plant.

7.2 Possibility for Enhanced Use of Hydro-generated Electricity

The implementation of the project offers a gateway for future exchange of electric energy and of an environmental operation of the power plants, with a maximum of substitution of thermally produced energy by hydro electricity. The optimum use of hydro and thermal power plants presents an important environmental issue for the complete region. Without the project this option is endangered.

A further important environmental matter of the proposed project is that the water flow of the Syr Daria and Amu Daria and their tributaries can be better controlled and regulated so that the environmental damages can be mitigated.

7.3 Social Aspects of the Proposed Project

The main benefits of the proposed project that effect social aspects are a better quality of electric energy and reduced outages of power supply. These benefits will be recorded in the whole interconnected CA power grid, so that the majority of population will benefit from better services. However, the improvements will not be much recorded by the users of electric energy, a good quality of electric energy (correct voltage and frequency) and few outages of power supply are self evident and are paid for with the monthly electricity bill.

The direct benefits of the proposed project are:

- Less interruptions of power supply
- Increased productivity

- Higher quality of services

The reduction of interruption of supply has a high relevance for industry since production is sensitive to all interruptions and power cuts cause financial losses for manufacturing industries. Food processing, commerce and agriculture are still sensitive to power cuts, but generally suffer less from interruption of supply. Domestic consumers experience the least damages if power is interrupted. In the same way, increased productivity and higher quality of services are of utmost importance for industrial consumers and of minor importance for domestic clients.

Indirect benefits of the proposed project are even more difficult to quantify. They include:

- Improved quality of life
- Stimulation of economic development
- Improved public services including health services.

8 Definition of Project Organisation

Each partner of the pool will be responsible and shall fund the equipment of the project that will be installed within the borders of his country. The equipment to be installed in the UDC (Interstate Power Dispatch Centre Energia) will be paid out of the funds of this organisation, which are shared among the participants of the power pool.

According to the planned organisation of the power complex in CA (refer to the organisation chart of Annex 8), the governments, signatories of the Energy Charter, will nominate their members in the Interstate Energy Power Council. The Interstate Power Dispatch Centre Energia will act as executive body of the Interstate Energy Power Council and perform the works as co-ordinating dispatcher of the power pool.

The UDC shall act as implementing agency of the project. The UDC has to operate as co-ordinating and responsible body for implementation of the project. Since the participating countries play an important role in the implementation and have to finance their national share of the works, the countries shall be represented in the administration of the project through the Interstate Energy Power Council.

8.1 Steps of Project Implementation

For the implementation of the project the following steps are necessary:

1. As a first activity, the results of the project identification must be presented to the countries. The most effective way would be the presentation of the results in form of a **workshop** with possible participation of load dispatchers and chief planning engineers of the participating countries, members of the Central Asia Regional Electricity Working Group and representatives of the Bank. This allows discussion of possible questions with the engineers of the countries and offers the possibility to include their comments in the further planning. In addition, the status of restructuring of the power complex can be assessed. The workshop must also contain the further steps for project preparation.

2. For further continuation, a **commitment** of the participating utilities is needed to continue and support the **project implementation.**

3. With this commitment, more detailed project identification and the **feasibility study** of the proposed works can be performed. The feasibility study will define the final scope of works.

4. The project definition allows **definition of the project implementing agency** and its duties for following the project. It is estimated that the UDC will take over a lead role and co-ordinate the activities among the participating countries.

5. Apart from the technical definition of the project, the **organisational and legal requirements** in each country must be defined and implemented in order to achieve successful project performance. These organisational and legal requirements are to be summed up again and compared with the actual institutional and organisational status of the power pool and the set up designed by the Consultant Hagler Bailly who drafted the bilateral wheeling agreement, CAEP operator agreement, inter-governmental agreement on creation of a CAEP, founder agreement of an independent international dispatch centre, etc.. Parallel to the agreements, the Consultant worked out recommendations for

power system operation and their status of implementation is to be verified also (i. e. provision of spare capacity, control equipment, dual tariff meters, etc.).

8.2 Necessary Structural Changes in the CA Power Complex

Parallel to the development of the regional power project several structural reforms must be implemented between the CA utilities. These changes have already been addressed within the USAID project for development of the CA power complex and the respective draft agreements have been prepared.

Not only structural changes between the utilities must be achieved, the utilities themselves must be restructured similar to the re-organisation of the Kazakh power sector. The new EPCA can only effectively function if a number of pre-conditions are fulfilled for all CA utilities, among others:

1. Each partner must have cost covering tariffs, otherwise the necessary rehabilitation works, fuel for the thermal power plants, maintenance, power exchanges, etc. cannot be paid;
2. Accounts receivable must be reduced to international standard, otherwise the partners cannot financially operate;
3. Power trade must be effected in monetary terms, barter trade with voluntary prices and book values must be abandoned;
4. Restructuring of the Soviet state monopolies for power generation, transmission and distribution must be completed and profit oriented entities must be established in each country;
5. A power market for power trade must be agreed upon among the participating countries and the agreements concerning its operation must be signed by the concerned countries;

Only Kazakhstan is on the way to implement these pre-conditions. The Kyrgyz Republic made the first steps for realisation but still has to perform many structural changes. However, only on the base of these pre-conditions the discussions be started how to organise the future operation of a new Central Asian Power Pool. For that purpose the new rules of operation, power exchange, spare capacity, power regulation, emergency control, etc. must be defined. Then, the necessary technical changes and new equipment for the regional power project can be determined, and finally implemented.

The risk of the project lies in the fact that various pre-conditions must be fulfilled by each country and that agreements must be signed to start and, in future, to continue the power pool. Certainly, the power pool can be drafted already, with the risk that implementation is delayed if several countries or a key country does not fulfil the pre-conditions.

ANNEXES